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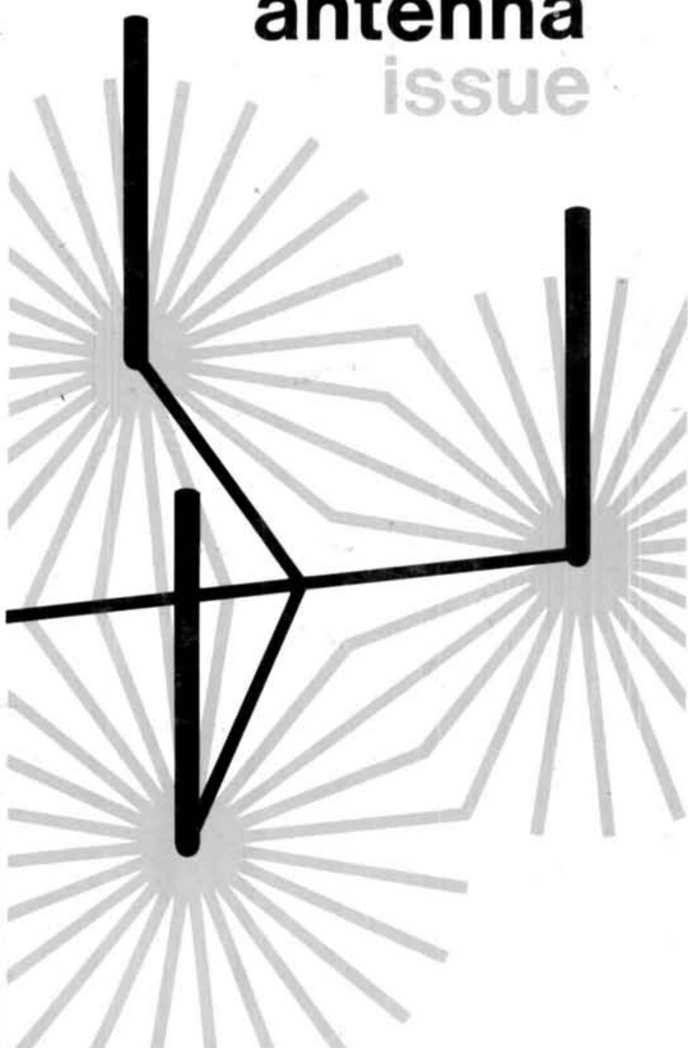
MAY 1977

8th annual **antenna** issue



More Details? CHECK—OFF Page 150

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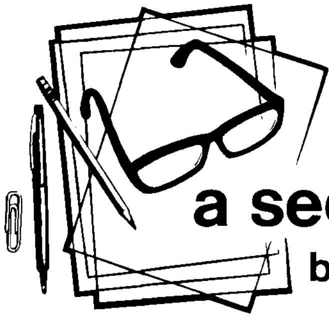

a second look

by Jim Fisk

The world distance record on 1296 MHz was shattered on the 25th of January when two amateurs in Western Australia, Wally Green, VK6WG, in Albany, worked Reg Galle, VK5QR, near Adelaide, over a distance of 1886 kilometers (1171 miles). The previous record on 1296 MHz was set in October, 1973, between WA2LTM and W9WCD over a distance of 1240 kilometers (770 miles).

During their record-breaking contact VK6WG used CW and VK5QR was on ssb. Wally tried a-m, but Reg was only able to copy a few words because of the narrow passband of his receiver. There were participating observers at each end of the link, and much of the contact was tape recorded at VK6WG. It is more than likely that the two observers, Roger Bowman, VK5NY, and Bernie Gates, VK6KJ, were themselves green with envy — VK5NY, who was using a Microwave Modules MMc1296-LO converter, made a recording of the contact at his own station but was unable to get his signals through to VK6.

The transmitting lineup at VK6WG consists of an 8-MHz crystal oscillator/multiplier to 144 MHz, followed by an 832 tripler to 432 MHz, and a 3CX100A5 tripler to 1296. All equipment is homebrew. Power output on 1296 MHz is 10 to 15 watts; a pair of 807s are used as an a-m modulator. The antenna is a 3-foot (90cm) dish similar to that described in the RSGB's *VHF/UHF Manual*. The receiver front end was provided by Ron Wilkinson, VK3AKC; the converter was a Microwave Modules MMc1296 with a 28-MHz i-f.

The single-sideband gear used by VK5QR was an experimental hookup of a circuit suggested in 1970 by Karl Meinzer, DJ4ZC, in an article in *VHF Communications*. In this system the 432-MHz ssb signal is specially processed to eliminate most of the distortion caused by frequency tripling. The output from a homebrew 9-MHz ssb generator was mixed to 28 MHz, then fed to a 432-MHz transverter and 2C39A linear amplifier. The 432-MHz ssb signal was multiplied to 1296 MHz with a varactor tripler. Power output was about 10 watts to a 3-foot (90cm) dish. The 1296-MHz receiver consisted of a mixer-only converter into a low-noise preamp and tunable i-f.

This contact was a culmination of previous work by all four stations on 144 and 432 MHz. Both VK6WG and VK5QR deserve high praise for their stunning success, but in view of the relatively low power levels and small antennas used, and the good signal reports, there's a good chance the record may be bettered in the near future. There are a considerable number of amateurs east of Adelaide who are set up for operation on 1296 MHz.

Jim Fisk, W1HR
editor-in-chief

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presstop

FCC'S PROPOSALS TO BAN 10-meter amplifiers and require type acceptance of Amateur equipment (April ham radio) have drawn a letter from Senator Barry Goldwater to Commission Chairman Dick Wiley commending the Chairman on his recent pro-Amateur Radio statement, but questioning whether further restrictions on Amateurs are really going to solve the Commission's problems with illegal operators.

Type Acceptance would probably have little effect on illegal operators but would certainly raise equipment costs and delay product improvements for Amateurs, according to industry sources. In his statement that accompanied Docket 21116, the amplifier ban, Chairman Wiley expressed the hope that "the comments we receive will suggest other and better alternatives to the Commission's proposals." One such alternative is that already proposed to the Commission, by the San Antonio Repeater Organization, which would place legal responsibilities on the seller and buyer of transmitting equipment. The R.L. Drake Company is one enthusiastic backer of that approach and has already worked out a modification which would take the paperwork burden off the FCC but would still provide the Commission with traceability and accountability for enforcement purposes.

ELIMINATION OF AMATEUR SECONDARY STATION licenses proposed recently by the FCC would apply across the board — only individual primary station licenses would be retained. Existing secondary station licenses would remain in force until their expiration date, but could not be renewed. Comments on the proposal, Docket 21135, are due June 2; Reply Comments, June 30.

The Closed Season on issuance of new secondary station licenses applies only to applications received after March 3rd. All applications for renewal of existing secondary station licenses will still continue to be processed as before.

A 90-Day Delay of the May 25 due date for Comments on both Docket 21116 (Linear Amplifier Ban), and Docket 21117 (Type Acceptance of Amateur Equipment), has been requested by the ARRL because the two are "so far reaching in their implications for the Amateur Service that the Amateur community needs more time to study and respond to them." The League has also requested an extension on Comments due date for Docket 21135, the proposal to eliminate Amateur secondary station licenses.

HARMONIC AND SPURIOUS EMISSIONS from all Amateur transmitters will be specifically limited by a first Report and Order on Docket 20777, the bandwidth Docket. The new limits are 40-dB below carrier level under 30 MHz and 60-dB down between 30 and 235 MHz, and apply to all Amateur equipment — homebrew and modified as well as commercial.

The Proposal Is Causing Concern because it provides no relief for equipment already in Amateurs' hands so it could work a hardship on both the industry and individual Amateurs. Though add-on filters or antenna tuners could bring individual transmitters into compliance, as written, the Rules make no provision for external cleanup modifications.

AMATEURS MOVING to a new permanent location are now no longer required to advise the FCC of the change within four months as has been required by Part 97.95(a)(2) of the Rules. One caution must be observed however: be sure mail sent to you at the address the FCC does have gets to you, as "failure to reply to official communications" — a pink ticket for example — can get you in deep trouble!

"INSTANT UPGRADE" WAS AVAILABLE at all FCC Field Offices on March 1. The temporary authority for the successful applicant to use his new privileges is provided by a form filled out by the FCC examiner, and until the upgraded license arrives the Amateur must sign his call plus "Interim Washington" on phone (or "/WN" when on CW) if he took the upgrading exam in Washington — but only when he's exercising his newly won privileges. Each FCC Field Office has a 2-letter designator for use on CW.

FCC CHAIRMAN RICHARD WILEY was presented a plaque on behalf of the Amateur Radio Service and the members of the ARRL for "his excellent support of the Amateur Radio Service" by League President Harry Dannals at the Quarter Century Wireless Association's Washington Chapter banquet, which was attended by a number of top FCC and OTP officials.

AMSAT'S PHASE 3 SPACECRAFT FUNDING campaign is now officially in operation though a few details are still being worked out. It involves sponsorship of one or more solar cells from the spacecraft's solar panels at $10 per cell, a tax deductible donation. Send contributions to AMSAT Phase 3, Box 27, Washington, D.C. 20044 — sponsorship certificates will be sent to contributors.

AMATEUR RADIO INSURANCE plans are still being investigated by the ARRL with interesting proposals in hand. There's a good possibility that coverage in addition to simple protection of equipment will end up in the final package, which was referred to the League's Management Finance and Membership Affairs Committees for further study.

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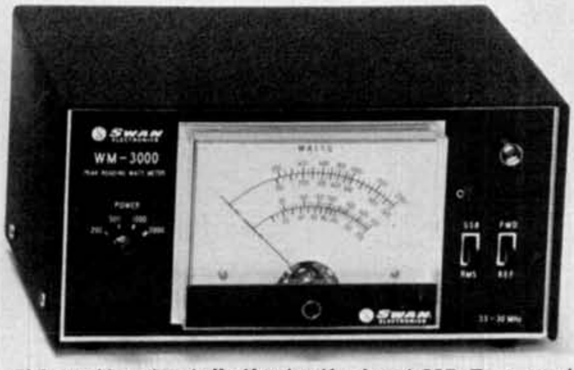

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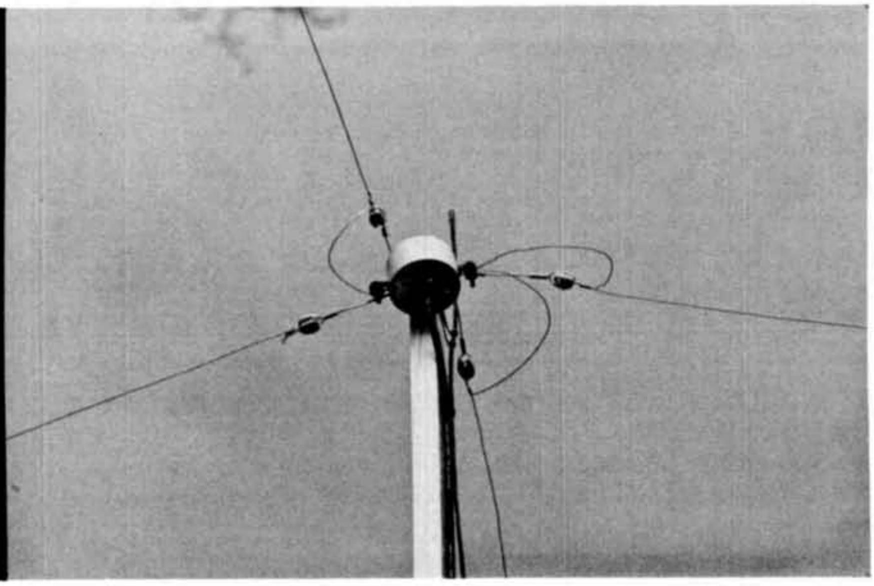


Photo by Douglas Fowley, WA4RPY

antenna design

using the longwire principle

A family of high-frequency amateur antennas with characteristics that should appeal to the experimenter and DX enthusiast

Amateur high-frequency antenna design has lagged behind the latest developments in amateur transmitters. The Ten-Tec and Heath solid-state transceivers, with their broadband output matching circuits, make transmitter adjustment as simple as tuning a receiver. The transceivers are easy to tune when terminated with a noninductive dummy load or a properly matched antenna operating near its resonant frequency. However, operating these transceivers on all bands becomes more complex. You must either switch antennas, or add an antenna tuner, or both. Broadband antenna designs, such as the discone and trap dipole are available, but each has its disadvantages. As a result of this restrictive situation, many amateurs operate near a frequency where the antenna resonates or operate in a narrow frequency band to avoid the nuisance of retuning.

design features

This article presents an approach toward a new family of antennas using the longwire principle. Design features:

1. Outperforms conventional longwires of similar size during the majority of contracts under skip conditions.

2. Broadband characteristics from 80 through 10 meters are superior to any other antenna design.

3. Simple to feed using conventional 50-ohm coaxial cable.

4. No tuning or adjustment required if the design shown here is duplicated.

5. Design may be varied to suit your needs for desired bands, bandwidth, and array size. Adjustment is simple.

6. Neat in appearance and unobtrusive. Cost is below $100 for 2-kW PEP capability.

performance under skip conditions

A justification of feature 1 is appropriate. Does the "best" technical design achieve the best performance during varying propagation conditions? Which antenna is best when several good alternative designs are being considered? I had a feeling that on-the-air antenna performance during skip conditions on the amateur bands was unpredictable. Conversations with other amateurs familiar with the use of different antennas

By Everett S. Brown, K4EF, 11100 Ridge Road, Anchorage, Kentucky 40223

confirmed this feeling. The evidence was strong that antenna characteristics based on theory and ground-wave measurements were *not* duplicated under skip propagation conditions.

I decided to make some experiments to test bandwidth improvement and the performance of alternative antenna design under skip conditions. Results were rewarding. These bandwidth experiments resulted in a new broadband antenna design. Although these tests were not under controlled laboratory conditions, I was nevertheless satisfied that the new antenna design gave outstanding performance. The purpose of this article is to acquaint you with the concepts, test results, and final design details so that you may understand the simple principles involved and, if you wish, design your own version.

objectives

The first objective was to develop an antenna with low swr on all amateur bands from 80 through 10 meters. The swr was to be 2:1 or lower but in no case to exceed 3:1 from band edge to band edge.

The second objective was to develop an antenna design with outstanding performance when compared with other antennas of similar size, cost, and complexity. Emphasis was to be placed on simplicity and low cost. The performance judgement was to be based on the relative signal strengths achieved under medium and short skip conditions on 80 and 40 meters with secondary emphasis on long skip DX and higher frequency bands. The successful antenna would provide that big signal that all amateurs strive for.

physical properties

Since I am blessed with a heavily wooded area and friendly neighbors, I decided to experiment with longwires. The operation was a low-budget affair from beginning to end. I used inexpensive aluminum electric-fence wire, which was purchased from Sears for about $15 for a quarter-mile roll. No insulators were used except at the ends of the wire. The wire was strung from tree-to-tree about 25 feet (7.6m) from the ground and laid in branches near the tree trunk.

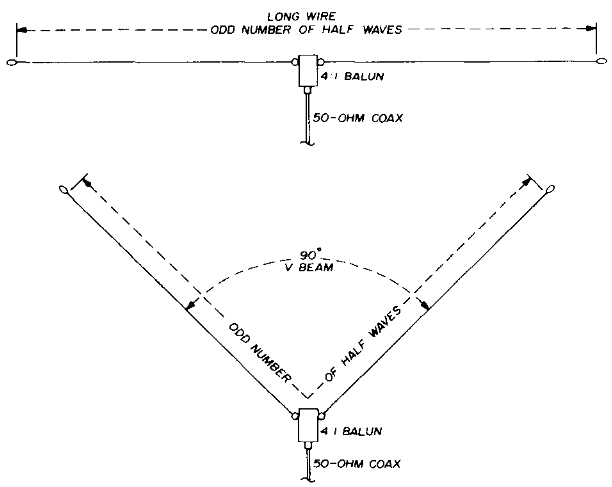


fig. 1. Basic elements author used to form 23 different antenna configurations for comparative signal-strength tests under skip conditions. Measured impedance at the feedpoint of both antennas was 200 ohms, which gave an excellent impedance match using the feed method shown.

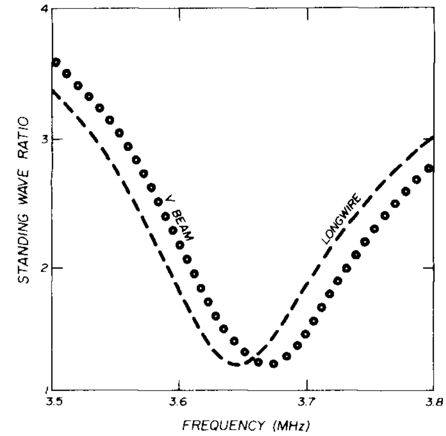


fig. 2. Swr measured on the two basic elements shown in fig. 1. At resonance the swr was 1.2:1; bandwidth at the 2:1-point was 120 kHz, or about 3% of the resonant frequency for both longwire and V beam.

To be acceptable to neighbors who owned the adjoining properties, the antenna had to be unobtrusive. The casual observer would have trouble seeing the thin aluminum wire in the trees.

During the experimental phase of the project the ends of the wires were brought into the operating room to facilitate both switching and measurements. Measurements and on-the-air comparisons were made over a two-year period before the final design evolved.

An unusually efficient ground system was needed to provide lightning protection, particularly during dry periods when ground conductivity dropped. The size of the array made it particularly vulnerable to electrical storms.

electrical properties

The basic antenna element consisted of an odd number of half-wavelengths, fed in the center. In the early stages I determined that the feedpoint impedance was a nominal 200 ohms as measured on an impedance bridge — regardless of the number of odd half waves in a single element or the use of several elements. This greatly simplified impedance matching. A 4:1 balun, fed by 50-ohm RG-8/U coaxial cable provided excellent swr performance, as will be shown later.

According to the literature, a longwire radiator, if center-fed, must be fed at a current loop.[1] The use of an odd number of half-wavelengths at the resonant frequency results in conventional performance based on the entire wire length.

Where V-beam configurations were used, each leg was one-half the "element" length referred to above. Thus, each leg is one or more half wavelengths long, plus one quarter wavelength. This length results in the convenient impedance of 200 ohms at the apex. This technique of adding a quarter wavelength to the length of each leg to achieve impedance matching is one of the unconventional features of this design. The impedance of 200

ohms remained constant when either a longwire was center fed or a V-beam of the same total length was fed at the apex.

Although the configurations to be tested included V-beam elements, they were not chosen for their theoretical gain. On 80 meters, the legs were one and one-quarter wavelengths long, which would provide only about 3 dB gain over a dipole. The low antenna height made even this small amount of gain questionable during skip conditions. The V elements were to be tested for their ability to deliver a signal in any direction; high reliance was placed on the large capture area of the array.

Multiples of two basic elements were to be tested: the V beam mentioned above and a simple center-fed longwire. **Fig. 1** shows the elements. The apex angle of the V was chosen as 90° partly because this was optimum for whatever gain this element provided at an electrical length of one wavelength on 80 meters. On the higher-frequency bands, gain was of little consequence because of deviation from the optimum apex angle. The primary reason for the choice was that two center-fed longwires at 90° made a symmetrical array with all feedpoints at one place. Further, numerous alternative configurations could be selected at this central feedpoint.

Fig. 2 shows the swr bandwidths for both the V-beam and longwires. Both antennas were just over 100 kHz wide at the 2:1 swr points on 80 meters which is far

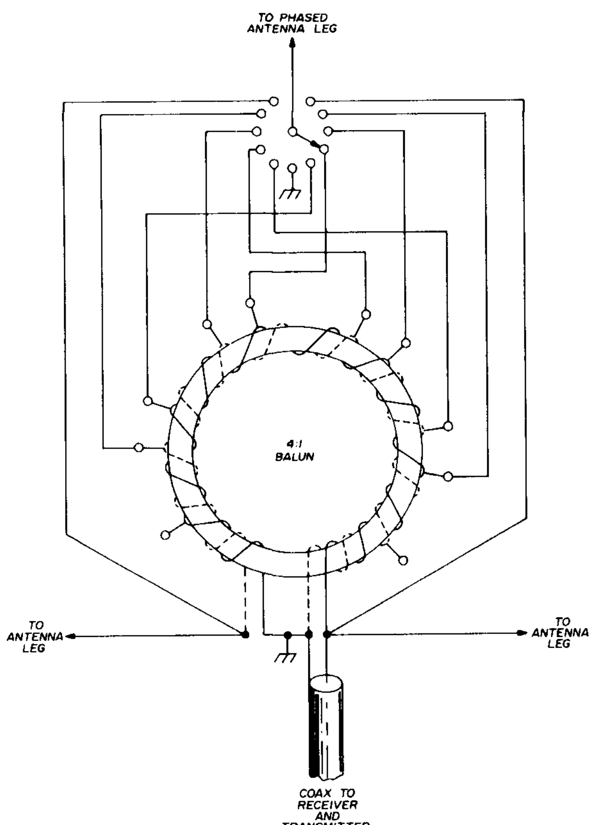


fig. 3. Special tapped balun using Amidon Associates KW balun kit to test steerable phased arrays.

from the desired 500-kHz bandwidth. To expand the bandwidth, I planned to stagger the element lengths.

One concern about staggering the element lengths was that such action would place the feedpoints off center in the element and adversely affect the impedance match. A check of this was hastily made, and it was a relief to find that the 200-ohm impedance measured by the bridge varied little with the imbalances contemplated. The swr measurements remained almost unchanged.

Terman[3] and others have described the steerable array. Changing directivity by changing phase relationships between multiple antennas was the usual method. I decided to attempt this by varying the phase relationships of several longwire elements and adding several steerable configurations to the on-the-air testing program.

Commercial steerable array designs were variable in the angle of radiation. They were most frequently used in a receiving system with phasing accomplished in the receiver circuits. It was my intention to test a high-level phasing system capable of transmitting as well as receiving. To test the steerable arrays, it was necessary to provide phase changes that could be switch-selected over a wide range. I made a special 4:1 balun with multiple taps as shown in **fig. 3.** I used a balun to test the effect on the transmitted and received signals by switching various phased elements during the on-the-air comparisons. I found that swr varied little when the phased arrays were switched.

electrical environment

I gave some thought to the ground conductivity in the area to be occupied by the test antennas. Previously, using conventional antennas, I observed that performance deteriorated during the dry summer months. This seemed to indicate that performance was directly related to ground conductivity. A heavy rainy period in the summer months restored performance.

This variation in performance, apparently due to changed ground conductivity, raises the broader question of how the antennas under test would perform in other locations with changed ground characteristics. It seemed logical to assume that, if the tests were repeated during dry and wet periods, a measure of the validity of the tests in differing ground conditions would follow. Was it possible that an inferior antenna over poor ground would become superior over good ground conductivity? Would the ultimate be two antennas, one for good and one for poor conductivity? Fortunately, test results were consistent in both wet and dry conditions. No discernible difference could be identified. I therefore concluded that test results would be valid for other locations and that other amateurs would most probably experience similar results. Another constant was antenna impedance. The bridge and swr measurements varied little between wet and dry months.

Unfortunately, it was impractical to vary antenna height. The low height probably caused a high angle of radiation, which was satisfactory in medium and short skip, but would it work DX? My primary interest was in short-distance contacts with occasional DX work. I

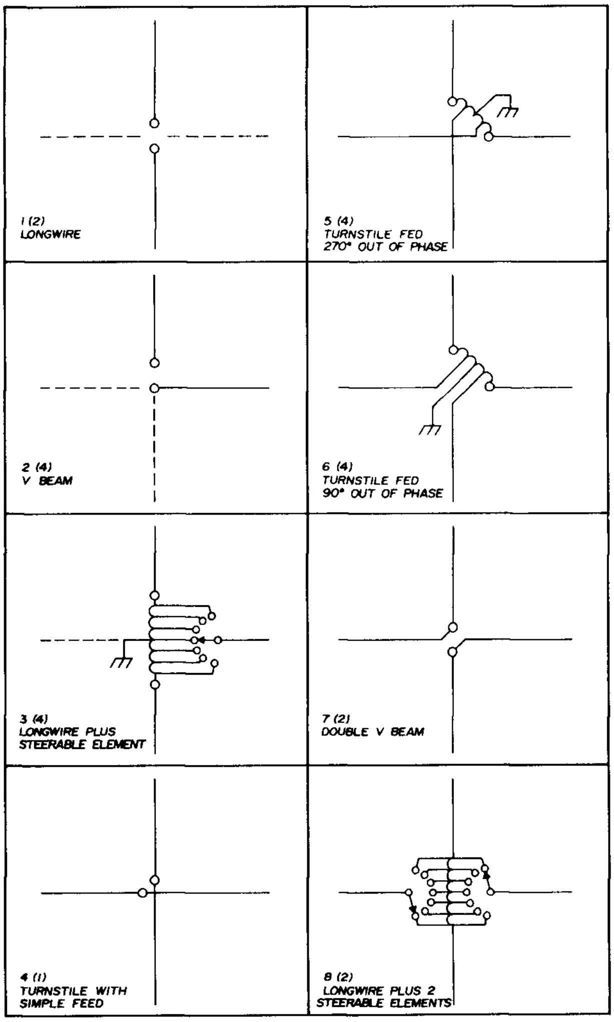


fig. 4. Eight basic antenna designs tested under skip conditions. Numbers in parentheses signify use of additional legs for variations.

decided to check low-angle radiation comparisons between the various antennas to be tested on a few DX contacts.

Nearby objects in the antenna site were relatively small and consisted of four houses, two power lines, and my electric fence. These objects undoubtedly had some effect on the antenna system, but it's unlikely they played a significant part in favoring one antenna configuration over another. As mentioned earlier, testing was not performed under laboratory conditions.

testing

Most amateurs erect a single antenna for a specific band or bands. Rarely are alternative designs compared. It was a shock to me to observe that a very substantial difference exists between comparable antenna systems. If power is increased from 100 to 1,000 watts, gain is predictable (10dB). In a number of cases a difference of 30 - 40 dB was measured between antenna types. In one instance I tuned the 80-meter band during daytime and found it completely dead. Another antenna configuration was switched in and the band produced an S9 station about 300 miles away calling CQ. I made contact with S9 signals both ways. The original antenna was switched in on both transmit and receive several times with the same result – absolutely no signal. I tried a third antenna configuration, which also yielded absolutely no signal. Only the one antenna provided communications at S9 both ways.

The three antennas in the preceding instance were comparable in size, cost and complexity. They were various combinations of the same longwires. I concluded that, when an antenna is chosen for its theoretical performance in free space or over perfect ground, that antenna may be completely out of context with theory for producing a maximum signal during many propagation conditions.

Ideally, a number of antennas should be available and the best one selected based on its performance at the moment. This technique was possible and seriously considered, but I hoped a configuration could be found during the testing program that would produce the best or nearly best signals in the vast majority of cases. This would eliminate the nuisance of continually monitoring signal strengths on several antennas. This simplification was especially valued after I discovered that during some propagation conditions the optimum antennna shifted during a single contact.

Testing produced quite a few surprises, but the most valuable result was that one configuration proved to be superior. The need to switch several alternative antennas was greatly diminished. The superior configuration has never been covered in the literature to the best of my knowledge.

test configurations

The basic test elements were center-fed longwires an odd multiple of a half wavelength long. Principal testing was on 80 meters, with fewer tests on 40 and a few

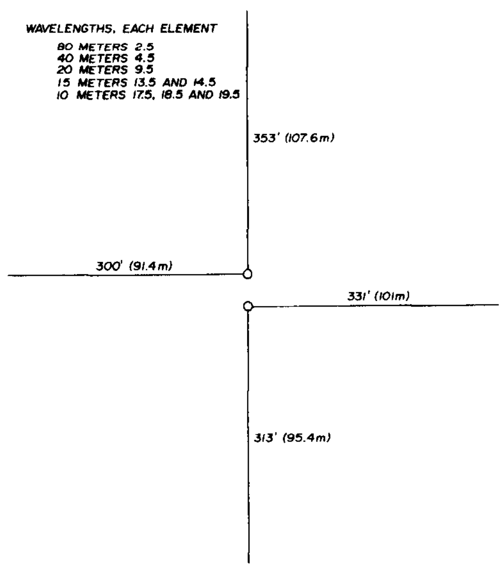


fig. 5. Author's final design, the "double V."

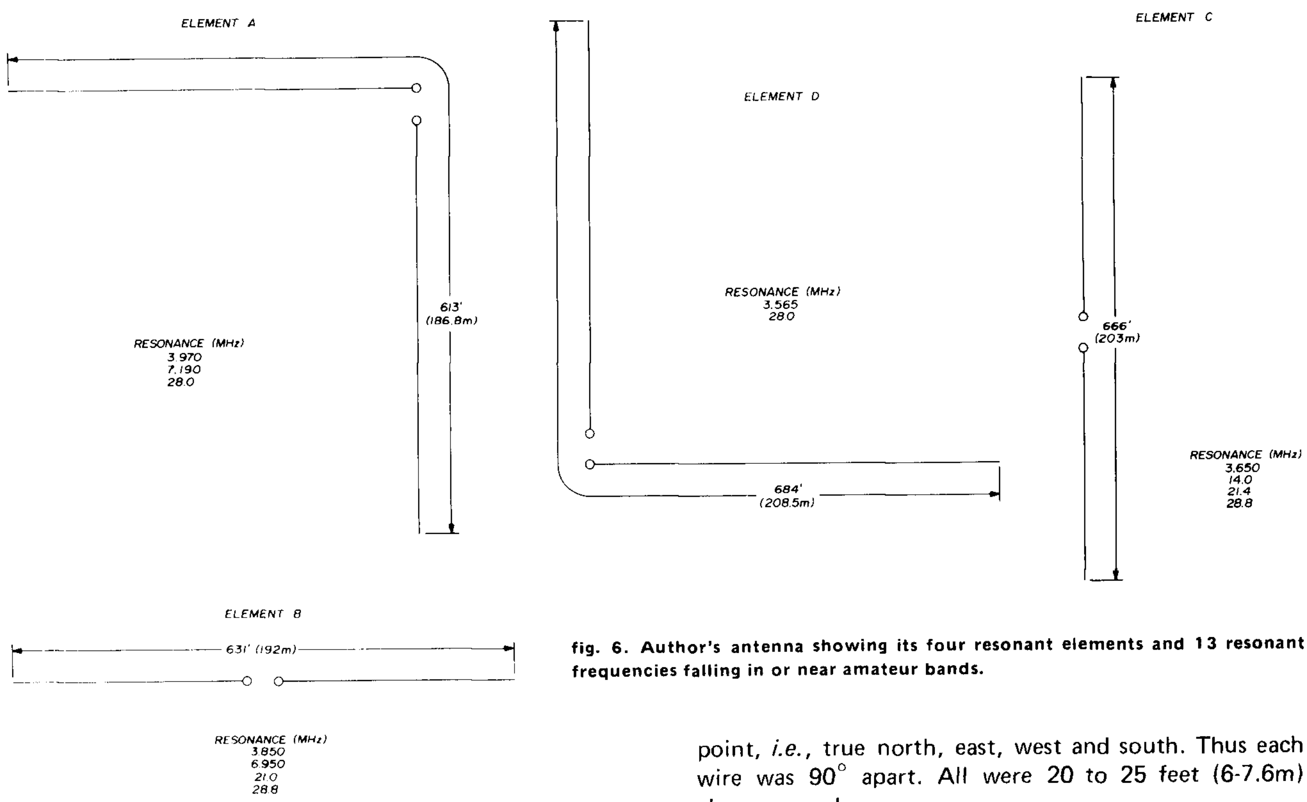


fig. 6. Author's antenna showing its four resonant elements and 13 resonant frequencies falling in or near amateur bands.

checks on 20. Note that a 625-foot (191m) wire is 2½ wavelengths long at 3.9 MHz and 4½ wavelengths long at about 7.05 MHz. This arrangement provides coverage of portions of both 80 and 40 meters. Another example of the physical length is a wire 660 feet (201m) long, which is 2½ wavelengths at 3.7 MHz and 9½ wavelengths at 14.1 MHz, giving coverage of portions of 80 and 20 meters.

The test elements were 680 feet (207m) long. They resonated just below 3.6 MHz; all 80-meter tests were made near this frequency. On 40 and 20 I had to tune out some reactance while using this wire length. Note also that the wire length referred to was the total length of the center-fed longwire, or the total length of both V-beam legs.

Emphasis was on the 80-meter-band tests because of the resonant condition. Fortunately results on the higher-frequency bands were similar to those on 80 despite the reactance offered by the test antennas on these bands.

The test configurations are shown in **fig. 4**. Eight basically different electrical designs were used with 23 variations. The large number of variations occurs because it was possible to combine different wires to obtain the same basic electrical design – but in a different direction. For example, antenna 1 has two variations: a north-south and east-west longwire. The number in parenthesis (**fig. 4**) signifies the number of possible variations. Let's take a look at the test configurations (**fig. 4**).

1. Longwire: All four legs were 340 feet (104m) long. Each wire was strung in the direction of a compass point, *i.e.*, true north, east, west and south. Thus each wire was 90° apart. All were 20 to 25 feet (6-7.6m) above ground.

This arrangement provided the alternative of a center-fed, north-south or east-west longwire. Center impedance measured 200 ohms on an impedance bridge at 3.6 MHz. The system was fed with a 50-ohm coax cable and a 4:1 balun. At 40 and 20 meters I added capacitance across the balun to compensate for the reactance. Unused elements were grounded at the operating position.

2. V-beam: Four V beams could be selected in different directions. Each leg was 1¼ wavelengths at 3.6 MHz.

3. Longwire plus steerable element: Four variations were possible with a switch-selected phase shifter connected to the steerable element. The phase shifter was a tapped 4:1 balun.

4. Turnstile – simple feed: This configutation is called a turnstile for want of a better name. The conventional turnstile has two half-wave elements spaced 90° around a common axis and is fed 90° out of phase. Before you dismiss this one on technical grounds, be advised that it performed very well.

5. Turnstile 270° out of phase: The phasing for this system was with a tapped 4:1 balun.

6. Turnstile 90° out of phase: Similar to no. 5 but with taps selected at 90°.

7. Double V-beam: Terminology is difficult for this one. It's not two V beams operating together in the usual arrangement with phasing lines. Again keep an open mind, because this antenna was a top performer.

8. Longwire plus two "steerable" elements: This

switched arrangement is really a combination of three antennas. At the extreme switch positions (as shown), the antenna is identical to no. 7 (double V-beam). At the center switch position the antenna is a simple longwire with the unused elements grounded. At the other intermediate positions, a variable phase shift is inserted between the longwire elements.

test procedures

Initial tests were made on 80 meters with two-way contacts. Signal reports were obtained on the alternative antennas while transmitting. Only reports obtained from the distant operator using an S meter were recorded. After about 20 reports of this type I concluded that the reports correlated closely with readings I observed when receiving the distant station. I made further comparisons on received signals only, which speeded up the process and allowed a greater number of observations to be made in the time available.

All tests were made using no more than three antennas at a time. These antennas were instantaneously switched to obtain a reading. Several readings were taken on each occasion to overcome fading conditions and to ensure accuracy. One "control" antenna was carried over from one series of tests to the next. The readings were taken over paths between 200 and 1,000 miles (321.8 and 1609 km) with the majority in the 300-500 mile (482.7-804.5 km) range. Although only 50 watts output was used, the antenna system proved so effective that several contacts were made with Europe on 80 meters with comparative reports obtained on several of the alternative configurations.

On 40 and 20 meters, a few two-way contacts confirmed the same results as experienced on 80 meters: comparative readings were equivalent on both transmitting and receiving.

test results

Five series of tests were performed. Results are as follows:

first test series. A comparison of antennas 1 and 2 (longwire and V-beam, **fig. 4**) was made. Results were surprising. The V beam outperformed the longwire by a substantial margin (10-20 dB) except on very rare occasions. By comparison the longwire was inferior, which seemed strange in view of its good reputation. Horizontal directional gain didn't appear to be a factor in achieving the superior performance from the V. In fact, a V aimed in the wrong direction frequently was *slightly* better than the "correct" V. The north-east path, which was over somewhat lower ground (not more than 8-10 feet [2.4-3m] elevation difference on flat ground), produced the best results in all directions – probably because of better ground conductivity.

second test series. These tests included the longwire plus steerable element (antenna 3 of **fig. 4**). At the extremes of switch travel a sort of lopsided V is in the circuit, while at the switch center position the antenna becomes a longwire with steerable element grounded. These tests again proved the superiority of the V configuration. Results of these tests ranged from inferior performance at the center switch position to best performance for the "lopsided V," with gradual improvement in between. The "steerable" element merely steered me back to the V for the best performance.

third test series. In this series I compared the turnstile with simple feed, turnstile with 270° phasing, and turnstile with 90° phasing (antennas 4, 5 and 6 in **fig. 4**. Antenna 4 has a slight edge over the other two test configurations. It seemed to be a good all-around antenna.

fourth test series. Here I tested antennas 2, 4 and 7 (**fig. 4**); *i.e.*, V beam, turnstile with simple feed, and double V beam. As I appeared to have top performers at this point, I decided to test extensively on 40 as well as 80 meters and to check alternatives on transmit as well as on receive. Some testing was also done on 20 meters.

Again, twenty contacts were made on 80 meters, where a transmitting report was received from the

Table 1. Feedpoint displacement from the center of the array.

	element A		element B		element C		element D	
element length, feet (meters)	613	(186.8)	631	(192.3)	666	(203)	684	(208.50)
resonances (MHz)	3.970 7.190 28.0		3.850 6.950 21.0 28.8		3.650 14.0 21.4 28.8		3.565 28.0	
actual feed displacement feet (meters)	6.5	(1.98)	15.5	(4.7)	20	(6.0)	11	(3.4)
worst possible displacements, feet (meters)	60 33 8	(18.0) (10.0) (2.4)	62 34 12 8	(18.9) (10.4) (3.7) (2.4)	64 17 12 8	(19.5) (5.2) (3.7) (2.4)	66 8	(20.0) (2.4)
ideal displacements, feet (meters)	120 66 16	(36.6) (20.0) (4.9)	124 67 24 16	(37.8) (20.4) (7.3) (4.9)	128 34 24 16	(39.0) (10.3) (7.3) (4.9)	132 16	(40.2) (4.9)

distant station. For simplicity, only the N-E, S-W Vs were used. The azimuth bearing, distance, time, band conditions and comparative dB readings were recorded. Results were:

	turnstile	V beam	double V
equal or best signal	6 reports	9 reports	11 reports
outperformed other antennas	2 reports	4 reports	7 reports

Careful examination of the test data disclosed no correlation between bearing or distance in providing the best result. Antenna 7 (double V) frequently outperformed the others by 5 - 20 dB. Antenna 2 (V beam) outperformed antenna 7 by only 2 - 5 dB, when it excelled. The turnstile (no. 4) excelled by 4 dB on skip once and by 4 dB on groundwave once. Antenna 7 not only produced the best signal most frequently but did so by the greatest margin.

Subsequently, a larger bank of data comprising one hundred and sixty two readings was obtained during varying conditions by recording the differences of received signals. The results:

	turnstile	V beam	double V
equal or best signal	26% of contacts	38% of contacts	36% of contacts
outperformed other antennas	12% of contacts	45% of contacts	43% of contacts

Again the phenomenon of greater average dB gain was observed for antenna 7 double V when it did excel; when it was inferior to the others, it was not far behind.

The several contacts with Europe on 80 meters indicated no discernible difference between antennas 4, 2 and 7. The differences seemed to disappear on long skip. On 40 meters antenna 7 was the undisputed leader:

	turnstile	V beam	double V
outperformed other antennas	13% of contacts	10% of contacts	77% of contacts

On 20 meters antenna 7 did even better. It provided the best signal on more than 80% of the readings on short, medium and long skip.

fifth test series. The fifth and final test series was an anticlimax. It involved antenna 8 (longwire plus two steerable elements). Turning the switch brought signals from minimum in the center position to maximum in either end position with rarely a difference between the end positions. These end positions are identical to antenna 7 (double V) and tend to confirm its excellence as found in the preceding test series.

test conclusions

The attempt to devise a steerable array was a dismal failure. There may be other ways to achieve an effective phase shift between elements, but the tapped balun is not the answer. I concluded that phase shifts were lost in the skip paths. The longwire is an inferior configuration. The same labor and materials can be used to construct a much more effective V or double V.

While the 80-meter performance difference between the V and double V is somewhat marginal, another factor heavily favors the double V. This is its ability to provide broadband performance.

This part of the article describes specific broadband designs. Performance figures and other data are provided so that you can tailor your own longwire array to suit your real estate and bandwidth requirements.

The V beam proved to be outstanding in an unusual configuration which I call a double V. The double V can be broadbanded by staggering its element lengths and easily fed with 50-ohm coax and a 4:1 balun. It will operate on all bands or on selected bands depending on the length and number of legs. At the sacrifice of bandwidth, three legs may be used instead of four.

the antenna

My antenna is the shortest practical design for adequate bandwidth to cover all HF amateur bands (except 160 meters). It has four legs approximately 20-25 feet (6-7.6m) above ground, which terminate on a 40-foot (12m) mast. The legs vary in length from 300-353 feet (91-107.6m) and are spaced 90° apart. The wires which are uninsulated run through trees and are supported by branches.

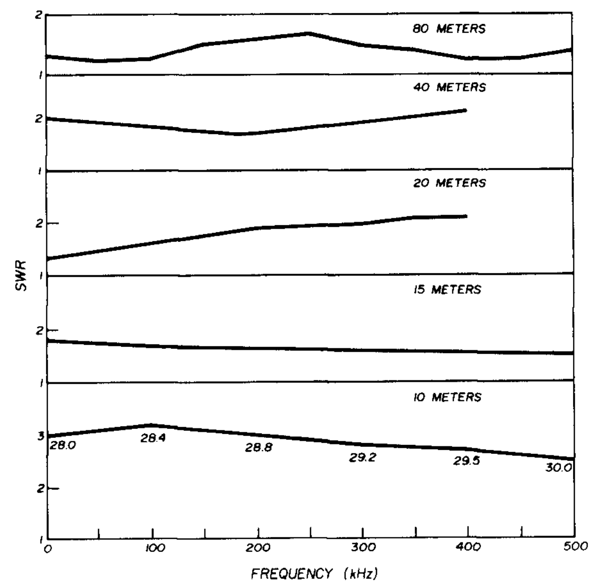
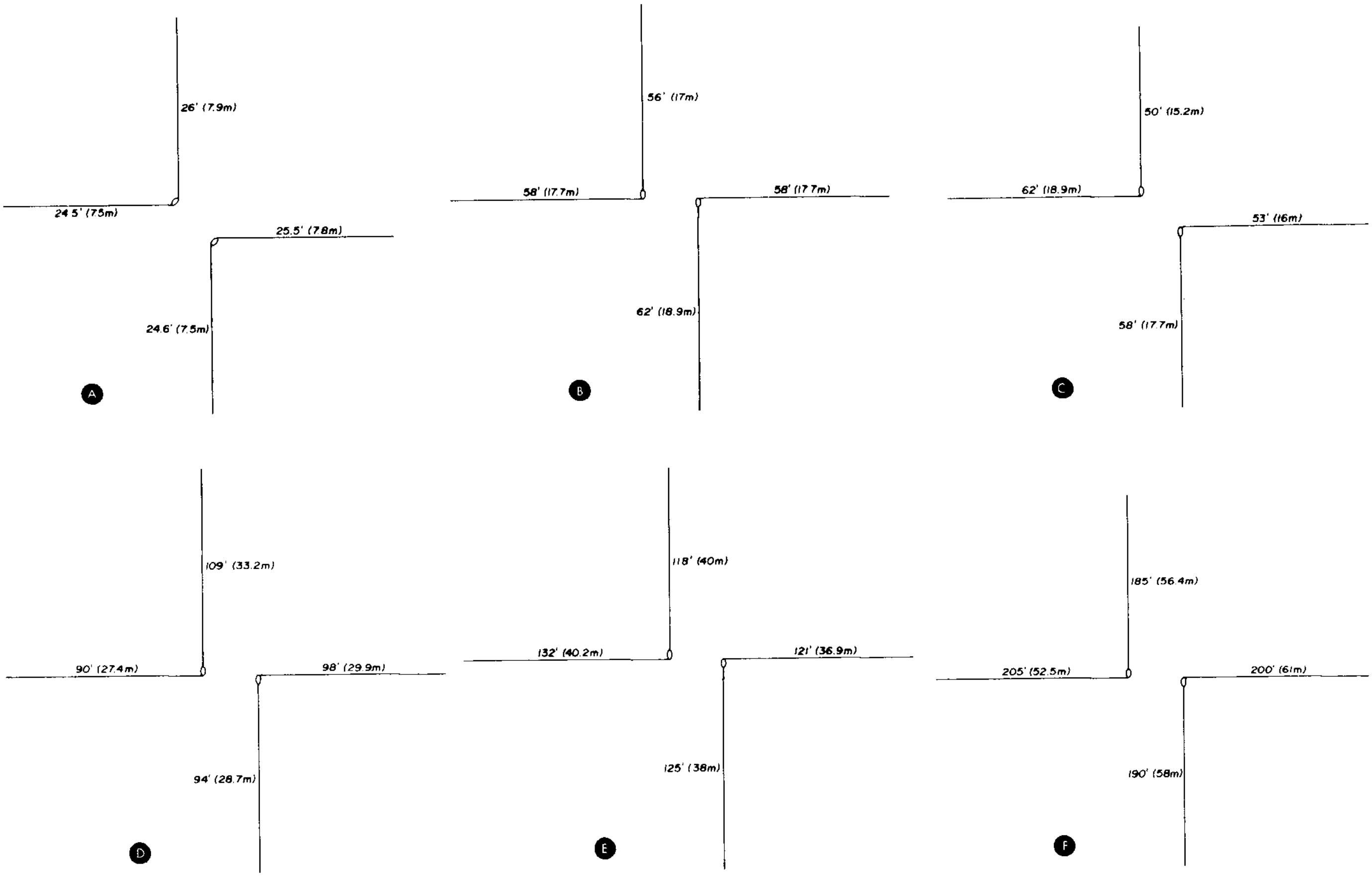


fig. 7. Measured swr of author's antenna on all bands, 80-10 meters. The curve for 10 meters covers 28 to 30 MHz. The curves for the other bands start with the lower band edge on the left side of the chart.

Aluminum electric fence wire is used, which can be purchased from Sears or Montgomery Ward for about $15 per quarter mile (0.4km) roll. The 5 kW PEP 4:1 balun by Palomar Engineers has stainless steel eyelets, which take 1/4 inch (M6) stainless nuts and bolts, and which I used for terminals. The terminals and wires were impregnated with zinc chromate metal primer paint to prevent corrosion.

Fig. 5 shows the final design. It's really a composite of four antennas with 13 resonances in the HF amateur bands as shown in **fig. 6**. The antenna is unobtrusive. Only a very alert observer would notice the small wire



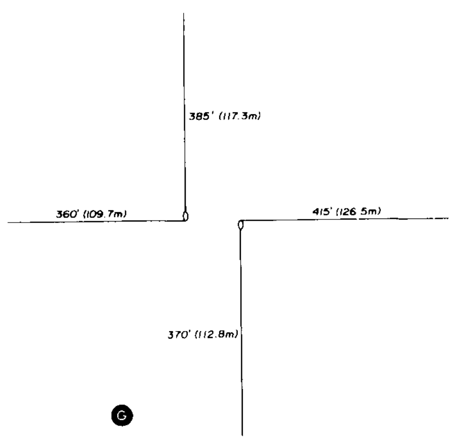


fig. 8. (A) 10-meter broadband design. This is an extension of the simple 10-meter antenna referred to previously. Its four staggered leg lengths will provide a low swr across the entire 10-meter band. It should make a good OSCAR antenna for the high end of 10 meters as well as a good communications antenna for the low end of the band. (B) 15- and 10-meter "shorty" design. This antenna should do a good job across the entire 10- and 15-meter bands but with some sacrifice in bandwidth. (C) 20-, 15-, and 10-meter design. This arrangement would cover the low end of 15 and 20 meters and virtually the entire 10-meter band with low swr. Its performance would be best on 20 and 10 meters, where it has V beams, while resonating as a longwire on 15 meters. This is the smallest possible triband design. (D) 40-, 15-, and 10-meter design. This antenna would behave nicely on 40-meter CW, 15-meter phone and 10-meter phone. Operation on 40-meter phone would be satisfactory in most cases, but the swr would be borderline. This is the smallest possible design that includes the 40-meter band. (E) 20-, 15-, and 10-meter design. This is a beautiful broadband antenna for these bands with a low swr across the band in each case. The design provides V-beam resonances on each of the three bands for best performance. Place each leg at a compass point and it would be a satisfactory radiator in all directions. (F) 80-, 20-, 15-, and 10-meter design. This is the smallest possible design that includes 80-meters. It will give superb performance on that band. The swr will be below 2:1 across the entire 80- and 20-meter bands. On 15 meters the bandwidth will not be quite as broad, but the design should yield good results. The design resonates in V configurations on all four bands. The 10-meter-band swr bandwidth is somewhat unpredictable because of feedpoint displacements close to current nodes. (G) 160-, 40-, 20-, and 15-meter design. Antenna designers and manufacturers seem to studiously avoid provision for 160-meter operation. This is unfortunate in view of the interesting characteristics and challenges presented by this band. It is significant that some of the most sophisticated amateurs are now operating on 160 and that the LORAN system with its interference is all but obsolete. When the final demise of LORAN occurs, hopefully the 160-meter band will be restored to its pre-WW2 status. This antenna should be a winner on 160. It should also provide good performance on 40, 20 and 15 meters. On 10 meters, so many loops and nodes occur that performance is unpredictable, but you might be pleasantly surprised. This is the smallest design possible that includes 160 meters, and it's unfortunate that no resonances fall in the 80-meter band, which renders this band unusable except with a high swr. A combination of 160 and 80 meters in this design isn't possible unless wire lengths over 1000 feet (304.8m) are used — somewhat impractical for the average urban lot.

snaking through the trees. Various parts of the system cross three adjacent properties with the permission of the owners.

With an array of this size, which covers some ten acres ($40470m^2$), lightning protection is essential. Secondary discharges from nearby strikes would produce lethal and damaging voltages. A direct strike would be devastating and would probably vaporize the wire. The objective should be to prevent these voltages from entering the operating position by providing a low

160 meters - 3% bandwidth: 60 kHz

frequency (MHz):		1.825		1.875		1.925		1.975	
element length: full waves	half waves	feet	(meters)	feet	(meters)	feet	(meters)	feet	(meters)
1.5	3.0	797.5	(243.0)	776.2	(236.6)	756.0	(230.4)	736.8	(224.6)
2.5	5.0	1338.1	(407.9)	1302.4	(397.0)	1268.4	(386.6)	1236.2	(376.8)
3.5	7.0	1878.9	(572.6)	1826.6	(556.7)	1781.0	(542.8)	1735.7	(529.0)

80 meters - 3% bandwidth: 120kHz

frequency (MHz):		3.6		3.7		3.8		3.9	
element length: full waves	half waves	feet	(meters)	feet	(meters)	feet	(meters)	feet	(meters)
1.5	3.0	403.2	(122.9)	392.3	(119.6)	382.0	(116.4)	372.2	(113.4)
2.5	5.0	676.5	(206.2)	658.2	(200.6)	640.9	(195.3)	624.5	(190.3)
3.5	7.0	949.8	(289.4)	924.2	(281.7)	899.8	(274.3)	876.8	(267.2)
4.5	9.0	1223.2	(372.8)	1190.1	(362.7)	1158.8	(353.2)	1130.0	(344.4)
5.5	11.0	1496.5	(456.1)	1456.0	(443.8)	1417.7	(432.1)	1381.4	(421.0)
6.5	13.0	1769.5	(539.3)	1722.0	(524.9)	1676.7	(511.0)	1633.7	(498.0)

40 meters - 3% bandwidth: 210 kHz

frequency (MHz):		7.0		7.1		7.2	
element length: full waves	half waves	feet	(meters)	feet	(meters)	feet	(meters)
1.5	3.0	207.3	(63.2)	204.4	(62.3)	201.6	(61.4)
2.5	5.0	348.0	(106.0)	343.0	(104.5)	338.3	(103.1)
3.5	7.0	488.5	(148.9)	481.6	(146.8)	475.0	(144.8)
4.5	9.0	629.0	(191.7)	620.2	(189.0)	611.6	(186.4)
5.5	11.0	769.6	(234.6)	758.7	(231.3)	748.3	(228.0)
6.5	13.0	910.2	(277.4)	897.4	(273.7)	885.0	(269.7)
7.5	15.0	1050.3	(320.1)	1036.0	(315.0)	1021.6	(311.4)
8.5	17.0	1191.3	(363.1)	1174.6	(358.0)	1158.3	(353.0)
9.5	19.0	1332.0	(406.0)	1313.1	(400.2)	1295.0	(394.7)
10.5	21.0	1472.5	(448.8)	1451.8	(442.5)	1431.6	(436.4)
11.5	23.0	1613.0	(491.6)	1590.3	(484.7)	1568.3	(478.0)
12.5	25.0	1753.6	(534.5)	1729.0	(526.5)	1705.0	(519.7)

20 meters - 3% bandwidth: 420 kHz

frequency (MHz):		14.1		14.2		14.3	
element length: full waves	half waves	feet	(meters)	feet	(meters)	feet	(meters)
1.5	3.0	103.0	(31.4)	102.2	(31.2)	101.5	(30.9)
2.5	5.0	172.7	(52.6)	171.5	(52.3)	170.3	(51.9)
3.5	7.0	242.5	(73.9)	240.8	(73.4)	239.1	(72.9)
4.5	9.0	312.3	(95.2)	310.1	(94.5)	308.0	(93.9)
5.5	11.0	382.1	(116.5)	379.4	(115.6)	376.7	(114.8)
6.5	13.0	451.9	(137.7)	448.7	(136.8)	445.6	(135.8)
7.5	15.0	521.7	(159.0)	518.0	(157.9)	514.4	(156.8)
8.5	17.0	591.5	(180.3)	587.3	(179.0)	583.2	(164.0)
9.5	19.0	661.2	(201.5)	656.5	(200.1)	652.0	(198.7)
10.5	21.0	731.0	(222.8)	725.9	(221.3)	720.8	(220.0)
11.5	23.0	800.8	(244.1)	795.1	(242.3)	789.6	(241.0)
12.5	25.0	870.6	(265.4)	864.5	(263.5)	858.4	(261.6)
13.5	27.0	940.4	(286.6)	933.8	(284.6)	927.2	(282.6)
14.5	29.0	1010.0	(307.8)	1003.0	(305.7)	996.0	(303.6)
15.5	31.0	1080.0	(329.2)	1072.4	(326.9)	1064.8	(324.6)
16.5	33.0	1149.7	(350.4)	1141.6	(348.0)	1133.7	(345.6)
17.5	35.0	1219.5	(371.7)	1211.0	(369.1)	1202.5	(366.5)
18.5	37.0	1289.3	(393.0)	1280.2	(390.2)	1271.2	(387.5)
19.5	39.0	1359.1	(414.3)	1349.5	(411.3)	1340.1	(408.5)
20.5	41.0	1428.9	(436.1)	1418.8	(432.5)	1408.9	(429.4)
21.5	43.0	1498.7	(456.8)	1488.1	(453.6)	1477.7	(450.4)
22.5	45.0	1568.5	(478.0)	1557.4	(475.0)	1546.5	(471.4)
23.5	47.0	1638.3	(499.4)	1626.7	(495.8)	1615.3	(492.3)
24.5	49.0	1708.0	(520.6)	1696.0	(517.0)	1684.0	(513.3)
25.5	51.0	1777.8	(541.9)	1765.3	(538.0)	1753.0	(534.3)

15 meters - 3% bandwidth: 630 kHz

frequency (MHz):		21.1		21.2		21.3	
element length:		feet	(meters)	feet	(meters)	feet	(meters)
full waves	half waves						
1.5	3.0	68.8	(21.0)	68.5	(20.9)	68.1	(20.8)
2.5	5.0	115.4	(35.2)	114.9	(35.0)	114.3	(34.8)
3.5	7.0	162.6	(49.6)	161.3	(49.2)	160.5	(48.9)
4.5	9.0	208.7	(63.6)	207.7	(63.3)	206.7	(63.0)
5.5	11.0	255.3	(77.8)	254.1	(77.4)	253.0	(77.1)
6.5	13.0	302.0	(92.1)	300.5	(91.6)	299.1	(91.2)
7.5	15.0	348.6	(106.3)	347.0	(105.8)	345.3	(105.2)
8.5	17.0	395.2	(120.5)	393.4	(120.0)	391.5	(119.3)
9.5	19.0	442.0	(134.7)	439.8	(134.1)	437.7	(133.4)
10.5	21.0	488.5	(149.9)	486.2	(148.2)	484.0	(147.5)
11.5	23.0	535.1	(163.1)	532.6	(162.3)	530.1	(161.6)
12.5	25.0	581.8	(177.3)	579.0	(176.4)	576.3	(175.7)
13.5	27.0	628.4	(191.5)	625.4	(190.6)	622.5	(189.7)
14.5	29.0	675.0	(205.7)	671.9	(204.8)	668.7	(203.8)
15.5	31.0	721.7	(220.0)	718.3	(219.0)	715.0	(218.0)
16.5	33.0	768.3	(234.2)	764.7	(233.1)	761.1	(232.0)
17.5	35.0	815.0	(248.4)	811.1	(247.2)	807.3	(246.1)
18.5	37.0	861.6	(262.6)	857.5	(261.4)	853.5	(260.3)
19.5	39.0	908.2	(276.8)	904.0	(275.5)	899.7	(274.2)
20.5	41.0	954.8	(291.0)	950.4	(289.7)	945.9	(288.3)
21.5	43.0	1001.5	(305.3)	996.8	(303.8)	992.0	(302.4)
22.5	45.0	1048.1	(319.5)	1043.2	(318.0)	1038.3	(316.5)
23.5	47.0	1094.8	(333.7)	1089.6	(332.1)	1084.5	(330.6)
24.5	49.0	1141.4	(347.9)	1136.0	(346.3)	1130.7	(344.6)
25.5	51.0	1188.0	(362.3)	1182.4	(360.4)	1176.9	(358.7)

10 meters - 3% bandwidth: 840 kHz

frequency (MHz):		28.2		28.4		28.6		28.8	
element length:		feet	(meters)	feet	(meters)	feet	(meters)	feet	(meters)
full waves	half waves								
1.5	3.0	51.5	(15.7)	51.1	(15.6)	50.8	(15.5)	50.4	(15.4)
2.5	5.0	86.4	(26.3)	85.8	(26.2)	85.2	(26.0)	84.6	(25.8)
3.5	7.0	121.3	(37.0)	120.4	(36.7)	119.6	(36.5)	118.7	(36.2)
4.5	9.0	156.1	(47.6)	155.0	(47.2)	154.0	(47.0)	153.0	(46.6)
5.5	11.0	191.0	(58.2)	189.7	(57.8)	188.4	(57.4)	187.0	(57.0)
6.5	13.0	226.0	(68.9)	224.4	(68.4)	222.8	(67.9)	221.2	(67.4)
7.5	15.0	260.8	(79.5)	259.0	(79.0)	257.2	(78.4)	255.4	(77.8)
8.5	17.0	295.7	(90.1)	293.6	(89.5)	291.6	(88.9)	289.6	(88.3)
9.5	19.0	330.6	(100.8)	328.3	(100.0)	326.0	(99.4)	323.7	(98.7)
10.5	21.0	365.5	(111.4)	363.0	(110.6)	360.4	(109.8)	358.0	(109.1)
11.5	23.0	400.4	(122.0)	397.6	(121.2)	394.8	(120.3)	392.0	(119.5)
12.5	25.0	435.3	(132.7)	432.2	(131.7)	429.2	(130.8)	426.2	(130.0)
13.5	27.0	470.2	(143.3)	467.0	(142.3)	463.6	(141.3)	460.4	(140.3)
14.5	29.0	505.0	(154.0)	501.5	(152.9)	498.0	(151.8)	494.5	(150.7)
15.5	31.0	540.0	(164.6)	536.2	(163.4)	532.4	(162.3)	528.7	(161.1)
16.5	33.0	574.9	(175.2)	570.8	(174.0)	566.8	(172.8)	562.9	(171.6)
17.5	35.0	609.8	(185.9)	605.4	(184.5)	601.2	(183.2)	597.0	(182.0)
18.5	37.0	644.7	(196.5)	640.1	(195.1)	635.6	(193.7)	631.2	(192.4)
19.5	39.0	679.6	(207.1)	674.8	(205.7)	670.0	(204.2)	665.4	(202.8)
20.5	41.0	714.5	(217.8)	709.4	(216.2)	704.5	(214.7)	699.6	(213.2)
21.5	43.0	749.3	(228.4)	744.0	(226.8)	738.9	(225.2)	733.7	(223.6)
22.5	45.0	784.2	(239.0)	778.7	(237.3)	773.3	(235.7)	768.0	(234.1)
23.5	47.0	819.1	(249.7)	813.4	(247.9)	807.7	(246.2)	802.0	(244.4)
24.5	49.0	854.0	(260.3)	848.0	(258.5)	842.0	(256.7)	836.2	(254.9)
25.5	51.0	889.0	(271.0)	882.7	(269.1)	876.5	(267.2)	870.4	(265.3)

table 2. Center fed element lengths to produce nominal 200-ohm impedance at resonant frequencies shown. V-beam configurations are recommended using an apex angle of 90° with each leg one-half the wire length shown. Antenna will be virtually nondirectional and may be fed with a 4:1 balun and 50-ohm coax for low swr. Approximate bandwidths are shown for individual elements operating alone.

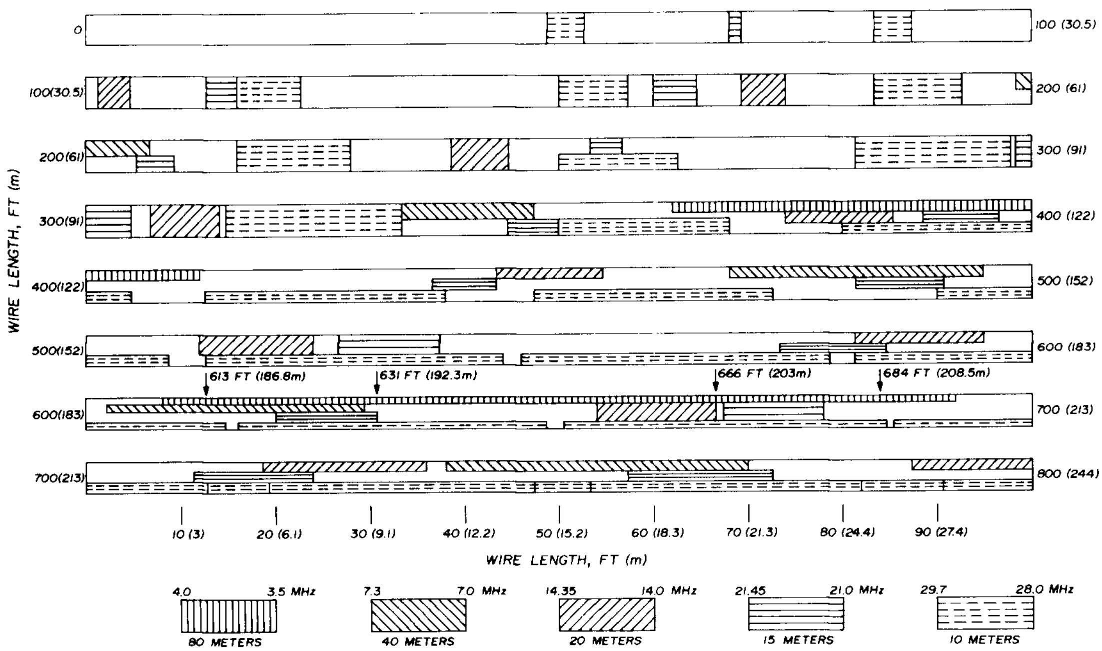


fig. 9. Design aid showing wire lengths from zero to 800 feet (0-244m) in 100-foot (30.5m) increments with amateur bands identified for odd number of half-wave resonances. Wire length of author's antenna is identified by arrows.

resistance path to ground. I installed a 9-foot-long (2.7m) ground rod at the base of the mast and ran a no. 4 AWG (5.2mm) copper wire from the balun to the rod. Thus, the entire system is grounded at all times.

bandwidth: One of the primary objectives was to achieve a low swr across all bands. **Fig. 7** shows the measured swr. It exceeded all expectations over the 80-meter band, where it was below 1.6:1. On 40, 20 and 15 it was below 2:1 from band edge to band edge.

The 3:1 swr on 10 was a surprise. From **fig. 6** you'll note that each of the four elements resonate on 10. The fact that they are fed offcenter because of the staggered leg lengths made calculating an impedance match difficult. This comes about because a mere 8-foot (2.4m) displacement from the element center produces a current node instead of the desired loop. Fortunately, impedance matching was quite tolerant so long as the antenna was not fed precisely at the node. This principle of considering the feedpoint displacement from the center in relation to the loops and nodes is quite important and is an inherent part of the design. The higher the frequency band the more critical this factor becomes. My antenna contained the following displacements as shown in **table 1**.

Examination of this data discloses an undesirable condition on 10 meters for elements A, C, and D. Only B is fed near the correct point. To correct this for 10 meters would result in bandwidth loss on the lower bands, so it was decided to accept this compromise. compromise.

Note that the relatively undesirable 15-meter-band feedpoint on element B may be balanced by the more desirable point on C, and the result is a tolerably low swr across the entire band.

The 20-meter performance is more difficult to understand. The only resonance within the band is given by C at 14.0 MHz. The feedpoint is displaced by 20 feet (6m) from center, which is quite close to the undesirable node. However, element D resonates at 13.7 MHz with a somewhat better match and this may account for the better swr skewed toward the lower end.

A probability that may explain the low swr on all bands is the combination of capacitive reactance of one element with the inductive reactance of another, which partially cancels the total reactance appearing at the feedpoint. A single resonant element alone appears to have a 2:1 swr bandwidth of about 3% of the frequency. However, it broadens out somewhat when other elements are added, even though they are not resonant near that frequency.

design variations

An almost infinite number of variations of the basic design is possible. Three legs instead of four produce a combination of one longwire and one V. A three- or four-leg configuration may be designed for one or more bands with bandwidth also variable. The amateur who operates CW exclusively would favor the CW bands and design a smaller array to suit his purpose by sacrificing bandwidth to achieve smaller size.

To assist the reader in designing his own version, wire lengths are provided in **table 2**. Several frequencies in each band are given to make it convenient to stagger the wire lengths to achieve the desired bandwidth. Some pruning may be necessary after swr readings are made.

Fig. 9 contains data for designing a multiple-band array. The wire is laid out in 100-foot (30.5m) increments, and the bands are identified where current loops occur in the center of the wire length. For example, a

50-foot (15.2m) length of wire will have a low swr on 10 meters if fed in the center with a 4:1 balun and 50-ohm coax. Its bandwidth will approximate 3% or 870 kHz. Thus, it will be useful from 28.5 to 29.4 MHz with an swr under 2:1. It should make a good antenna for 10-meter phone. If CW operation also is desired, let's add a leg 26.5 feet (8m) long to one of the balun terminals. This will give an additional resonance at about 28.2 MHz and result in a bandwidth from 28.0 to 29.5 MHz. Each active element will be 1.5 wavelengths long. As mentioned earlier, it's preferable to use the V configuration rather than the straight longwires. A number of alternate designs are shown in **fig. 8**.

conclusion

The first advantage that impresses the operator who uses one of these broadband systems is the convenience. Gone is the need to adjust an antenna tuner. With a modern broadband solid-state transceiver, such as the Ten Tec or Heathkit designs, operation is instantly available in any portion of the band. Contest operating is greatly speeded up. When band conditions are marginal, band changing is immediate and the state of other bands can be checked with a flick of the band switch.

Operating habits will quickly change. Instead of concentrating in a small frequency range, the operator becomes a nomad who explores every nook and cranny of our broad frequency allocations. Interesting contacts are made with stations who rarely venture from their "home" frequencies.

The second advantage is performance. The capture area of the system gives a big signal on the band. When band conditions were poor and signals weak, I frequently experienced a pileup of weak stations calling in response to a CQ. An RST 599 report was common from stations flirting with the noise level.

Outstanding performance was not limited to the lower-frequency bands. The results in working long skip on 20 meter CW were the final pleasant surprise. Despite its low height, the antenna consistently turned in 589 and 599 reports from Europe and the Middle East during marginal conditions. ZL, VK and J stations could be heard and worked when other U.S. stations apparently could not hear them.

Operation on 10 and 15 meters was somewhat limited and I have yet to encounter the bands open for long skip. However, results were excellent on medium and short skip. Rarely did a station fail to respond to a call. Signal reports were outstanding.

In summary, the double V was the best all-around antenna I have used in some 40 years of hamming. While not tried as an inverted V, it would probably lend itself to such an arrangement when mounted on a tall tower.

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ham radio

ground screen — an alternative to a buried radial system

Using a ground screen to complement or replace the wire radial system to reduce ground losses

As an alternative to a radial system, the ground screen consists of a wire mesh of sufficient size to act as a capacitive connection to the earth, similar to a counterpoise, but laid on the ground instead of suspended overhead. It can consist of hardware or construction mesh, welded fencing, or even chicken wire, although the latter is less durable. I have been using a screen for fifteen years as a replacement for a radial ground system and find that it works quite well, although until recently I had been unable to make quantitative measurements on its efficiency.

A 1/2-wavelength wire radial system is a very effective ground return, although it has certain practical disadvantages. First, a lot of work is involved in installing the radials, especially if you move very often. Second, the area required for a low-band system is quite large and hurriedly-buried wires are prone to damage by the lawn mower. The ground screen has none of these drawbacks. My first ground screen was installed under a 60-foot (18.3m), base-insulated tower erected in my parent's back yard in suburban Cincinnati, Ohio. I tried this system since the driveways on each side of the tower left room for nothing else. The screen then consisted of two 15 by 5-foot (4.6x1.5m) lengths of construction mesh, one on each side of the tower.

I also tried a 1/4-wavelength flat top but found a single wire has such a small cross-section that it was an ineffective loading system for the tower. After many variations, I finally settled on a 65-foot (19.8m) sloping vertical wire with a 1/8-wavelength flat top. This system worked quite well both stateside and into Europe and was an effective testimony for the ground screen. Unfortunately, my beautiful base-insulated tower was a bust on 160 meters.

Several years later, I had my own home in Denver, Colorado, and could hardly wait to erect an extensive antenna system. Finances were short, however, so I settled on a 48-foot (14.6m) vertical made from 1-inch (25mm) aluminum tubing. A good radial ground system

By J. Robert Sherwood, WBØJGP, Sherwood Engineering, Inc., 1268 South Ogden Street, Denver, Colorado 80210

could not be installed under this vertical either, since the house and patio blocked the area to the South and the lot line was only 25 feet (7.6m) away to the North.

As before, I decided to install a ground screen due to the limited space available. I bought a 20 by 3-foot (6.1x0.9m) length of 1/2-inch (13mm) hardware mesh which was woven with no. 18 AWG (1mm) steel wire and then heavily dip galvanized. It was laid out along the house right under my 48-foot (14.6m) L-network-fed vertical, and the results were excellent on 40 and 75 meters.

table 1. Ground screen configurations under the test vertical.

1	10 x 3 feet (3x0.9m) with vertical centered
2A	20 x 3 feet (6x0.9m) with vertical centered
2B	20 x 3 feet (6x0.9m) with vertical 5 feet (1.5m) from one end
3	30 x 2 feet (9x0.6m) with vertical centered (same area as no. 2)
4	50 x 2 feet (15.2x0.6m) with vertical centered
5A	75 x 2 feet (22.9x0.6m) with vertical centered
5B	75 x 2 feet (22.9x0.6m) with vertical 25 feet (7.6m) from one end
6	75 x 2 feet (22.9x0.6m) + 20 x 3 feet (6x0.9m) in a 90° cross with vertical centered
7	45 x 2 feet (13.7x0.6m) + 20 x 3 feet (6x0.9m) in a 90° cross with vertical centered
8	45 x 2 feet (13.7x0.6m) + 30 x 2 feet (9x0.6m) in a 90° cross with vertical centered (same area as no. 7)
9	45 x 2 feet (13.7x0.6m) + 25 x 5 feet (7.6x1.5m) in a 90° cross with vertical centered
10	45 x 2 feet (13.7x0.6m) + 30 x 2 feet (9x0.6m) + 20 x 3 feet (6x0.9m) in 60° radial strips with vertical centered
11	45 x 2 feet (13.7x 0.6m) + 30 x 2 feet (9x0.6m) + 20 x 3 feet (6x0.9m) in overlapping parallel strips with vertical centered
12	30 x 2 feet (9x0.6m) + 30 x 2 feet (9x0.6m) + 20 x 3 feet (6x0.9m) + 15 x 2 feet (4.6x0.6m) in overlapping parallel strips with vertical centered

About a year later the vertical came down in an ice storm – I replaced it with a 50-foot (15.2m) tower and a four-element, 20-meter beam. For 40 meters I suspended a 45-foot (13.7m) vertical wire 5 feet (1.5m) from the side of the tower and tuned it with an L network, as I had done with the previous vertical. The tower affected the feed impedance of the wire, but did not seem to degrade its radiation since the wire vertical worked as well as a 40-meter inverted Vee.

A year and a half later the 40-meter wire vertical was replaced by a 40-meter beam on a 20-foot (6.1m) mast above the existing 20-meter antenna. With the additional top-loading provided by the 40-meter beam, it was now possible to use the existing 20 by 3 foot (6.1x0.9m) ground screen to shunt-feed the tower system on 160 meters. According to an article in *ham radio*,[1] the 65-foot (19.8m) tower with a two-thirds size 40-meter beam at the top and a four-element 20-meter beam 15 feet (4.6m) below should have an electrical length of about 110 feet (33.5m). The radiation resistance, however, is lower than that of a wire that long, so my ground screen was put to the test again. The tower ground-screen system was quite effective on 160 meters, and it allowed me to maintain weekly schedules through the 1976 season until May, over the 1100 mile path between Denver and Cincinnati. Reports up to 20 dB over S9 that were received from K1PBW made me decide that more quantitative data had to be obtained on the ground-screen idea.

In May, 1976, I went to WØSPM's farm with my GR916A rf bridge, GR1001-A signal generator, Drake R-4C receiver, three lengths of tubing for an antenna, and 210 square feet ($20m^2$) of new chicken wire for a ground screen. While chicken wire is no rival for mesh or fencing in a permanent system, it was much cheaper to cut it up into different lengths for experiments.

A 36-foot (11m) high, 1 inch (25mm) constant cross-section aluminum tubing vertical was erected and used for all of the following tests. This length was chosen since it was easy to install and could be part of an easily built phased array. Antenna impedance measurements were made on 1.8, 3.6, and 7.2 MHz. Various shapes and sizes of ground screen were tested under the vertical including a single strip, two lengths in a 90° cross, radial strips at 60°, and different overlapping lengths laid parallel to each other. The fourteen arrangements of screening are listed in **table 1**, while **table 2** gives the resistive and reactive antenna measurements for each case.

resistive changes

Since no significant change in reactance was noted beyond 60 square feet ($5.6m^2$) of ground screen, only resistive changes will be discussed. These resistive values consist of the radiation resistance R_r plus the ground loss R_g. When a single two-foot (0.6m) wide strip was used, the lowest total resistance ($R_r + R_g$) occured with a screen length of 50 feet (15.2m) on 1.8 MHz and 3.6 MHz, and 30 feet (9.1m) on 7.2 MHz. With greater lengths, the radiation resistance (R_r) probably increased as the screen departed from a lumped capacitance and began acting as part of a dipole leg. There was a similar occurrence with the long cross in **case 6** which resulted in a larger R value than with the smaller screen area of the **case 7** cross. **Case 9** yielded the lowest total R on all three bands.

table 2. Impedance measurements for the 36 foot (11m) vertical with the different ground screen arrangements.

	1.8 MHz	3.6 MHz	7.2 MHz
1	25.0 – j730	28.0 – j286	85 + j67
2A	18.7 – j739	22.0 – j285	80 + j72
2B	17.7 – j739	23.0 – j278	80 + j71
3	13.5 – j728	18.5 – j281	78 + j81
4	11.0 – j719	20.0 – j274	81 + j81
5A	12.8 – j711	21.7 – j276	82 + j71
5B	12.6 – j717	21.5 – j275	81 + j81
6	11.2 – j714	18.0 – j281	74 + j77
7	8.8 – j717	16.6 – j278	74 + j76
8	8.8 – j719	15.7 – j279	72 + j78
9	7.9 – j717	14.6 – j279	71 + j76
10	8.2 – j717	15.6 – j279	72 + j76
11	8.2 – j717	14.5 – j279	73 + j78
12	8.5 – j717	14.8 – j279	72 + j76

The radial strip configuration of **case 10** had a resistive component slightly higher than in **case 9**, which was somewhat surprising. I thought it would have been equal to or better than that of the cross, but since more of the screen overlapped itself in this configuration, it is

probable that the decrease in area caused the increase in R. The ground resistance of the overlapping parallel strips was also slightly higher than the **case 9** cross. I decided not to make the strips shorter and more numerous because of the difficulty in keeping all the pieces bonded together.

As would be expected, there were greater percentage changes on 1.8 and 3.6 MHz due to the ground losses (R_g) being a larger part of the R component. With approximately 200 square feet (18.6m^2) of screening, the cross (with one leg at least 5 feet [1.5m] wide) yielded the lowest ground loss. A single 30 by 3-foot (9.1x0.9m) strip of half that area, however, was only 38 per cent less efficient. This is the layout I am using under my tower at the present time.

A GR-916A rf-impedance bridge was used to make the impedance measurements. The chicken-wire mesh can be seen laid on top of the ground.

theoretical losses

Now, compare the theoretical impedance of a 36-foot (11m) vertical over a perfectly conducting ground with that of the test installation. This will enable the ground losses to be calculated. The following data, for 36-foot (11m) verticals, is from the *ARRL Antenna Book* graphs:

7.2 MHz	0.277 wavelength	100° = 48 ohms
3.6 MHz	0.139 wavelength	50° = 9 ohms
1.8 MHz	0.069 wavelength	25° = 2 ohms

Subtracting the theoretical from the measured values yields the following ground losses and efficiency

7.2 MHz	23.5 ohms	67%
3.6 MHz	5.6 ohms	62%
1.8 MHz	5.9 ohms	25%

The ground losses are higher on 7.2 MHz than were expected, but are probably due to the lower conductivity of the earth at this frequency. On the other hand, to obtain more than 60 per cent efficiency for a 1/8-wavelength vertical on 3.6 MHz is quite encouraging and might foster some interest in phased arrays on 80 and 75 meters, using only a ground screen instead of wire radials.

The 25 per cent efficiency on 160 meters is not spectacular, but compare it with the results of Brown, Lewis, and Epstein[2] using eight 135-foot (41m) radials on 3 MHz. With a 25 degree antenna they obtained only 27 per cent efficiency and a 5-ohm ground resistance, but a 50 degree antenna gave a 51 per cent efficiency with an 8.5-ohm ground resistance. The efficiency goes up because the radiation resistance increases 4.5 times, yet the ground resistance also goes up because the taller radiator induces currents into the earth at a greater distance from the antenna.

Using fifteen 135-foot (41m) radials on 3 MHz, Brown measured a ground resistance of 3.2 ohms. When he added a 9 by 9-foot (2.7x2.7m) copper screen the resistance dropped to 1.6 ohms. One hundred and thirteen radials 135 feet (41m) long (0.4 wavelength) brought this down to 1 ohm, but, unfortunately no information is available on the ground screen alone. One might use the parallel resistor equation however, to extrapolate from his data a probable ground screen resistance of 5 to 6 ohms. These values are very similar to the 5.6 and 5.9 ohm reading obtained on 3.6 and 1.8 MHz with my test system.

With ground losses as low as 6 ohms obtainable by using only 200 square feet (18.6m^2) of ground screen, efficient vertical radiators are within the reach of most amateurs. While good efficiency is obtained with a 36-foot (11m) radiator on 80 meters, some sort of top loading is advised on 160. A 2-ohm radiation resistance is just too low for good efficiency with most amateur ground systems.

I feel the ground screen is a good alternative to the wire radial ground system. I've used it for a long time and am glad to see test measurements that confirm its effectiveness.

An additional aspect of wire screening is that its application does not have to be limited to one type of installation. If you have the room and initiative to install a radial ground system, add a screen, too. If the antenna is approximately 1/4 wavelength or shorter, a screen will reduce the ground losses in the high-current zone at the base of the antenna. For your next vacation or Field Day project, a screen made of chicken wire offers the added benefit of being as easy to roll back up as it was to unroll. It is available almost anywhere, so you do not have to bring it with you. The next time you erect a new vertical, or plan to improve an existing one, consider a ground screen as either a substitute for radials, or as an adjunct to an existing radial ground system.

I wish to thank George Heidelman, K8RRH, and Dr. Mike Lee for their help in preparing this manuscript.

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ham radio

a new coaxial balun

Re-examining the basic balun and applying new techniques makes it a useful, wide-range tool

The basic and sole purpose of a balun is to prevent the coaxial feedline from radiating and becoming part of the actual antenna structure. This should be understood before its operation is explained. By connecting one side of the dipole to the outer conductor of the coax, the radiating structure shown in **fig. 1** is formed. The coaxial cable connected to one side of the dipole and extending at right angles has currents flowing on the outside surface of the braid and will radiate just as effectively as the conductors making up the actual dipole.

Fig. 2 shows the effect using a balancing device. Electrically the dipole is now fed by the two generators. The important point to be understood is that the electric field in space is zero in the plane perpendicular to and passing through the center of the dipole. Because of this, conductors may be placed in this plane without changing antenna operation in any way. Thus, if the coaxial feedline is brought away from the antenna at right angles it will not disturb antenna operation; there will be no rf current flowing on the outside braid so there is no radiation from the feedline. Other conductors that are normally in this plane, such as a mast or the metal boom of a Yagi array, will also have no effect on antenna operation.

typical baluns

The sleeve and half-wave loop baluns are two well-known balancing devices (**figs. 3** and **4**). The transformation ratio of the sleeve balun is variable by changing the characteristic impedance of the inner line. However, its chief disadvantage is the difficulty of construction. If flexible cable is used for the inner line, then connection of the sleeve section and support of the cable in the sleeve present problems. If the jacket is left on the cable, the correct balun length will be less than a free-space quarter wavelength and will depend on the diameter of the sleeve. Also, when used at the higher uhf frequencies, 432 MHz and up, the sleeve diameter must be kept small enough to avoid having a structure that supports higher order modes of propagation.

The half-wave loop balun of **fig. 4** is simple to build using flexible coax but has limited usefulness since the

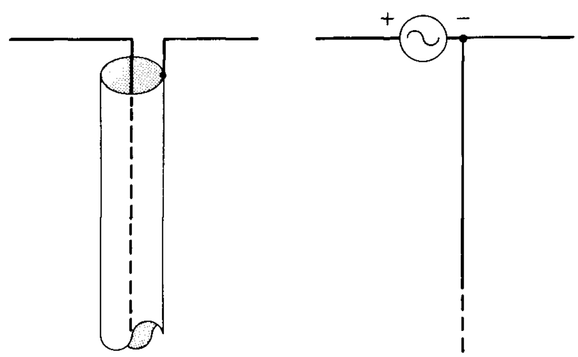


fig. 1. A dipole antenna fed directly with coaxial cable, left, and its electrical equivalent, right.

transformation ratio is fixed at 4:1. The characteristic impedance of the half-wave section, Z_1, has no effect on the transformation ratio or the balancing action of the device. The only effect for different values of Z_1 is to change the swr in the half-wave section, which is $2Z_0/Z_1$ when the load impedance, Z_L, is $4Z_0$. Typically, this balun is operated with $Z_1 = Z_0 = 50$ *ohms* and $Z_L = 200$

By Jim Dietrich, WAØRDX, Box 208, Mulvane, Kansas 67110

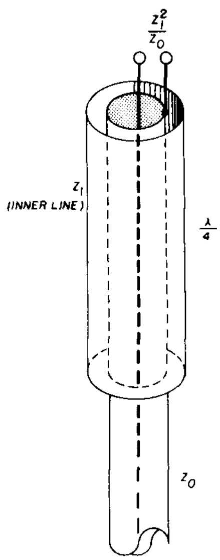


fig. 3. The sleeve or bazooka balun has a fixed transformation ratio of 1:1. Its construction can be complicated by the lack of readily available materials for different impedance ratios.

ohms. In this case there will be an swr of 2:1 in the half-wave section. To achieve unity swr in the half-wave section requires $Z_1 = 2Z_0$ which means a 100-ohm section if the main line is 50 ohms.

a different balun

A coaxial balun configuration which is apparently new to amateur use is shown in **fig. 5**. The transformation ratio is adjusted by changing the characteristic impedance, Z_1, of the quarter-wavelength and three-quarter-wavelength sections. It will match a coaxial line (impedance Z_0) to a balanced load with an impedance of $Z_1{}^2/Z_0$. With this Z_L, the swr in the two short sections is $2Z_0/Z_1$ (or $Z_1/2Z_0$ if it is greater than unity), as in the half-wave balun. However, in this case the swr is set by the transformation ratio and will be unity only when $Z_L = 4Z_0$. You can see that the balun is simply a combination quarter-wave matching section and half-wave balun. The same thing may be achieved by using a regular half-wave loop balun and a quarter-wave matching section of either coaxial line or balanced line on one end. The variable configuration is useful because in a particular situation, the required coaxial impedance values may be easier to obtain.

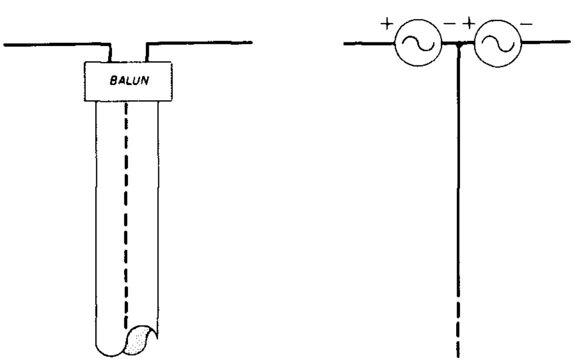


fig. 2. A dipole fed through a balancing device will appear as two balanced generators. In this case there is no radiation from the feedline.

As an example, consider the case where the main feedline has a characteristic impedance, Z_0, of 50 ohms. If the quarter-wavelength and three-quarter-wavelength sections are 50 ohms then Z_1 equals 50 ohms and you can now match a balanced load impedance of 50 ohms. The swr is 2 on the balun sections. Thus, a 1:1 transformation ratio is achieved using the same type coax in the balun as in the main feedline. It also avoids the construction difficulties of the sleeve balun by requiring only a coaxial T-fitting for connection between the coaxial line sections. Finally, note that multiband operation is possible with this balun as well as with the half-wave loop and bazooka baluns. For example, if cut for 144 MHz, they operate identically on 432 MHz and 1296 MHz. This assumes that the dielectric constant, and hence

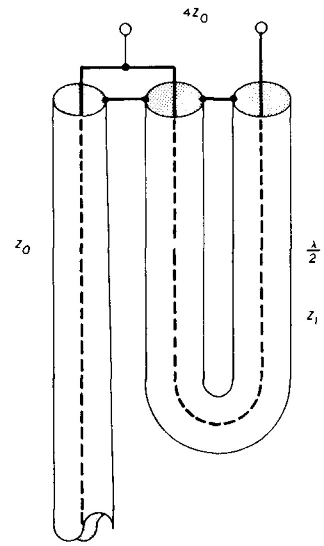


fig. 4. The halfwave-loop balun has a normal transformation ratio of 4:1. The characteristic impedance of the matching section has no effect on the transformation ratio.

velocity factor, in the balun sections is not appreciably different at the higher frequencies.

multi-element coaxial lines

The variable transformer balun can be applied to a practical problem — the feeding of a high-gain Yagi antenna which presents a balanced load of 10 to 15 ohms to the transmission line. If the main feedline is 50 ohms and the load is 12.5 ohms, then $Z_0 = 50\ ohms$, $Z_L = 12.5\ ohms$, and the characteristic impedance of the balun sections is $Z_1 = \sqrt{Z_0 \cdot Z_L}$ or 25 ohms.

The problem of building coaxial line with low impedance is easily solved by using the multi-element coaxial line shown in **fig. 6**. Here, two 50-ohm lines are connected in parallel to obtain a 25-ohm line. The attenuation of the multi-element line is equal to the loss for the type of coax used. In general, any number of different types of coax cable may be paralleled as long as their velocity factors are equal. The result is a coaxial line with a characteristic impedance equal to the parallel combination of individual cable impedances. For

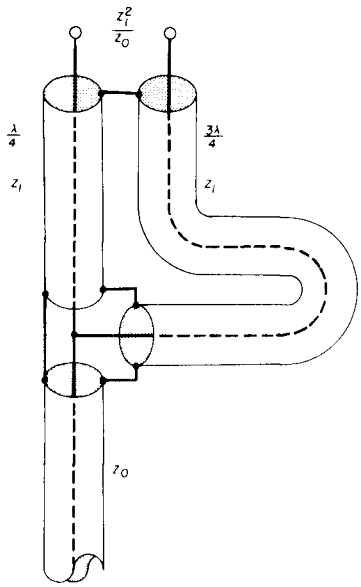


fig. 5. The variable transformer balun as described by the author. By selecting the correct value of characteristic impedance for the matching section, the transformation ratio can be changed.

example, 75-ohm and 50-ohm sections placed in parallel form a 30-ohm line. The sections can be soldered together or coaxial T-connectors may be used.

The solution to our matching problem, therefore, is shown in **fig. 7**. A system has been constructed that matches a balanced 12.5-ohm load and is built entirely of 50-ohm coaxial cable.

shielded balanced line

Coaxial transmission line may also be used to form a balanced line when connected as shown in **fig. 8**. In this configuration, the characteristic impedance of the coaxial lines must be identical to maintain balanced operation. Also, the outer conductors must be connected at each end. The characteristic impedance of the balanced line is then twice that of the coax used. Two points should be noted. First, since the line is shielded, it may be run anywhere and, second, relatively low values of characteristic impedance may be obtained. A low impedance may be the simplest solution to a particular matching problem.

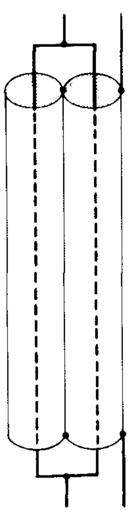


fig. 6. A two-element coaxial section. The characteristic impedance of the composite line is the parallel combination of the individual sections.

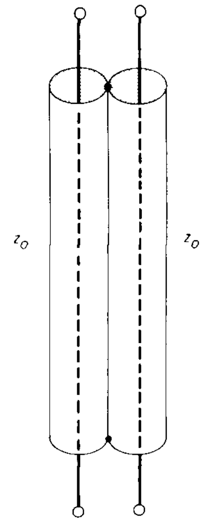


fig. 8. Low impedance, balanced transmission line can be built by using two sections of coaxial cable. This line will retain the shielded characteristics of coaxial cable.

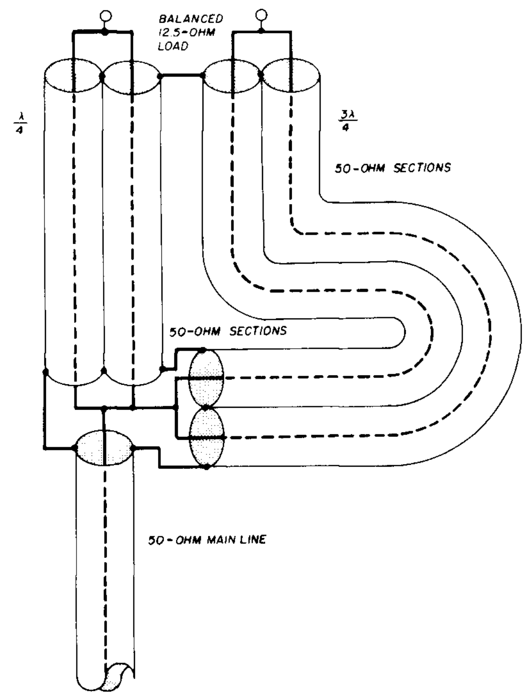


fig. 7. A balun can be built by combining the techniques of composite lines with the variable transformer. This balun will match a 4:1 unbalanced-to-balanced, impedance ratio using only 50-ohm cable.

summary

I have tried to create a better understanding of the balun by discussing its purpose in an antenna system. A new configuration of coaxial balun has been presented, along with unusual coaxial cable techniques, that I believe will be found useful. At WAØRDX, the 50-ohm, 1:1 transformer balun, in particular, has proved to be a valuable alternative to the half-wave loop balun and bazooka balun for feeding vhf antennas.

ham radio

antenna-transmission line analog

a key to designing and understanding antennas

Practical applications of this valuable tool in designing your own antenna systems

In the first part of this article it was shown in some detail how an antenna may be regarded as possessing both radiating and non-radiating properties.[1] I also discussed how the non-radiating TEM wave mode function may be used to convert the antenna into a special kind of rf transmission line. Using the antenna/transmission line concept in a way first made clear by Dr. Schelkunoff,[2] you can determine the mean or average characteristic impedance K of this antenna/transmission line and use it to calculate the antenna's input impedance behavior either at a single frequency, or over an entire band of frequencies.

In this section I will show you how to apply the antenna/transmission line analog concept to a number of typical antenna design problems which arise in both amateur and commercial radio communications. No higher mathematics is needed to use the analog key in the modified form presented here. **Table 1** references the basic equations used, based on everyday trigonometric functions. However, to remove any possible difficulty for the interested amateur who may be a bit rusty in ac math, not only are all examples fully worked out, step-by-step, but the Smith chart[3,4] is also used to clearly present the progression of events leading to each solution of the antenna design problem.

The best way to understand something new is to plunge in and start using it. Let's begin with an antenna which is of increasing interest to the amateur who is faced with shrinking backyard space or a nasty tempered landlord: the electrically small antenna. Many forms of this antenna have been around for a long time, yet it is a tricky little beast and requires surprising care in its design if you want to obtain a reasonable level of performance from it.

inductance loaded, electrically small antennas

When the electrical length, $2h_t^\circ$, of a doublet antenna is less than 180 degrees ($\lambda/2$), or the electrical length, h_t°, of a grounded monopole is less than 90 degrees ($\lambda/4$) at the operating frequency, the antenna is too

By **Joseph M. Boyer, W6UYH,** Antenna Consulting Engineer, 17302 Yukon, Suite 63, Torrance, California 90504

short electrically to oscillate in a state of natural resonance. For a linear antenna to oscillate at its first (lowest) natural resonance, the series inductance and shunt capacitance *distributed per unit length* along its conductor (or conductors) must add up to the reactive sum $+jX_L + (-jX_C) = jo\ ohms$ in a way similar to that of lumped, series LC circuits.

It is easy to understand how the distributed series inductance comes about, even in a perfectly straight conductor, but the distributed shunt capacitance is less obvious. The shunt capacitance is distributed to ground from each tiny incremental length of conductor forming a grounded monopole, or from one arm of a balanced doublet to the opposite arm in the same bit-by-bit way. As shown in the first part of this article, the distributed shunt capacitance in the cylindrical linear antenna is *not* uniformly distributed along the conductor length: It is maximum nearest the antenna input terminals, and at a minimum at the end (or ends) of the antenna.

table 1. Mean characteristic impedance of cylindrical antennas.

Doublet $K_A = 120\,[\log_e \frac{2(h_t')}{a'} - 1]\ ohms$ **1**

Grounded monopole $K_m = 60\,[\log_e \frac{2(h_t')}{a'} - 1]\ ohms$ **2**

Input impedance, Z_{in}, of uniform characteristic impedance transmission lines (of length equal to $h_n°$ where $n = 1, 2, 3 \ldots n$)

End open circuited

$(Z_s = \infty)$ $Z_{in} = -jK_{A,M}\ cotan\ h_n°$ **3**

End short circuited

$(Z_s = 0)\ Z$ $Z_{in} = +jK_{A,M}\ tan\ h_n°$ **4**

End terminated in complex impedance

$(Z_s = R \pm jX)$

$$Z_{in} = K_{A,M} \frac{(Z_s) \cos h_n° = jK_{A,M} \sin h_n°}{K_{A,M} \cos h_n° + j(Z_s) \sin h_n°} \quad \textbf{5}$$

Note: when $j(Z_s) = j(R \pm jX) = jR + jjX = \begin{matrix} jR + j^2X \\ jR - j^2X \end{matrix}$, where: $\begin{matrix} +j^2 = -1 \\ -j^2 = +1 \end{matrix}$

Useful Relationships

Inductance (henries)	$L = X_L/2\pi f$	*henries*	**6**
Capacitance (farads)	$C = 1/2\pi fX_c$	*farads*	**7**
Inductive reactance	$+jX_L = 2\pi fL$	*ohms*	**8**
Capacitive reactance	$-jX_c = 1/2\pi fc$	*ohms*	**9**

Where f is in Hz, L is in henries, and C is in farads

$Q\,(3\ dB)$ $Q = f_o/(f_{high} - f_{low})$ **10**

When the linear antenna is too short electrically to oscillate naturally, two interesting things happen to its input impedance, $Z_{in} = R_{in} + jX_{in}$. First, that part of R_{in} representing the resistive-like radiation term R_r is smaller than that found in the naturally resonant antenna; that is, R_r is less than the 36-ohm radiation resistance of the quarter wave, grounded monopole or less than the 72-ohm radiation resistance of the half-wave doublet.

At the same time, the input reactance, jX_{in}, of the electrically short antenna becomes capacitive. In the limit, when $h_t°$ approaches zero degrees in length, the radiation resistance R_r approaches zero ohms and $-jX_{in}$ approaches infinity. Because the electrically short linear* antenna acts like a series-resonant circuit operating on the low frequency side of resonance, we can "force" it back into electrical resonance by doing something which cancels out the reactive part of its self impedance. One way to do this is to insert a lumped inductor (loading coil) in series with the antenna conductor. The reactance, $+jX_{coil}$, of the lumped loading reactor needed to force-resonate an electrically short antenna of given length, $h_t°$, will vary in magnitude, depending upon just *where* it is inserted in the antenna conductor. To investigate how the short antenna operates when the loading coil is placed *anywhere* along the antenna conductor, you must arrange the analogue transmission used to represent the antenna in such a way that it can handle any possible coil location.

Fig. 1A shows a *doublet* antenna of total length, $2h_t°$, in the form of an analog coaxial transmission line. This is a model of the actual antenna, so think of the inner conductor of the analog line as the equivalent antenna conductor and the coaxial shield as the surrounding ground plane surface beneath the vertical monopole (or the influence of the capacitance to the other half of the doublet). The analog transmission line has a "uniform" characteristic impedance K_A, K_m, (the subscript A will be used for the doublet and m for the monopole). This analog transmission line $K_{A,m}$ is the mean or average value of the characteristic impedance of the cylindrical antenna which *actually varies* along its length. The mean characteristic impedance of the cylindrical antenna, given by Schelkunoff's **eq. 1** and **2** in **table 1**, forms the basis for the antenna/transmission line analog key method as it is used here.

The analog line "inner conductor" is broken in the exact center to form two balanced input terminals A-B (balanced to a fictional ground located midway between them); these are the doublet input terminals. You may view a doublet of length, $2h_t°$, as being composed of *two identical monopole elements* each of length $h_t°$. As was shown in the first article, the input impedance of any doublet operating in free space is just twice the input impedance of *one* of its monopole elements operated against perfect ground. Because of this, from now on you can totally ignore the part of the doublet to the left of the dashed line G-G in **fig. 1A**, knowing that once you have completed the design of a grounded monopole which meets your performance requirements, you can convert it into a doublet by merely duplicating the monopole design and placing it on the other side of G-G.

The monopole has *unbalanced* input terminals A and G ground. Moving away from the terminal A toward the right, along the inner conductor of the analog line mono-

*The term "linear" is used here to distinguish between the electric antenna and its dual, the magnetic dipole or loop antenna.

pole, a break appears in the inner conductor at a distance $h_1°$ from terminal A. On the other side of the gap the analog line continues on an additional length $h_2°$ to its end. The end line terminals A_3, G_3 of the analog line are open circuited; exactly the same condition prevails at the tip or end of the actual monopole antenna which the line represents. The two analog line section lengths $h_1°$ and $h_2°$ always add up to the sum $h_1° + h_2° = h_t°$. Finally, in **fig. 1A** you will notice that there are terminals A_1, A_2, A_3 at all locations where the analog line inner conductor is cut, and just opposite on the "shield" of the analog line are corresponding "ground" terminals G_1, G_2, G_3.

Approach: You will have to occasionally refer to the equations of **table 1** in what follows. However, we want to do something other than just solve a string of equations and become bored. To do this we will use the Smith impedance chart shown in **fig. 2**. The Smith chart is sort of a motion picture version of the famous transmission line **eq. 5** in **table 1**. One important feature of the chart is that it lets you actually "see" what goes on as an impedance "moves" along the analog line (monopole), changing its magnitude as it travels to some particular place on the line.

Comparing **figs. 1A** and **2**, note that the "output

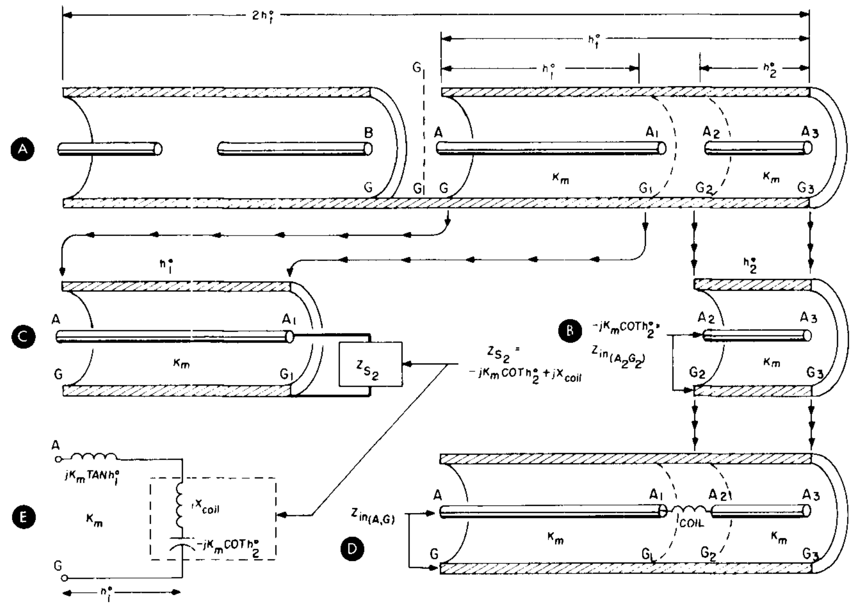


fig. 1. (A) Analog transmission line representation of a doublet antenna of length $2h_t°$ composed of two identical monopoles of length $h_t°$. Each monopole is cut into additional length sections, $h_1°$ and $h_2°$, for insertion of the loading coil. (B) shows input impedance of line end section $h_2°$. (C) shows line section $h_1°$ terminated in load Z_{S2}. Short monopole with series loading coil is shown in (D). Equivalent circuit of inductively loaded monopole antenna is shown at (E).

Actually, in advanced work, any number of gaps or line sections can be used. In the equations of **table 1**, then, where you see a length denoted $h_n°$, you may substitute n equals 1, 2, 3 . . . n.

Why is the analog line broken in this way? It is to permit you to insert any "gadgets" such as loading coils, series capacitors, insulators, isolating parallel resonant LC "traps", and so forth which you may wish to use in your antenna designs. This is the "antenna-dissection-by-parts" technique mentioned at the end of the first part of this article. What has been said above applies to *any use* of the analog key in solving *any* antenna problem. In what follows, however, we will restrict ourselves to just two line sections, $h_1°$ and $h_2°$, to explore the electrically short, coil loaded antenna.

design of coil loaded, electrically short antennas

Design objective: By applying the antenna/transmission line analog key to any electrically short cylindrical monopole antenna, you want to find the size of the loading coil needed to resonate the antenna at any frequency, with the loading coil located at any distance $h_1°$ from the input terminals A, G.

terminals" A_3,G_3 at the very far end of the analog line (which represent the top or tip of the monopole) are located at the bottom of the Smith chart. These output terminals are located on the very edge of the inside rim scale at a point where $R + jX$ equals infinity. Such impedance magnitude corresponds to an open circuit; that is what the antenna tip sees as a "load" impedance. The two circular scales around the outside rim of the chart are marked off in wavelengths. In what follows, you will normally use only the one labeled "Wavelengths Toward Generator" (WTG). Just below this scale is one labeled "Wavelengths Toward Load" (WTL) which permits movement in the opposite direction along the analog line. To use these scales, all you have to do is to divide the distance in degrees you wish to move by 360 degrees to obtain distance in wavelength. The "generator" referred to is the transmitter, when it is thought of as being directly connected to the line input terminals A, G.

Because the modified analog key used here deals only with reactance (the resistive R part will be added later), all the impedances will be found on the very inside rim scale edge representing pure reactance. Observe that all inductive reactance $+jX$ is distributed around the right

hand half of the chart circle; all capacitive reactance $-jX$ is around the left hand half. There is one more important matter: At the very center of the chart is a point which represents $Z = K_m\ (1.0 + j1.0)$ *ohms*. An impedance which reaches this particular spot on the Smith chart has a resistive R part equal in magnitude to that of the characteristic impedance K_m of the *particular* transmission line you are dealing with in the problem, and a zero reactance part jX. At point P, on the other hand, the impedance is $K_m(1.0 + j1.0)$, meaning its real part R and its *inductive* part jX are both equal in magnitude to the characteristic impedance K_m assigned to the chart.

To "enter" an actual impedance $R \pm jX$ into the Smith chart you must first divide the actual magnitudes of both R and jX by the K_m you have *assigned* to the chart for that particular problem. After you solve your problem on the chart and wish to "remove" your answer, you merely multiply both the real and reactive parts indicated on the chart by your assigned K_m value. Charts labeled in this way are said to be *normalized*. A normalized Smith chart can be used with transmission lines of *any* characteristic impedance you feel like assigning to the chart. This feature makes the normalized chart very handy to have around. Here, in working with the analog key, we will deal only with pure reactance $\pm jX$, all located on the very inside rim of the Smith chart, but in other applications an impedance point may appear anywhere on the chart.[5]

Up at the very top of the Smith chart in **fig. 2** is a point on the inside rim edge where $Z = K_m\ (0 + j0)$ *ohms*. This is "home plate" in the ball game we will play on this Smith chart "diamond." When the objective is to resonate an antenna at a desired frequency, we *always* have to reach "home plate."

design values

Let's start right off with a specific set of conductors for the coil loaded monopole antenna. Also, for convenience, we will use a frequency, $f = 1.97 \times 10^6$ *Hz* $= 1.97$ *MHz* in the old 160-meter ham band. Because wavelength λ' equals $984/1.97$ *MHz* $= 499.49$ *feet* at our selected frequency, even "short" antennas are physically large on 160 meters.

Conductor length: The monopole conductor length can be anything you wish as long as it is less than ninety degrees, so let's choose a total conductor length, $h_t^\circ = 33$ *degrees*. With 1.97 *MHz* as the selected frequency, $33^\circ/360^\circ = 0.0917$ *wavelength*. At this point in the design we will deliberately *not make any distinction whatsoever between the physical and electrical length of the monopole conductor*. The reason for this "error" will be explained later on. Taking this viewpoint, the 33 degree monopole conductor length becomes: $h_t' = 499.49$ *feet* $\times\ 0.0917 = 45.80$ *feet*.

Conductor diameter: Conductor diameter may be any size you want. However, since that conductor diameter just might have some effect on the loading coil size needed to resonate the short 33 degree monopole, select three different conductor radii: $a_1 = 0.05$ *inch*; $a_2 = 0.5$ *inch*, and $a_3 = 1.5$ *inch*. To keep units the same in subsequent calculations, change these three conductor radii to feet, getting: $a_1 = 0.004$, $a_2 = 0.04$, and $a_3 = 0.125$ *feet*.

Loading coil location, h_1°: Since we are exploring loading-coil placement, let's choose: base loading, center loading, and "almost" top loading. Now, by the convention given in **fig. 1**, base loading a monopole means that $h_1^\circ =$ *zero degrees*, because no break or gap would exist along the inner conductor for this case. With $h_1^\circ =$ *zero*, that makes $h_2^\circ = h_t^\circ = 33$ *degrees*. For the center loading case h_1° becomes $\frac{1}{2}h_t^\circ$, or in our case, 16.5 *degrees*. This choice also makes the remaining length h_2° equal 16.5 *degrees*, too, because the sum, $h_1^\circ + h_2^\circ$, *always* has to equal $h_t^\circ = 33$ *degrees*. Finally, we will explore the almost top loading case, $h_1^\circ = 32$ *degrees*, leaving h_2° equal to 1 *degree*.

Monopole mean characteristic impedance, K_m. Because we are going to use three different conductor radii with the 45.80-foot conductor length, we will obtain three different values of the mean characteristic impedance, K_m, to represent each of the monopoles, even though $h_t^\circ = 33$ *degrees* is fixed in this case. From **eq. 2** of **table 1**, for the cylindrical monopole, first work out $K_{m(1)}$ representing the first conductor radius, $a_1 = 0.004$ *feet*:

$$K_{m(1)} = 60[(\log_e \frac{2(h_t')}{a'}) - 1] = 60[(\log_e \frac{245.8}{0.004}) - 1]$$

$$= 60[(\log_e 22900) - 1] = 60(10.04 - 1)$$

$$= 542.32 \text{ ohms}$$

Substituting the remaining two conductor radii, a_2 and a_3 into **eq. 2**, with $h_t^\circ = 45.80$ *feet*,

$$K_{m(2)} = 404.18 \text{ ohms}$$

$$K_{m(3)} = 335.80 \text{ ohms}$$

Case 1. Base-loaded monopole. Coil in series with base terminal A at monopole input ($h_1^\circ =$ *zero degrees*). Enter the normalized Smith chart (**fig. 2**) at its "output" end terminals A_3G_3 located at $0.250\ \lambda$ on the WTG scale (the monopole top). Since the loading coil is located all the way down at the base of the 33-degree long monopole, we must travel that entire distance along the analog line to reach this "coil location" point. When we get there the chart will give us the normalized value of the capacitive input reactance, $-jX_{in(A,G)}$ of our monopole for this case. Since the "starting point" in the journey along the line is designated $0.250\ \lambda$ on the chart, we must *add* the distance $33^\circ/360^\circ = 0.092\ \lambda$ to that of our starting point to get the total distance:

$$0.250\lambda + 0.092\lambda = 0.342\lambda$$

Therefore, 0.342λ is the "stopping point" on the WTG scale. If you very carefully draw a straight line from the center of the chart to intersect this 0.342λ point on the WTG scale, it cuts through the -1.54 magnitude on the capacitive reactance scale. The rest is easy. The reactance -1.54 means simply $-jK_m(1.54)$ *ohms*. This is the *normalized* reactance $-jX_{in(A,G)}$ of any *cylindrical monopole* whose *electrical* length is 33 degrees. To

change this normalized capacitive reactance to represent the actual reactance $-jX_{in(A,G)}$ of the three particular monopoles under discussion, you need only multiply that normalized value by each of your three calculated K_m values. But wait! For *only* the case of a loading coil located at the monopole input terminals, the size of the loading coil reactance is the *same* as the absolute magnitude of $-jX_{in}$, if you just change the sign of the reactance to a plus. You can immediately determine the reactances of all three loading coils. They are simply $+jK_m\ (1.54)\ ohms$:

$$+jX_{coil(1)} = +j\ 835.10\ ohms \qquad (K_m = 542.32\ ohms)$$
$$+jX_{coil(2)} = +j\ 622.22\ ohms \qquad (K_m = 404.18\ ohms)$$
$$+jX_{coil(3)} = +j\ 517.13\ ohms \qquad (K_m = 335.80\ ohms)$$

It's a good thing we chose three different conductor radii; the calculations indicate that conductor diameter certainly does change the size of loading coils in an electrically short antenna of the *same* electrical length h_t°. Not only that, but "fat" conductors need smaller loading coils than thin conductors to produce resonance in short monopoles.

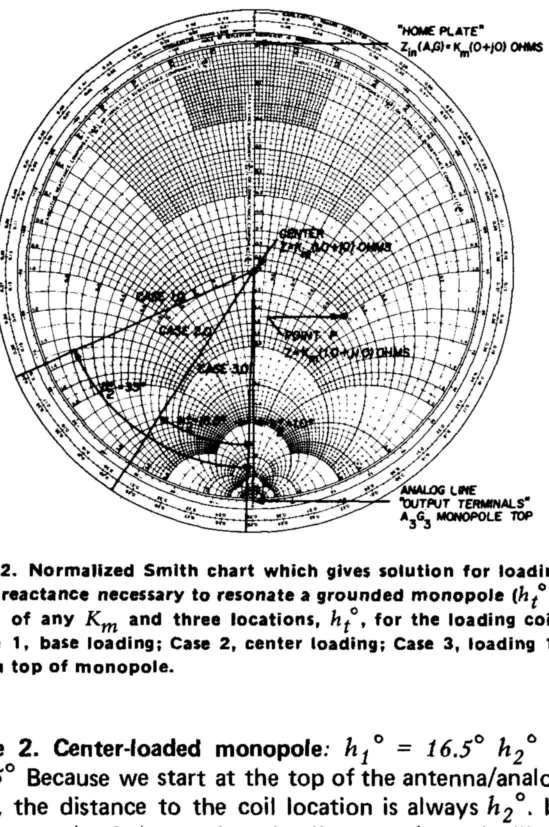


fig. 2. Normalized Smith chart which gives solution for loading coil reactance necessary to resonate a grounded monopole ($h_t^\circ = 33^\circ$) of any K_m and three locations, h_t°, for the loading coil: Case 1, base loading; Case 2, center loading; Case 3, loading 1° from top of monopole.

Case 2. Center-loaded monopole: $h_1^\circ = 16.5^\circ\ h_2^\circ = 16.5^\circ$ Because we start at the top of the antenna/analog line, the distance to the coil location is always h_2°. In the center loaded case, then the distance of travel will be $16.5^\circ/360^\circ = 0.046\lambda$. Adding that to the 0.25λ starting point, the stopping point on the WTG line from the center of the chart through this new point, 0.296λ, you'll find a larger normalized value of capacitive reactance, -3.38, which you now know to be $-jK_m(3.38)\ ohms$. Before you get ahead of me and begin happily changing the sign of that reactance multiplied by the three values of K_m, and generating a new table of loading coils, *hold it*! The h_1° is no longer zero degrees! This capacitive reactance $-jK_m(3.38)\ ohms$ is really $-jX_{in(A_2G_2)}$, as shown in **fig. 1B**.

Looking over to **fig. 1E**, you'll see that this "capacitor" produced by monopole analog line section of length h_2° is connected in series with the loading coil reactance $+jK_{coil(5)}$ and this *combination* becomes load impedance $Z_{s(2)}$. Now $Z_{s(2)}$ is seen in **fig. 1C** to be connected across the output terminals, A_1-G_1 of the lower monopole analog line section of length h_1°. In **fig. 1E**, the lower line section h_1° will "insert" an additional inductive reactance $+jK_m(tan\ h_1^\circ)$ in series with the monopole analog line input terminals A-G. If you cancel out *all* the capacitive reactance at the loading coil gap which is produced by the upper line section h_2°, by inserting a loading coil reactance $+jX_{coil}$ of equal magnitude, you will go "skidding past" the *home plate* at $Z_{in(A,G)} = K_m(0 + j0)\ ohms$, and end up with a $Z_{in(A,G)}$ reactive part jX_{in} just equal in magnitude to this $jK_m tan\ h_1^\circ$ produced by the lower monopole analog line section. What you really need is the "resonant" reactance condition

$$jX_{in(A,G)} = jK_m(X_{coil}) + (-jK_m X_{in}(A_2G_2)) + jK_m\ tan\ h_1^\circ = jK_m(0.0), \qquad (1)$$

where $-jK_m X_{in(A_2G_2)}$ is really just $-jK_m cot\ h_2^\circ$ from **eq. 3** in **table 1**. **Eq. 3** is the thing we are solving with the Smith chart when we enter it at the antenna top and go traveling along the WTG scale a distance h_2° to the "stopping" point. When you want high accuracy, use **eq. 3**, because you can't read the Smith chart that closely. It is like a slide rule in this respect, but good enough for preliminary design. Looking at **eq. 1** above, you can now see how to determine the size of the loading coil; just leave $+jX_{coil}$ on the left side, and put everything else on the other side of the equals sign. Then,

$$jX_{coil} = jK_m(cot\ h_2^\circ) - jK_m(tan\ h_1^\circ)\ ohms \qquad (1\text{-}1)$$

Since you just obtained $jK_m(cot\ h_2^\circ) = jK_m(3.38)$ from the Smith chart, and you know h_1° also equals 16.5 *degrees*, and $16.5^\circ - 0.30$

$$jX_{coil} = jK_m(3.38) - jK_m(0.30) = +jK_m(3.08)\ ohms$$

Now you can go ahead and generate a list of center loading-coil reactances:

$$jX_{coil(1)} = +j\ 1670.35\ ohms \qquad (K_m = 542.32\ ohms)$$
$$jX_{coil(2)} = +j\ 1244.87\ ohms \qquad (K_m = 404.18\ ohms)$$
$$jX_{coil(3)} = +j\ 1034.26\ ohms \qquad (K_m = 335.80\ ohms)$$

Notice that the loading coils for the center-loaded case in the $h_t^\circ = 33$ *degree* monopole are $3.08/1.54$ or two times as large as the loading coils needed to base load the *same antenna* to the *same* frequency. Also again, "fat" conductors still require smaller loading coil size. Does this coil growth trend continue with increasing h_1°? If

so, what is the "rate" of increase? To find out, go on to the "almost top loaded" case where $h_1°$ is 32°, and $h_2°$ is only 1 degree.

Case 3. Almost top-loaded monopole $h_1° = 32°$ and $h_1° = 1.0°$. Having to go only $1.0°/360°$ equals 0.002λ, add that to 0.250λ and obtain 0.2520λ as the stopping point on the WTG scale. However, now you cannot read the normalized capacitive reactance $-jK_m(X_{in})A_2,G_2$ – the Smith chart reactance scale is too cramped in this region, which is approaching infinite values. No problem! Simply use **eq. 3** from **table 1** and to find $-jK_m(X_{in})A_2G_2$:

$$-jK_m(X_{in})A_2G_2 = -jK_m(\cot 1.0°)$$
$$= -jK_m(57.29) \text{ ohms}$$

Flipping the sign of the answer above to plus (and knowing that tangent $h_1° = \text{tangent } 32° = 0.625$) we plug these values into **eq. 1-1**:

$$+jX_{coil} = jK_m(57.29) - jK_m(0.625)$$
$$= +jK_m(56.66) \text{ ohms}$$

Our final table of coil reactances follows

$jX_{coil(1)} = +j\ 30730$ *ohms* ($K_m = 542.32$ *ohms*)
$jX_{coil(2)} = +j\ 22902$ *ohms* ($K_m = 404.18$ *ohms*)
$jX_{coil(3)} = +j\ 19028$ *ohms* ($K_m = 335.80$ *ohms*)

Clearly, above the center loading-coil location, coil reactance grows rapidly, at an exponential rate. At *1.97 MHz*, **eq. 6** from **table 1** gives the inductance of these coils for a location only one degree from the antenna top as

Coil (1) $= 2.48 \times 10^{-3}$ *henry* $= 2.48$ *mH*
Coil (2) $= 1.85 \times 10^{-3}$ *henry* $= 1.85$ *mH*
Coil (3) $= 1.53 \times 10^{-3}$ *henry* $= 1.53$ *mH*

Coils of this size are large enough to serve as decoupling chokes in the power supply leads in your transmitter! Incidently, before turning to other matters, note that if you want to translate the short, coil-loaded monopole design technique to any *other* ham band; select an $h_t°$ other than 33 degrees; or use monopole conductor radii other than 0.050, 0.50, or 1.5 inch, you will have to calculate K_m again for the new case. Once this is done, you can quickly proceed as shown here to find the reactance of the needed loading coils at any height, $h_1°$. Also, as you will later see, in terms of antenna efficiency it is best to reduce the size of the loading coil; the largest diameter conductor you can use will help in this respect.

Now that you have seen how the size of the loading coil changes with its placement in the monopole, you may well ask, "Why should I use a coil location other than $h_1°$ equals zero degrees? Why not just base load short monopoles?" To answer these critical questions we must turn to the problem of antenna radiation resistance in electrically short antennas.

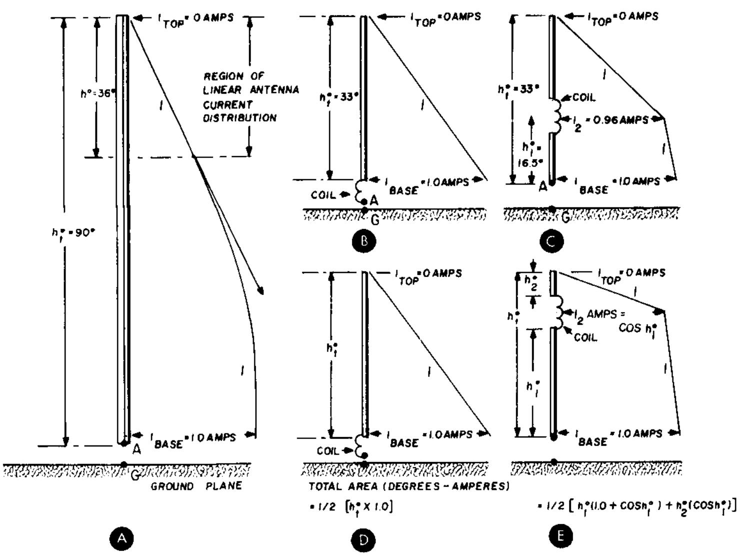


fig. 3. (A) Sinusoidal current distribution along naturally resonant quarter-wavelength monopole antenna. (B) Linear current distribution for base-coil loaded monopole, $h_t° = 33$ *degrees.* **(C) Same height monopole with center-coil loading. (D) Total current area for base coil loaded monopole,** $h_t°$ **less than 36°. (E) Total current area for short monopole antenna with loading coil at distance** $h_1°$ **from base. All monopoles are assumed to be resonant.**

radiation resistance of electrically short antennas

Up to now we have been merely plugging in $R = 0$ ohms in our antenna input impedance, $Z_{in(A,G)} = R_{in} + jX_{in}$ *ohms*. The modified antenna/transmission line analog key we've been using here gives us only the reactive part. Don't blame Dr. Schelkunoff for that. His elegant mode theory model *gives both* R and jX answers for $Z_{in(A,G)}$, but it employs some high power math. However, it turns out that the answers we are getting for jX_{in} compare quite accurately to those obtained by his more refined equations. That's fine. But how do we get the resistive part, R?

To add the R part to our answer, we assume R equals the antenna radiation resistance R_r. Then we just look it up in graphs giving R_r as a function of antenna length $h_t°$. Such curves are found in the literature.[6] This is fortunate, because calculating radiation resistance, R_r,

for any antenna length h_t° and current distribution is not exactly child's play. So it seems we have it all wrapped up: Just look up R_r for our particular antenna length h_t° in degrees, and plug it into $Z_{in} = R + jX$. Unfortunately, it's not quite that easy. For antennas whose length is greater than $h_t^\circ = 36$ *degrees*, the published curves give only the radiation resistance of electrically short antennas *which do not use reactive loading*. Therefore, you must be able to calculate the R_r of the reactively loaded, electrically short antennas when h_t° is less than 36 degrees. When you do that you will see why base loading is not the optimum way to resonate electrically short antennas.

Fig. 3A shows the idealized, sinusoidal current distribution along a *naturally* resonant, quarter-wavelength vertical monopole antenna operating against a ground plane. If you plot the function, sine h_t°, on graph paper, starting with zero degrees at the top of the monopole (where current in this case is zero), you will find that within the first 36 degrees you do not obtain a curve at all; for all practical purposes, you will get a straight or linear line plot. Only at lengths greater than 36 degrees does the graph plot begin to look anything like a curve. Because of this fact you can deal with the current distribution of monopole antennas, less than 36 degrees high as *straight-sided* geometric figures. Accordingly, **fig. 3B** shows a base-loaded monopole of height $h_t^\circ = 33$ *degrees*, with a triangular current distribution. In **fig. 3C** the same height antenna, center loaded, still has a straight-sided current distribution in the shape of a trapezoid.

Now, if you measure antenna section heights h_1° and h_2° in electrical degrees, and the current amplitude in amperes, the total area of the current distribution can be expressed in units of degree-amperes. One of the cruder (but good enough ways) to explain radiation resistance is to say that Nature only "sees" the antenna's total "exposed" current area. Based on this engineering "viewpoint" you can write an expression* which gives the radiation resistance, R_r, of electrically short (h_t° less than 36°) monopole antennas operating over a ground plane as

$$R_r = 0.01215\, A^2 \qquad (1\text{-}2)$$

where A is the total exposed antenna current area in degree-amperes.

For a doublet of length $2h_t^\circ$ in free space, composed of two short, reactively loaded monopoles of length h_t°, just double the R_r magnitude calculated from **eq. 1-2. Fig. 3D** provides a formula for finding the triangular shaped, degree-ampere area of base-loaded monopoles over ground; **fig. 3E** gives the formula for the case where the loading coil is located a distance h_1° from the input terminals *A-G*. It is important to note that, in all antennas shown in **fig. 3**, the antenna base current is *always* one ampere. This is the relative current amplitude which you must use because the radiation resistance of an antenna does not change with the different amplitudes of actual currents when you vary transmitter input power. For reasons which space does not permit me to go into here, when the antenna is *resonated* by a loading coil placed at a distance h_1° from the base input terminals, the *relative* current I_2 at the coil position has an amplitude of $I_2 = cosine\ h_1^\circ$.

*Eq. 1-2 is based on the theory of monopole moment.

Using the above information, you can now see what happens to radiation resistance in short antennas as h_1° is changed while antenna height, h_t°, is fixed. For example, consider your antenna, $h_t^\circ = 33$ *degrees* when it is base loaded. From **fig. 3D**, the current area is then

$$A = \tfrac{1}{2}\,(33^\circ \times 1.0\ \text{ampere})$$
$$= 16.5\ \text{degree-amperes}$$

From **eq. 1-2**:

$$R_r = 0.01215\,(16.5\ \text{degree-amperes})^2 = 3.3\ \text{ohms}$$

For the case where the loading coil was moved to $h_1^\circ = 16.5^\circ$, to center load it, $I_2 cosine\ 16.5^\circ = 0.96$ *amperes relative*, giving us the area from **fig. 3E** as,

$$A = \tfrac{1}{2}[16.5^\circ\,(1.0 + 0.96) + 16.5^\circ\,(0.96)]$$
$$= \tfrac{1}{2}[32.34 + 15.84]$$
$$= \tfrac{1}{2}[48.18] = 24.10\ \text{degree-amperes}$$
$$R_r = 7.06\ \text{ohms}$$

You can see that center loading *increased* the radiation resistance by a ratio of *7.06/3.3 or 2.14 times*. The ohmic loss produced by a radial wire ground plane, insulator leakage, soil current resistance, and the like, might have a realistic ohmic resistance magnitude of 10 ohms. Antenna radiation efficiency, N, is related to the ratio between antenna radiation resistance, R_r and total environmental ohmic loss, R_Ω, as

$$N = \left(\frac{R_r}{R_r + R_\Omega}\right) 100\ (\text{per cent}) \qquad (1\text{-}3)$$

With ohmic loss equal to 10 ohms, the base-coil loaded monopole ($h_t^\circ = 33^\circ$) would yield an efficiency of,

$$N = \left(\frac{3.3}{3.3 + 10.0}\right) 100 = 24.8\ \text{per cent}$$

The same height monopole, when center loaded, would yield

$$N = \left(\frac{7.06}{7.06 + 10.0}\right) 100 = 41.4\ \text{per cent}$$

Not only is more input power radiated from the center-loaded monopole, but since $Z_{in} = R_r + R_\Omega + jX$, the magnitude of input impedance at resonance is increased, which makes impedance matching with a base network less of a headache. Right about here someone is going to remember the case where the loading coil was only 1 degree down from the top. Using the relations given, $R_r = 10.93$ *ohms*. This looks promising — increased R_r means increased efficiency, right? I am sorry I must dash cold water over this happy discovery. If you could raise the current-degree ampere area of the 33-degree monopole to the indicated total area *without introducing additional ohmic loss*, you could increase

efficiency because R_r would increase toward its theoretical limit. The theoretical limit in reactively-loaded short monopole (or dipole) antennas is *four* times that of the base-loaded R_r (or doublet feedpoint loading), and is based on a perfectly rectangular current distribution. However, you can't approach this limit except in very short antennas, and *never* in the case of any *coil-only* loaded short antenna.

The words "without introducing any additional loss", however, lets the air out of this little balloon. Remember the rapid increase in loading-coil reactance (and thus inductance) as it climbed to higher and higher $h_1°$? You might think a loading coil is just hacked out of any commercial length of coil stock you have laying around the shack. Not true. An antenna loading coil must be tailored to your radiating system if you want to obtain maximum efficiency.

loading coils in electrically short antennas

Space limitation prevents me from going too deeply into the critical matter of loading-coil design. Still, being terse, I'll try to cram in some vital facts. By now your intuition must tell you that loading coil loss should be kept to the barest possible minimum. That clearly means use of a high value of coil Q. Unfortunately, coil ohmic loss R_L is related to coil Q by the expression

$$R_L = \frac{X_{coil}}{Q} \text{ ohms} \qquad \textbf{(1-4)}$$

Eq. 1-4 says that, as coil reactance grows with increasing $h_1°$, coil Q must be increased to retain this minimum R_L coil loss. Here, also, is a sobering thought: the coil shape factor for maximum Q in a single layer coil is represented by a coil *diameter twice that of coil length*.[7] This ratio is not especially critical, but you should stay pretty close to it. So you see that as reactance increases, demanding more coil turns in increasing length, the physical diameter of the loading coil keeps increasing as it climbs the short antenna. Another important matter is the insulation holding the turns to the correct pitch. The material used for coil insulation should have the lowest possible dielectric loss factor, and a *minimum* amount of it should be employed. Moisture from the weather should be kept from the exposed loading coil by a sealed dielectric housing, because the slightest moisture film-bridging between turns, across the insulation, will reduce coil Q. Because of their low value of radiation resistance, the input current to short antennas is considerably larger than it is in, say, a naturally resonant quarter-wavelength monopole at the same input power. The antenna input (base) current, in terms of its actual magnitude, is

$$I_{in} = \sqrt{\frac{Pi}{R_r + R_o}} \text{ amperes} \qquad \textbf{(1-5)}$$

where Pi is power input in watts.

Consequently, provisions must be made to handle the calculated current amplitude in the coil conductor.

*Multiply actual I_{in} by cosine $h_1°$ to find I_c when the coil is located at a point higher than the antenna's base-input terminals.

Voltage stress (voltage drop) across the loading coil is given by

$$V_{coil} = (I_c \times X_{coil}) \text{ volts} \qquad \textbf{(1-6)}$$

Where I_c is the current flowing through the coil at its location $h_1°$ in the antenna.* If I_c is in rms amperes, multiply V_{coil} by *1.414* to get peak volts of stress.

Practical antenna engineers, adding this all up, feel that the center-loaded case is about optimum in terms of a trade off between increase in radiation resistance to offset environmental ohmic loss, and design of the loading coil within practical and economic limits.

A final word about tuning a short, coil-loaded antenna: Once you have achieved the high Q coil you need to resonate the little monster to the frequency in the band you select, don't try to change its inductance by means of tapped turns, turn sliders, or shorted-out turns to tune the antenna around the band. The resulting change in coil shape factor, and the eddy currents which will circulate in the unused turns, will murder coil Q. Instead, in fixed site home station versions retune the impedance matching base network you have to use anyway to lower transmission line vswr. In electrically short, mobile antennas use a telescoping section of the antenna conductor *above* the loading coil to establish resonance of the antenna at frequencies above or below f_o. Finally, I hope that you will now look at the long, skinny loading coils wound on massive insulating forms which you may see used in some short antenna designs with a healthy bit of skepticism. However, with use of the analog key, you can now design any coil-loaded, short antenna which comes to mind.

calculated coil size accuracy

Real antennas of any kind are *not* lumped circuits. Their extensive fields reach far out into the so called near-zone region surrounding them to "feel and sense" their electromagnetic environment and to react to it. They do this by automatically adjusting their electrical characteristics to always satisfy Nature's laws of *minimum energy balance*. Electrically short antennas are the most sensitive of all, due to the much larger storage of energy within their near-zone region. To an antenna, each station site, each mobile vehicle, differs considerably from another.

It is due to this peculiar nature of the antenna, in contrast to that of lumped circuits, which makes it impossible for man to devise a calculation method which can *exactly* predict in the design stage all the changes which will occur in a real antenna operating in some actual electromagnetic environment. Therefore, working antenna engineers make the best calculations they can at the office desk, then put on their hard hats and go out to the antenna measurement laboratory and prune their creations exactly to size. This problem is least at microwave frequencies, and at its worst at frequencies in the low- and high-frequency bands. In the case of the electrically short antenna, this means pruning calculated coil size. But you can use an "insurance policy" here because first, you don't want to start out with a coil which is too small, and secondly, you don't want to do too much

pruning. How does the analog key satisfy these two design requirements for the practical designer?

Recall that when you started to select antenna conductor length for the electrically short antenna you did not make a correction between conductor physical length and its electrical length. I said we would regard them at the start as equal to one another. It turns out that unless an antenna conductor is of zero diameter, its electrical length is always greater than its physical length. If you examine **eq. 3** in **table 4**, you will realize that if such is the case, all the magnitudes of capacitive reactance calculated from it, or its solutions via the Smith chart, are somewhat smaller than those obtained. That means that all of the calculated coil reactance values are too large.

In matter-of-fact, their size error on the plus side of tolerance is in inverse proportion to the mean antenna characteristic impedance K_m you calculated them to match. Thus, the coil calculated for $K_m = 335.8$ *ohms* would resonate the 45.8 foot tall monopole to a frequency below *1.97 MHz* in the 160 meter band; the coil for K_m = 542.3 ohms would resonate the same height monopole closest to, but still a bit below *1.97 MHz*. Not too much below *1.97 MHz* (or whatever frequency you designed for) but enough that you may safely prune the coil *up in frequency* to resonate in your own particular environment. I do that with a grid-dip oscillator which is *loosely* coupled to the grounded coil/monopole combination.

At the end of our next example, you will see how to make the correction between conductor's physical and electrical length when you need to. This, however, will be in working with naturally resonant antennas which are least sensitive to environment.

frequency bandwidth of antennas

Design objective. You want to design a naturally resonant antenna in such a way that the vswr on the transmission line feeding the antenna does not exceed a specified maximum value at any frequency within the limits $f_{high} - f_{low}$ of a given amateur band.

Such antenna design will provide you with an antenna into which a modern transmitter, using a pi-network tank circuit, will easily load full power at any spot in the band. Most amateur transmitters are designed to load full power only into a transmission line vswr of 2.8:1 or less.

Foreward to problem. Remember that I said that the input reactance, jX_{in}, of an antenna of fixed length changed far more rapidly in magnitude with a change in transmitter frequency than the resistive part, R_{in}. The resistive part of antenna input impedance, in fact, changes so little over the frequency width $f_{high} - f_{low}$ of any presently assigned high-frequency amateur band that we may make an engineering *approximation* and view R_{in} as a constant over the frequency width $f_{high} - f_{low}$.

With R_{in} assumed constant over the frequency width of any amateur band, let's take up the case of a naturally resonant quarter-wavelength monopole antenna, remembering that we can always combine two such monopole designs into a single half-wave doublet if we wish.

The radiation resistance, R_r, of a naturally resonant quarter-wavelength monopole over perfect ground is equal to 36 ohms. If we select the natural resonant frequency, f_o, of the monopole to be that of the band center, then its input impedance at, f_o, will be $Z_{in(A,G)} = 36 + j0$ *ohms*. When we tune the transmitter vfo above and below f_o, the linear monopole antenna will exhibit the impedance characteristics of a series-resonant circuit. That is, it will exhibit a $-jX_{in}$ capacitive reactance in series with R_r at frequencies below that of f_o, and a jX_{in} inductive reactance at frequencies above f_o.

When the absolute magnitude of the reactive part of the antenna input impedance becomes just equal to the magnitude of the resistive part, antenna designers refer

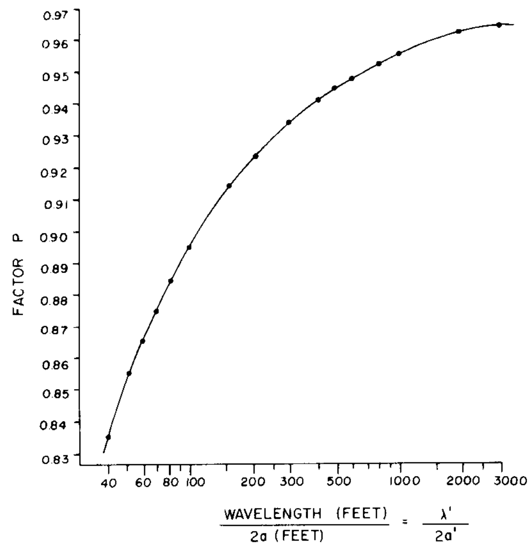


fig. 4. Correction to obtain height, h_t (feet) equal to 90 electrical degrees at resonant frequency. To use this chart use the following procedure:

1. **Calculate wavelength from** $\lambda = 984/f\,(MHz)$.
2. **Divide monopole conductor diameter,** $2a$ **(feet) into** λ **(feet).**
3. **Enter graph to obtain length correction factor,** P.
4. **Use** $246P/f_o$ **(MHz) to obtain resonant monopole length,** h_t **(feet).**

For example, what is the correct height at 3.6 MHz for a monopole constructed of 3-inch (0.25 foot) aluminum pipe?

$\lambda = 984/3.6 = 273.33$ *feet*

$\lambda/2a = 273.33/0.25 = 1093.33$

From the graph, $P = 0.956$. **Therefore, correct monopole length is** $(246 \times 0.956)/3.6 = 65.3$ *feet*.

to the total frequency span between the input impedance values as the 3-dB or half-power bandwidth of the antenna. This impedance behavior looks like this:

$$f_{low} = 36 - j36 = 50.91 \angle -45^\circ$$
$$f_o = 36 + j0 = 36.00 \angle 0^\circ$$
$$f_{high} = 36 + j36 = 50.91 \angle +45^\circ$$

Following good practice, let's select a transmission line for our monopole antenna whose uniform characteristic impedance, Z_o, is equal to that of the radiation resistance, R_r. This calls for a coaxial line of $Z_o = 36$ *ohms* (two 72-ohm coax lines connected in parallel). When we do this, at the resonant frequency at the band

center, the vswr on the feedline will have a value of 1:1 because it is matched to its load impedance. When we tune the vfo to some frequency limit above or below resonance, $Z_{in} = 50.91 \angle \pm 45^\circ$ *ohms.*

At the two frequencies on either side of resonance where this impedance value is reached, the vswr in the feedline will have climbed to 2.6:1. Since the point where the absolute value of the reactive and resistive parts are equal, $|jX| = |R|$, marks the limits of the 3-dB bandwidth of the antenna, it is easy to wrongly assume that a vswr of 2.6:1 means that 3 dB or half the input power is reflected due to mismatch. However, a 2.6:1 vswr represents a mismatch condition where only 0.97 dB of the incident power is reflected. The reason for this much lower reflection is based on an important electrical law, Thevenin's theorem.*

The actual frequency width, $f_{high} - f_{low}$, at which the vswr rises to 2.6:1, however, depends upon the electrical nature of the antenna. To find out how to solve this problem, first write the quality factor Q for an antenna in terms of the 3 dB bandwidth as

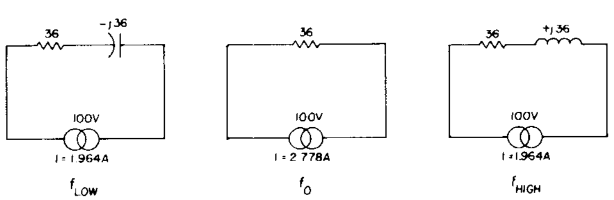
$$Q = \frac{f_o}{f_{high} - f_{low}} \qquad \textbf{(1-7)}$$

All you need to solve the problem is a single design parameter of the antenna which is related to Q in frequency width. As you probably have guessed by now, this needed antenna design parameter is the mean characteristic impedance K_m of the monopole antenna. It is related to frequency Q as,

$$K_m = (46.5\ Q) + 3 \text{ ohms} \qquad \textbf{(1-8)}$$

Once you know these relationships, you can take the following design steps: First plug your particular amateur frequency limits, $f_{low} - f_{high}$, and f_o, into **eq. 1-7** to find Q; then plug the obtained Q value for the band into **eq. 1-8** and determine the needed K_m of the monopole. Then, all you have to do is solve for the antenna conductor length-to-radius ratio to give you this value of K_m.

*Basically, Thevenin's theorem states that the current in any impedance connected to two terminals of a network is the same as if that impedance were connected to a generator whose voltage is equal to the open-circuited voltage at the terminals of the network. This can be illustrated by feeding an antenna with a constant-voltage source as shown below:



With a 100-volt constant-voltage source in series with the impedance, the current flow is 1.964 amp at f_{low} and f_{high}, and 2.77 amp at f_o. The power dissipation in the real part of the impedance at the three frequencies is as follows:

Power at f_{low}	= *138.86 watts*
Power at f_o	= *277.72 watts*
Power at f_{high}	= *138.66 watts*

Note that the power difference is exactly 3 dB.

To obtain this conductor size ratio, rewrite **eq. 2** of **table 1** in the following way,

$$\frac{K_m}{60} + 1 = \log_e \frac{2(h_t')}{a'} \qquad \textbf{(1-9)}$$

Let's try this method out, first for the 10-meter band, and then for 80 meters. For 10 meters, the bandwidth limits are *29.7 MHz* to *28.0 MHz*. The band center of 28.85 MHz is our f_o. Solving for Q from **eq. 1-7**

$$Q = \frac{28.85}{29.7 - 28.0} = 16.97$$

$K_m = (46.5 \times 16.97) + 3 = 792$ *ohms* (from **eq. 1-8**)

$\frac{792}{60} + 1 = \log_e \frac{2(h_t')}{a'} = 14.202$ (from **eq. 1-9**)

The needed conductor length-to-radius ratio is simply the natural antilogarithm obtained from **eq. 1-9**, or

$$\frac{2(h_t')}{a'} = 1.472 \times 10^6$$

$$a' = \frac{2(h_t')}{1.472 \times 10^6}$$

Here you need h_t' for the band f_o. Again start by *first assuming* that $h_t' = 0.250\lambda$ at 28.85 MHz (no correction as yet). Then $h_t' = 0.250 \times 34.11' = 8.53$ *feet;* $2(h_t') = 17.05$ *feet.*
Therefore,

$$a' = \frac{17.05'}{1.472 \times 10^6} = 1.16 \times 10^{-5} \text{ feet}$$

$$= 1.39 \times 10^{-4} \text{ inches}$$

conductor diameter $= 2.78 \times 10^{-4}$ *inches*

This is like shooting down a butterfly with a cannon! Here you went to some effort only to find that any gauge copper wire, physically strong enough to be suspended as an antenna, will give you the needed frequency vswr bandwidth on 10 meters. All this fancy frequency bandwidth design isn't for amateurs, right? To check on that, knowing how touchy Mother Nature can be, let's try the same exercise on the 80-meter band. It's width is 4.0 MHz to 3.5 MHz, with 3.75 MHz in the center. So

$$Q = \frac{3.75}{4.0 - 3.5} = 7.5$$

$$K_m = (46.5 \cdot 7.5) + 3 = 351.75 \text{ ohms}$$

$$\frac{351.75}{60} + 1 = \log_e \frac{2(h_t')}{a'} = 6.86$$

Antilog (e) of 6.86 = 955.75

$$h_t'\ (0.250\lambda) \text{ at } 3.75 \text{ MHz} = 65.6 \text{ feet}$$

$$a' = \frac{131.2'}{955.75} = 0.137 \text{ feet} = 1.65 \text{ inches}$$

conductor diameter is 3.29 inches

This is a horse of another color! You need an antenna

conductor whose minimum diameter is 3.3 inches to use in an antenna which will cover the entire 80-meter band without exceeding 2.6:1 vswr in the feedline. This means a length of 3.5 inch aluminum irrigation tubing; or triangular, but uniform diameter, triangular cross section tower at least 3.5 inch on each side for the 80 meter monopole.

For a doublet we can simulate the needed conductor diameter in the form of a lightweight cage design using a minimum of eight wires of say no. 18 AWG Copperweld. These wires can be arranged equally around the perimeter of circular plastic formers spaced along the length of each half of the doublet. At both ends of the dipole sections all wires should be brought to a point to form a taper where the insulators are attached. This is for reduction of shunt capacitance across the doublet input terminals. Excess shunt capacitance, either from the monopole conductor base to ground — or across the balanced doublet input terminals — will produce a nonsymmetrical vswr curve at frequencies equally spaced above and below resonance. Reduction of base shunt capacitance is the reason you see those long tapers at the base of large cross section, vertical tower monopoles used by broadcast stations.

Finally, I promised to give a correction factor to take in the physical length of the monopole conductor, as a function of its diameter, so that it is ninety electrical degrees long at the resonant frequency. **Fig. 4** gives the correction curve and the detailed procedure needed to do this. When you actually design and put one of these naturally resonant, broad-banded antennas on the air, you will find that the vswr at the band edges will be somewhat less than 2.6:1. This comes about because of the addition of environmental ohmic losses induced in the antenna input impedance by the antenna site, as well as from the small decrease in antenna K_m when you shorten the conductor to resonance by use of the data in **fig. 4**.

In this article I have only scratched the surface in applying the analog key to the field of practical antenna design; to do a thorough job would require a book on the subject. Enough material has been given here, however, to enable you to quickly become proficient in the use of the analog key and to turn it loose on your own pet ideas for antenna design.

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ham radio

simple broadband antenna for 10 GHz

The coax-to-waveguide adapter provides an excellent broadband antenna for amateur microwave work

Interest in the 10-GHz amateur band is growing rapidly as the lower vhf and uhf bands are filling with fm repeaters. However, getting started on 10 GHz is difficult due to the absence of commercially available rigs;* this forces amateurs to resort back to home-brewing their own equipment. One problem is antennas. Having built several antennas for the 3 cm band, including polyrods, helix, dish, horn and even a Yagi beam, we have found that, generally speaking, the simpler, the better. The simplest and most reliable antenna we used is a Hewlett-Packard model X281A coax-to-waveguide adapter. Similar results can be had with adapters from other manufacturers. However, the Hewlett-Packard unit was available and covered the 3 cm amateur band.

Fig. 1 shows the vertical radiation pattern of the H-P X281A, and **fig. 2**, the horizontal radiation pattern. Waveguide antennas are like slot antennas in that the electric vector or polarization vector is perpendicular to the wide dimension of the waveguide. The vertical half-angle beamwidth is 65° and 80°, respectively, at the 3-dB and 10-dB points. The horizontal half-angle beamwidth for the 3-dB and 10-dB points is 35° and 45°. The horizontal beamwidth is narrower than the vertical

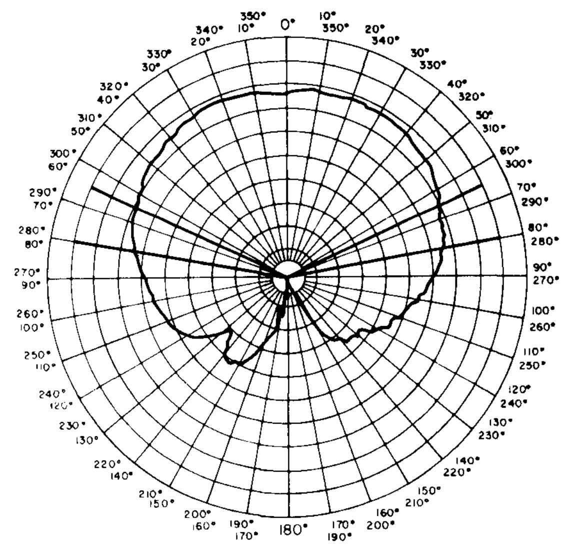

fig. 1. Vertical radiation pattern for the Hewlett-Packard X281 coax-to-waveguide adapter measured at 10.25 GHz. The 3-dB half-angle beamwidth is 65 degrees; 10-dB half-angle beamwidth is 80 degrees.

*An exception is the recently announced 10-GHz *Gunnplexer* available from Microwave Associates (see page 86, March, 1977, and page 10, April, 1977, *ham radio*).

By John M. Franke, WA4WDL, and Norman V. Cohen, WB4LJM, Apartment 225, 1006 Westmoreland Avenue, Norfolk, Virginia 23508

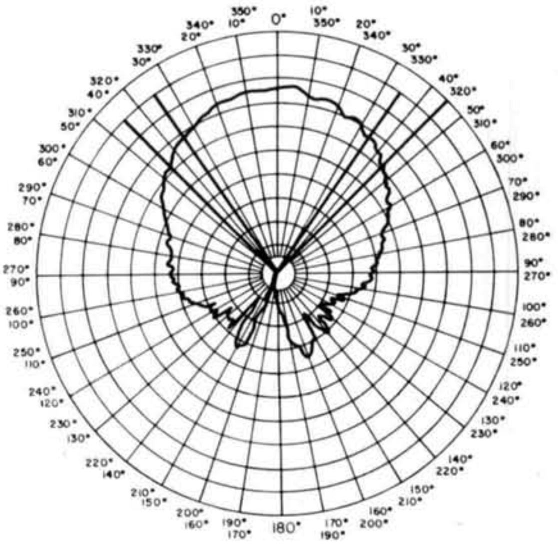

fig. 2. Horizontal radiation pattern of the Hewlett-Packard X281 coax-to-waveguide adapter measured at 10.25 MHz. The 3-dB half-angle beamwidth is 35 degrees; 10-dB half-angle beamwidth is 45 degrees.

because the horizontal antenna dimension is larger than the vertical dimension.

The reason for measuring the 3-dB and 10-dB points is that, when the antenna is used as a feed for a parabolic reflector, we use the 10-dB beamwidth; the 3-dB beamwidth is quoted when the antenna is used by itself. Plotted in **fig. 3** is a graph of the optimum feed 10-dB half-angle beamwidth as a function of the ratio of the reflector's focal length to diameter ratio or *f* number. It is apparent that the coax-to-waveguide adapter works best when feeding parabolic reflectors which have *f* numbers between 0.68 and 1.25.

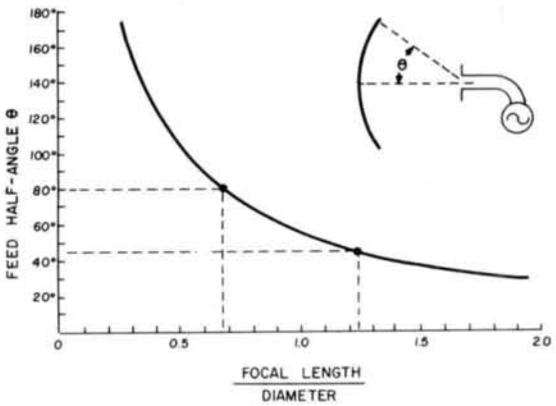

fig. 3. Optimum feed half-angle beamwidth vs focal length to diameter ratio (*f* number) of a parabolic reflector. The simple antenna described here should be used with reflectors with *f* numbers between 0.68 and 1.25 as shown by the dashed lines.

In conclusion, whether used directly as an antenna or used in conjunction with a parabolic dish, the simple, broadband coax-to-waveguide adapter provides a low-cost, dependable microwave antenna.

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automatic position control for the HAM-M rotator

IC logic provides automatic brake release and positive position control for this popular antenna rotor

When I built my cubical quad antenna, I selected the Ham-M rotor because of its rugged construction. A particularly important feature that influenced this decision was the brake, which protects the gear drive from damage in a wind storm. The brake, however, has the disadvantage of engaging before the antenna has stopped turning, which puts a severe torque on the tower. I felt it was easier to design a brake delay circuit than to find a way to reinforce my tilt-over mast.

Having decided to modify the brake circuit, it was natural to see if additional improvements could be made to the Ham-M control circuit. The result of my analysis was that it would also be beneficial to have an automatic position control, so I designed the following circuit to provide these features.

principle of operation

The control concept is shown in **fig. 1**. A regulated power supply drives a bridge circuit consisting of R8 and R9. R8 is the existing position-sensing pot in the rotator with R9 being in the control box. When the rotor is in the desired position, voltages on each of the pot wipers will be equal. If you turn R9, the voltages will no longer be equal. The voltage difference is proportional to the position error. This error voltage is amplified by error amplifier U2. U2 output is checked by comparators U3 and U4, which determine if the rotor is to turn to the left, turn to the right, or stay in place. Logic signals $\overline{LEFT}$ and $\overline{RIGHT}$ go to a timing circuit, which drives the relays. The relays in turn, actuate the rotor motor and brake release coils.

As the rotor turns, R8 is turned. When the desired position as set on R9 is reached, the error voltage goes to zero. The motor is then turned off, and after a short delay, the brake is engaged. This action occurs automatically.

circuit description

Fig. 2 is the schematic of the error amplifier and comparators. Since the wiper of R8, the position-sensing pot, is grounded to the rotor housing, a floating power supply is needed. This supply is provided by meter transformer T1 and voltage regulator U1. The meter circuit is the same as in Ham-M design.

Error amplifier. Error amplifier U2 is a common 741 op amp. Any voltage difference between pins 2 and 3 is amplified by 10,000 times or more. This gain is reduced by negative feedback through R11 and R12. The overall effect is that U2 output is 1 volt for every 6 degrees of error in position.

Comparators. U3 and U4 are LM311 comparators. These devices are similar in function to the op amp except that the output is a digital signal. If pin 3 is more positive than pin 2 the output is grounded; otherwise, the output is pulled up to the +12-volt supply through the external components.

U3 pin 2 is connected to a threshold voltage, which can be adjusted between 0.5 and 2 volts. If U2 output is greater than this threshold voltage, U3 output will be

By Paul Zander, WB6GNM, 86 Pine Lane, Los Altos, California 94022

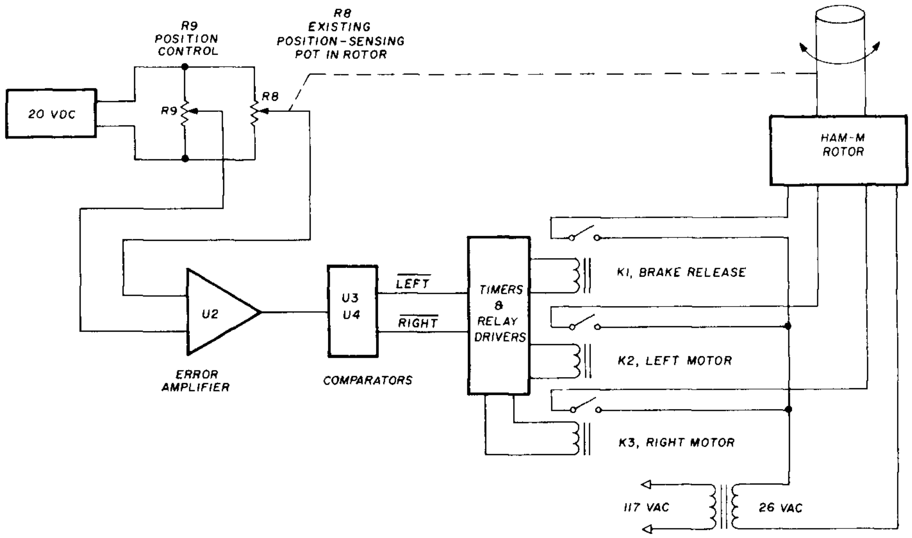


fig. 1. Simplified block diagram of the automatic position control system for HAM-M antenna rotor.

low, indicating that the rotor should turn to the right. As the rotor turns, U2 output decreases until U3 output again goes high. U4 works in a fashion similar to U3 when the antenna is turning to the left. R26 and R27 provide positive feedback, and hence a little hysteresis, to the comparator action so that no uncertainty will occur when the inputs are nearly equal.

There's a small range in the error amplifier output where neither comparator output is low. This results in a dead band in the control action, which is unavoidable for two reasons. First, there's no simple means of gradually reducing motor speed so that the rotor stops exactly in the right place. (SCR circuits are well known rfi generators.) Furthermore, the brake locks in incre-

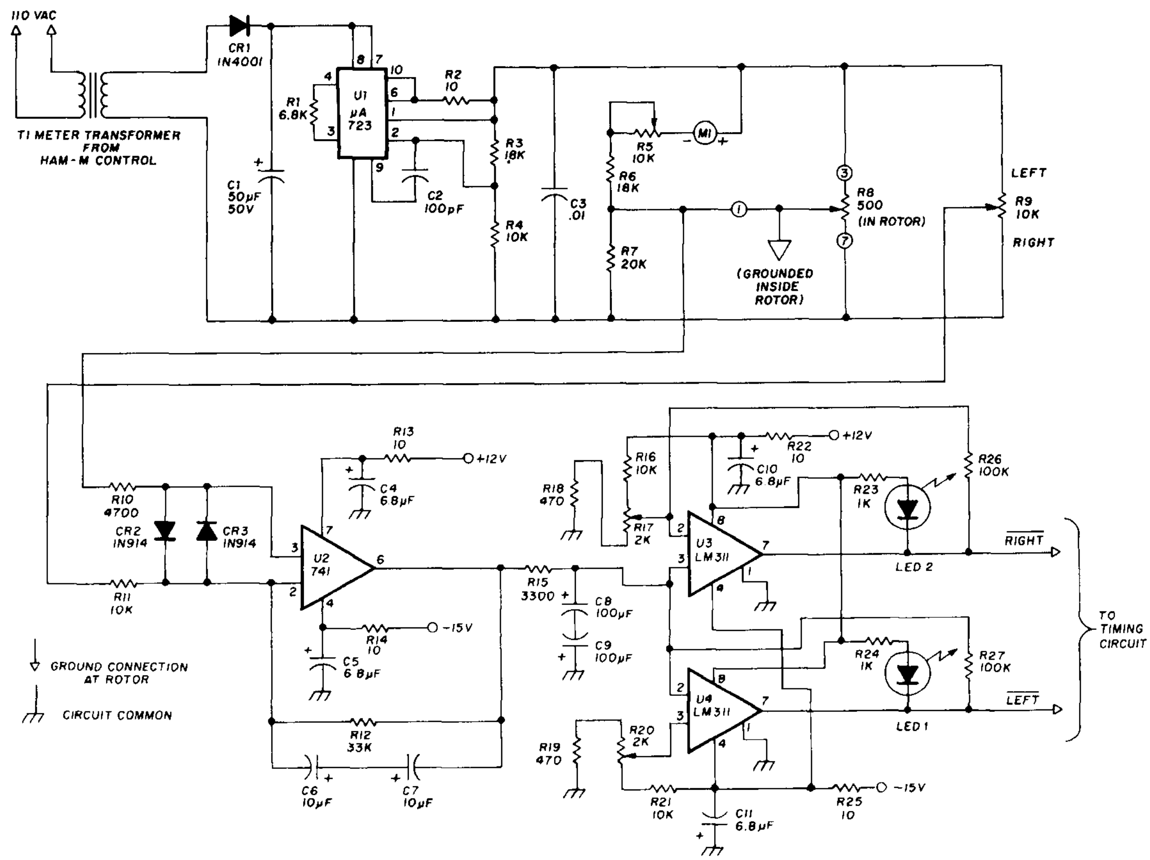


fig. 2. Error amplifier and comparator schematic.

ments of 3° 45′, which is of little practical concern since few antennas have extremely narrow beamwidths.

The bypass capacitors and decoupling resistors in the power-supply leads of U2, U3, and U4 are a precaution against instabilities that sometimes bother IC circuits. This part of the circuit design is possibly overcautious, but I felt it was better to be safe.

Because the wires from the position-sensing pot, R8, are in the same cable as the wires supplying power to the motor, a considerable 60-Hz signal is superimposed on the position signal. C6, C7, C8, C9, and R15 filter this hum before it reaches the comparators. The hum is further reduced by not grounding the circuit common inside the control box. However, safety and rfi considerations require that the cabinet be properly grounded.

Timing circuit. The timing circuit, **fig. 3**, is based on the popular NE555 timer IC. A low input on pin 2, from either the comparator or the manual test switch, will start the timing sequence. U5 discharges C13 through pin 7. Normally C13 could begin to recharge through R29; but in this circuit, Q2 keeps C13 discharged as long as the input is low. Meanwhile the output, pin 3, is high, which causes CR3 to conduct, energizing brake-release relay K1. Simultaneously Q3 is also turned on. Q3 then turns on K2, which causes the rotor to turn to the left. U5 output also acts through Q4 to keep U6 reset. U6 cannot start timing until U5 has timed out.

When U5 input goes high, Q2 and Q3 turn off; hence the motor is turned off. C13 then begins to charge through R29. When C13 reaches 8 volts, U5 turns off and the brake is engaged.

If, during the coasting period, you wish the antenna to rotate further, Q2 and Q3 can be turned on immediately and the motor will be reenergized. If you wish to reverse rotation direction, it will be necessary for U5 to time out before U6 can be set and K3 energized to turn the rotor to the right. In short, an operator error cannot cause the circuit to jam.

Power supplies. This control circuit requires three dc power supplies. These are a 20-volt, 60 mA supply for the positioning bridge and meter; (**fig. 2**) a +12-volt 300 mA supply for the ICs and relays; and a −15 volt supply for the error amplifier and comparators. The +12-volt and −15-volt supplies are shown schematically in **fig. 4.**

The design is based on the μA723 regulator. It would probably be easier and less expensive to use the newer

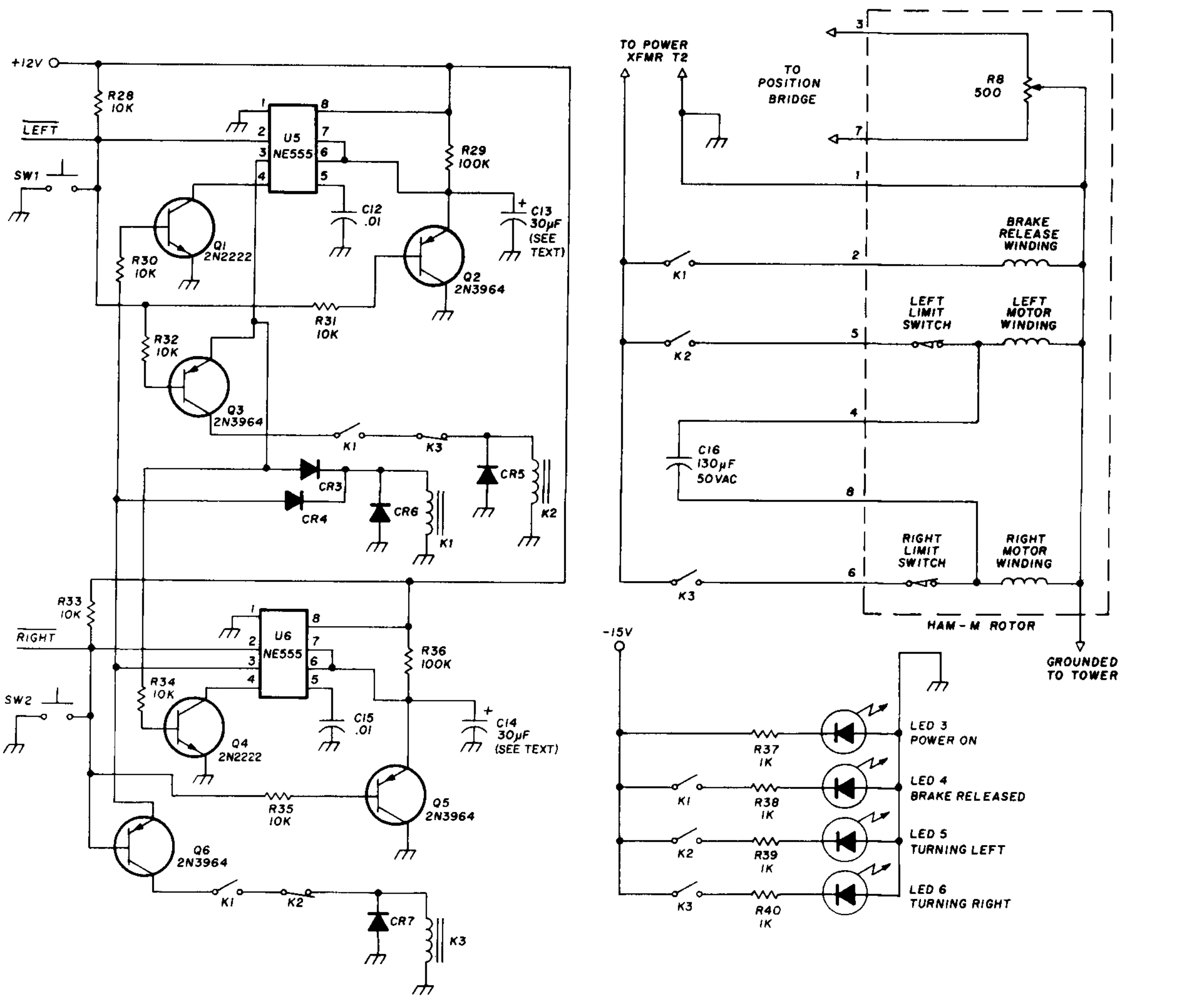


fig. 3. Timing-circuit schematic. C13, C14 see text. CR3-CR7 1N645A or similar. K1-K3 12 Vdc 185-ohm coil, 29 V 5A contacts (Potter & Brumfield R10-E1-X4-V185 or Allied TF154-CCCC-12V). LEDs are HP 4403.

three-terminal regulators such as the LM320 and LM340 series. Because there are few, if any, 20-volt regulators available, the position-bridge circuit could be operated at 18 volts. Whichever voltage you choose, the supply should be fused at no more than 1/8 ampere unless the regulator has internal current limiting.

Nothing is critical about the control-circuit assembly. I removed the transformers, meter, and motor capacitor from the Ham-M control box and put everything into a larger cabinet. Alternatively, the transformers and meter can remain in the Ham-M box and the new circuit put

pot in the rotor. The meter should indicate the position of this temporary pot. The meter can be calibrated initially by adjusting R5 to give a full-scale meter reading when the temporary pot is turned fully to the right. When the temporary pot and the position control pot, R9, are in the same position, all the relays and LEDs (except of course the power indicator) should be off. As the pots are turned, the relays and LEDs should go through the sequence of turning the motor and brake on and off, as discussed previously.

When you're satisfied that the control circuit is

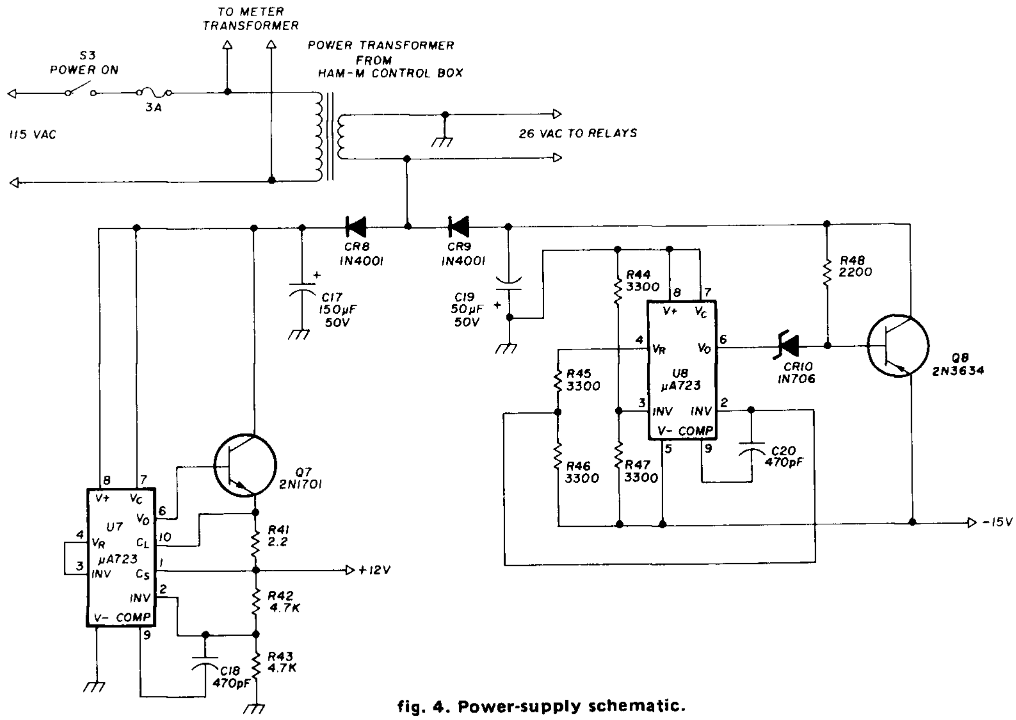


fig. 4. Power-supply schematic.

into a separate enclosure. Either way, most of the wiring can be done with a Vector wiring pencil or on a PC board.

Position control R9 deserves some comment. I used a standard 270° rotation pot with a pointer knob. The panel was labeled S-W-N-E-S. If you can obtain a 360° rotation pot, the front panel could include a map to show the area to which your antenna is aimed.

LEDs 1 and 2 and switches 1 and 2 are needed only for testing and can be mounted inside the box. I also recommend that the connections between U3 and U5 and between U4 and U6 be jumper wires that can be easily removed for testing.

testing and adjustment

This control circuit, if carefully built, can be connected to your Ham-M rotor without removing it from the tower for the following procedure.*

First check the control operation with the rotor disconnected by using a 500-ohm linear pot in place of the

*This design is based on a series-5 rotor. Series 1 and 2 rotors will require changes in the rotor.

working properly, set R17 and R20 for the widest dead band, remove the jumpers between the comparators and the timing circuit, then connect the rotor. The rotor can be operated by using the test switches, S1 and S2. Your antenna may require more brake delay than mine did. If so, increase timing capacitors C13 and C14 until the antenna comes to a smooth stop. Adjust the meter calibration if necessary. Check to see that the comparators are still functioning as indicated by LEDs 1 and 2.

Now, reconnect the comparators to the timers and check out the automatic positioning control. The final step is to adjust the dead band. Adjust R17 and R20 to make the dead band smaller, then rotate the antenna. When the dead band is too small, the antenna will coast through it before the brake is engaged. After the time delay, the motor will reverse only to coast through the dead band again. Increase the dead band until this searching action doesn't occur.

This automatic rotor control has proved satisfactory in two years of use at my station. A self-addressed stamped envelope would be appreciated with any correspondence relating to this article.

ham radio

fine tuning the phased vertical array

Design and construction of a 2-element vertical in which phasing is stepped between zero and 180 degrees

Several years ago I described an antenna using two mobile whips mounted on the terrace railing of my apartment.[1] The antenna was a close-spaced array for 20 meters. The primary purpose of the design was to provide a means of reducing interference during reception. A secondary purpose was to provide some gain in line with the north-south pattern of the array. A simple switching arrangement provided a choice of zero degrees for no directivity, 135 degrees for a reversible cardioid pattern, and a spare position for "in between" phasing for experimentation.

While experimenting with this array over a two-year period, I made many observations, which convinced me (strictly from a reception standpoint), that it would be desirable to be able to shift the phasing quickly over a range between zero and 180 degrees in as many small steps as practical. This article describes a phase-shifting unit that accomplishes this objective.

background

The popularity of the two-element phased array has been due to the work of Brown[2] and the charts he prepared (**fig. 1**) and, of course, to Kraus.[3] Since the publication of these articles many others have appeared in the literature. As background reading, I recommend a series of 12 articles on vertical antennas, which were published in *CQ* magazine.[4]

Brown's chart[2] was prepared under a given set of conditions that required the currents in each driven element to be of equal magnitude. This can be accomplished by power dividers and branching networks, several of which have been described in the amateur literature. The Wilkinson divider[5], the jeep-coil type, and the ohms-law type[6] are examples.

Most of the published amateur work on phased arrays has followed the rule of equal currents and has adhered pretty closely to the standard pattern structure and phasings as shown in **fig. 1**. Very few amateurs have ventured

By William Tucker, W4FXE, 1965 South Ocean Drive, Apartment 18-S, Hallandale, Florida 33009

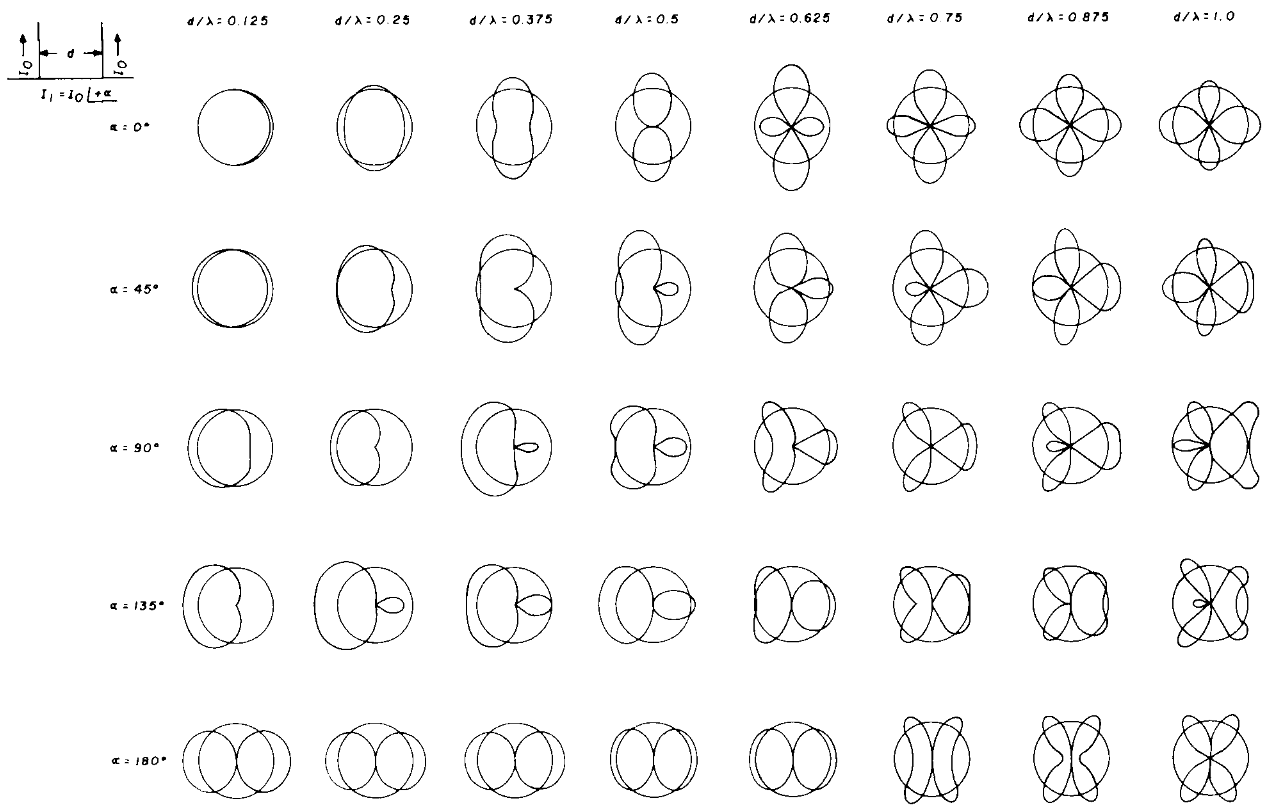


fig. 1. Horizontal patterns for two vertical radiators fed with currents of equal magnitude (after Brown, reference 1). Circles indicate the relative field from one radiator alone with the same power input.

the region of unequal currents and "in-between" phasing.

In an antenna system where the phasing will be varied from zero to 180 degrees, it's not a simple matter to keep the currents equal. In this case, the fact that the currents usually are not equal allows us to use those variations of the pattern from the norm created by a wide assortment of phase shifts.

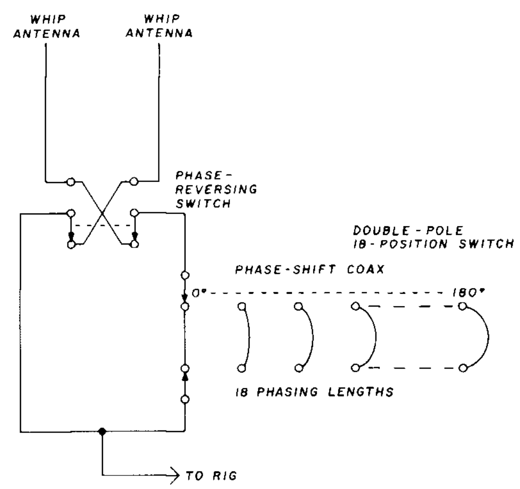


fig. 2. A method for shifting phase in 10-degree steps. Eighteen separate pieces of coax cable would be required — not a very practical scheme.

null variations

For practical purposes the resultant patterns follow the classical patterns fairly well insofar as gain and directivity are concerned, but the main difference seems to be in the intensity and directivity of the nulls. Broadcast stations, for example, place their antennas so that the nulls avoid interference with other stations using the same frequency. Their patterns require a power division usually not equal to, and a phasing seldom a multiple of, 45 degrees.

The ease of reversing the directivity of a phased array quickly, with the flick of a switch, proved valuable in making observations that would have been otherwise impossible with a slow-moving rotary beam. All observations were made on the 20-meter band using two mobile whips spaced 12 feet (3.7m) apart in a north-south plane, mounted on the terrace railing of my apartment, which serves as a rather skimpy ground plane. The antennas are not vertical but extend out from the terrace at a 45-degree angle.

It was observed that the intensity of the null in the cardioid pattern obtained with approximately 135-degree phasing varied greatly as the vertical angle[7] of arrival responded to ionospheric changes and could be altered by a shift in phasing. This condition also existed

on the nulls in a figure-8 pattern obtained with 180-degree phasing.

Another observation made was the fact that there was an apparent shift in the azimuth of the deep null of the cardioid pattern, perhaps as much as 45 degrees, by small shifts in phasing. This phenomenon was also noticed in the nulls of the figure-8 pattern but to a smaller degree. This proved very helpful in eliminating interference on reception without materially affecting forward gain. Also, in the case of noise, a minimum could be obtained by proper phase selection; and in many cases the noise level could be reduced from an S-9 to an S-2 level.

The variable phase shift unit described here can be used with any 20-meter phased two-element array, regardless of spacing or polarization, and will allow you to select the most suitable pattern and then proceed to "fine tune" the system to ionospheric conditions and interference, which are both usually in a state of flux.

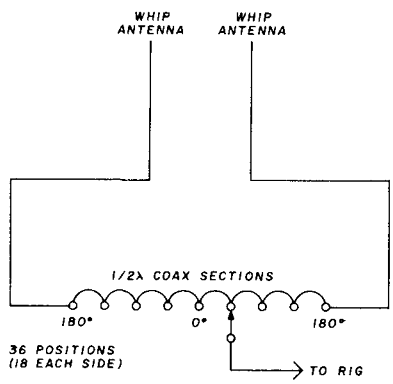


fig. 3. Simple and practical method for an antenna phasing system using a half-wavelength of coax cable with as many taps as desired.

design

The original phase-shift unit I had been using with the two mobile whips provided a selection of four phasing positions, which were entirely inadequate for the "fine tuning" needed. I could have provided addition switching and shifted phase every 10 degrees, but I would have ended up with 18 separate rolled-up coils of coax, an unwieldly arrangement to say the least (**fig. 2**).

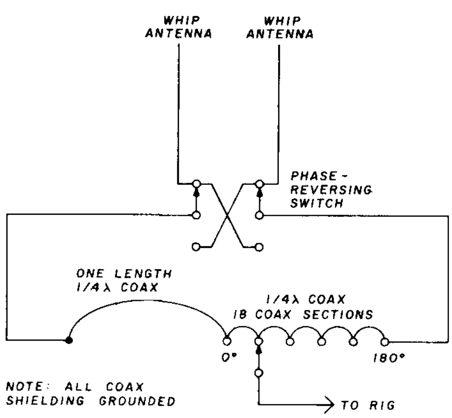


fig. 4. System as shown in fig. 3 but with only one side of cable tapped and a dpdt switch used for phase reversal.

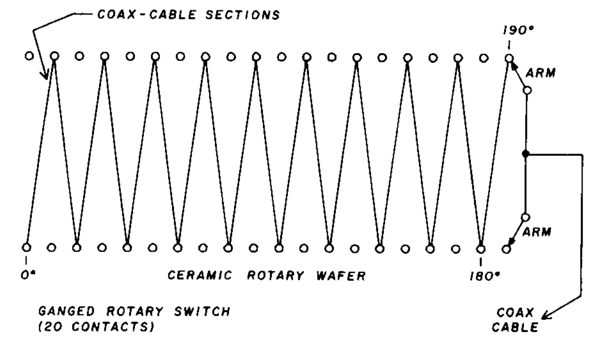


fig. 5. Method for connecting small-length coax sections to a 20-position rotary switch. The switch was modified so that the wafers were far enough apart to accommodate each coax-cable segment. The switch should be able to carry the rf current.

A quick solution appeared: why not just use one length of coax cable, 1/2-wavelength long, for the 180-degree phase shift and divide it into 18 sections so it could be tapped? Simple, but it won't work; the unused portion of the cable will act as an open-ended stub and detune the entire system.

A simple and practical method evolved in which there would be no unused section of cable. The entire half wavelength of coax would straddle the two antenna feedlines (**fig. 3**). At the centertap, the two antennas would be in phase (0 degrees) and at either end would be 180 degrees out of phase. It's apparent that as the tap is shifted, the amount of coax added to one feedline is automatically subtracted from the other. Of course, a further simplification is to tap one side of the line and use a dpdt lever switch for phase reversal (**fig. 4**).

The electrical length in inches* of a quarter-wavelength line (90 degrees phase shift) is determined by:

$$L = \frac{2952k}{F} \quad (1)$$

L = length (inches)
k = coax-cable velocity factor
F = frequency (MHz)

Inasmuch as coax cable varies, the line should be trimmed to frequency with the aid of a grid-dip meter. After the proper length is found, the number should be divided by 18 to give that many pieces of cable for 10-degree steps in phase shift. One additional piece of cable should be added to provide an overlap that may be needed for full 180-degree coverage because of differences in rotary switches and workmanship. For example, at a frequency of 14250 kHz you might grid-dip a quarter wave of coax and find it to be 135 inches (342.9cm). If so, each of the segments will be 7.5 inches

*For coax length in millimeters, the factor 2952 in **eq. 1** becomes 74980; for the length in centimeters it is 7498. **Editor**

(19cm) long. Adding one length will give 19 sections with a total length of 142.5 inches (363cm).

After the 19 sections of coax have been mounted on the switching assembly, the unit should be grid-dipped as a quarter wave and the frequency noted. This new frequency will be the guide for cutting a matching piece of coax to balance the system so the centertap position will be zero degrees.

A mechanical problem occurs in trying to cram 19

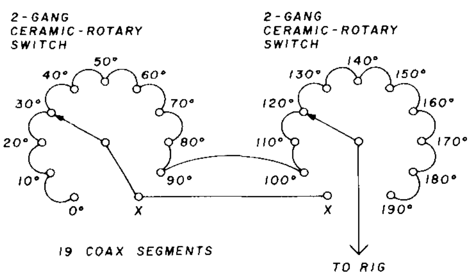


fig. 6. Switch arrangement using two ganged sections. One phasing coax-cable segment is used as a link between each ganged section. Whichever switch is not in use should be set at contact marked with an X.

short lengths of RG-58/U coax around a 20-position switch. This problem was solved by modifying a two-section rotary ceramic switch so that the wafers were placed just far enough apart to accommodate the length of coax segment. The coax was then placed lengthwise and attached to alternate contacts on each switch as shown in **fig. 5** and using a common rotor for selection. The unused portion of the coax on the selector arm is short and of little consequence. The rotary switch, of course, should be of good quality and be able to carry the rf current. A word of caution: *do not* rotate the switch on transmit!

RG-58/U cable is used throughout the phasing unit because of its small size and ease of handling. Unfortunately, the use of this cable will limit the power to somewhat less than may be desired. I've been using 300 watts of key-down power output, but the coax should handle twice that power and even more. Of course, larger cable can be used as feedlines for the antennas.

The 18-segment number was chosen so that phasing could be divided into 10-degree steps, and the added segment to 190 degrees. This 10-degree number can be varied to conform to the amount of contacts available on your rotary switch. If you can accommodate more than 20 positions, fine. The more positions you have, the greater the selection of phasings and the shorter will be the coax sections. Conversely, fewer contacts mean longer segments and fewer phasing selections. I would limit the size of the segments to between 5 and 10 inches (13 and 26cm).

If you can't obtain a rotary switch with sufficient contacts, I suggest you use two ganged assemblies as shown in **fig. 6**. Mount the two separate ganged assemblies close enough together so that one phasing segment can be used as the link between them. Whichever switch is not in use should be set at contact X.

In preparing the coax for mounting on the switch, try to leave a minimum of exposed inner conductor. The shield should be wrapped together with a fine copper wire, then soldered (**fig. 7**). Also, the phasing unit internal wiring should be balanced right up to the fixed and variable phasing lines. Coax should be used in the internal wiring unless the leads are very short.

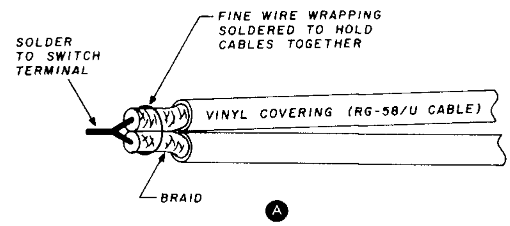
matching impedances

Close-spaced elements will usually have a fairly low impedance because of the mutual impedance involved and will usually be in the neighborhood of about 15 ohms. An swr of even 3:1 can be tolerated unless the feedline is several wavelengths long. However, a simple linear matching transformer can be used consisting of 1/4 wavelength of two lengths of 52-ohm coax in parallel, grid-dipped to frequency. This section is used to match the 15-ohm impedance of the antennas to the 52-ohm feedline. This follows the formula for quarter-wave linear transformer design where the surge impedance of the linear transformer is equal to the square root of the product of the input and output impedances. The 26-ohm impedance of the parallel coax lines comes out pretty close to the desired value.

checking and adjustment

Once the two antennas are connected together in the phasing unit, the output of the unit should be matched to the rig with an antenna tuner. The lead between the tuner and the phasing unit should be as short as possible and the tuner adjusted for minimum swr with the phasing set at 130 degrees. This setting will usually allow other phasing settings to be used without having to readjust the tuner (**fig. 8**).

This phasing unit can also be used on 10 and 15



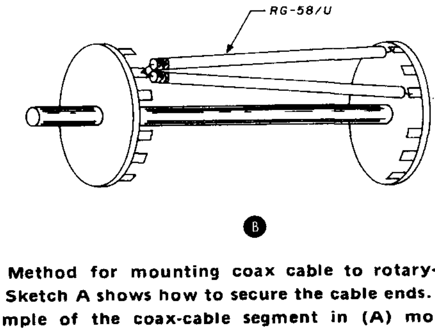


fig. 7. Method for mounting coax cable to rotary-switch segments. Sketch A shows how to secure the cable ends. Sketch B is an example of the coax-cable segment in (A) mounted to a two-gang ceramic rotary switch.

meters if desired without any changes. The calibration will be doubled on 10 meters to indicate 20 degrees per division and 15 degrees per division on 15 meters. A phasing unit can be designed for 80 meters and also used on 40 meters.

The effectiveness of the phasing unit can be checked and calibrated in the receive position by using a steady signal source such as a grid-dip meter placed 30 or 40 feet (9 or 12m) away from the array, first in the position where the cardioid null falls, then where the null of either side of the figure-8 falls. The phasing setting that provides the best front-back ratio for the cardioid pattern should be designated as 135 degrees (130 degrees will do); and for the best broadside nulls, 180 degrees. The calibration can then be verified by tests with local stations in known directions. The other calibration points can be determined by interpolation.

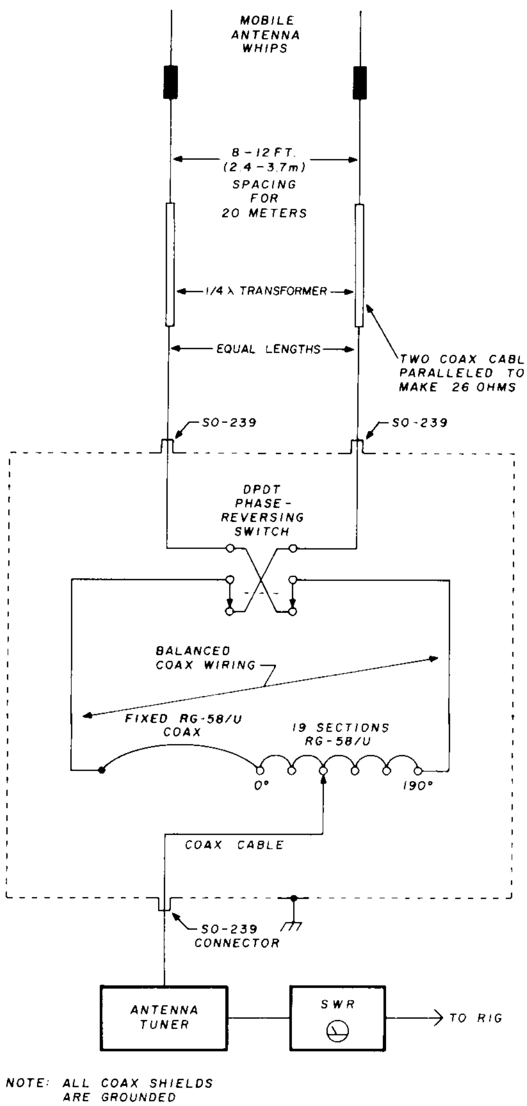


fig. 8. Final schematic diagram of phasing unit shown connected to antennas, tuner and swr indicator.

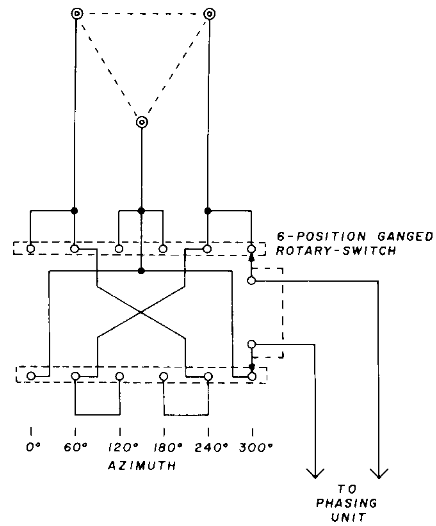


fig. 9. Arrangement of three vertical antennas in a triangle for full directional coverage.

In operation, when in contact with another station, the phasing control is usually set at 135 degrees with the reversing switch set for strongest reception. If interference is present, an attempt is then made to reduce it by adjusting the phasing control. Sometimes reversing the array will reduce interference more than the wanted signal. If this occurs, simply flip the reversing switch back to normal for transmitting. This situation will occur often when there is a high noise level, which can be reduced considerably by reversing the cardioid pattern. The figure-8 pattern is normally used when the interference or noise level is broadside to the array.

concluding remarks

The flexibilty of this phasing system can be rewarding once the user becomes familiar with its capabilities. For those with space for three close-spaced verticals in a triangular arrangement, this system can be used with any two of the verticals. The advantage will be complete coverage in azimuth in six steps. The switching arrangement in **fig. 9** should do the trick.

I welcome comments from those who have built the phasing unit described here and have obtained experience with its use on the amateur bands.

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ham radio

a comparison of vhf mobile antennas

Mobile antenna gains depend not only on antenna type but — deflection due to vehicle speed

The issue of antenna gains, especially at vhf, seems to be shrouded in some mystery. At times, the gain figures of antennas appear to be determined more by the sales department than the engineering department. As part of my job I had the occasion to test a number of vhf mobile antennas to determine their in-use performance. It is hoped the results will prove useful to the amateur fraternity.

gain references

Usually the gain of a base station antenna is referenced to a half-wavelength dipole and the gain of a mobile antenna to a quarter-wavelength monopole. The Electronic Industries Association (EIA) has previously established standards for both base and mobile antennas. These standards are EIA-RS-329, part 1, for base antennas and EIA-RS-329, part 2, for mobile antennas. Commercial antenna manufacturers now rate the gains of their land-mobile base antennas per EIA-RS-329 although few, if any, rate their mobile antennas by the same standard.

antenna gains

Mobile antennas are usually tested on a 56-inch (22cm) ground screen or on a standard automobile. In the testing presented, all the antennas were mounted on the rear cowl (passenger side) of a Dodge police cruiser. All the antennas were adjusted for a vswr of less than 1.5:1. Each test consisted of transmissions from the mobile to a base receiver using a DB-224 antenna at 175 feet (53m). Signals were then recorded on a calibrated limiter meter using step attenuators as required. The tests were performed at various locations at distances of 1 to 20 miles (1.6 km to 32 km) from the base station. At every location two tests on each antenna were performed, one with the vehicle pointed toward the base station and the other with the vehicle pointed away from the base station. **Table 1** shows the average gains referenced to a quarter-wavelength whip with the vehicle stationary.

Although above data was taken at 155.5 MHz, the gain figures are equally applicable at 146 MHz. The gains are somewhat higher than might be expected due to the effects of the roof of the vehicle. The roof shields the quarter-wavelength antenna more than the five-eight wavelength antenna when the auto is pointed toward the base station. In all tests, however, the relative gains were in the same order as the final averages.

Since we have the antenna on an automobile, gain with the vehicle stationary is only part of the story. Tests were also performed to see how much degradation was suffered at high vehicle speeds. Since testing was being done for a police agency, high speed meant 100 mph (160kh/h)! **Table 2** shows the antenna deflection at 100 mph.

As mentioned previously, the test frequency was 155.5 MHz; at 146.5 MHz the antennas are longer, 3 inches (1cm) for five-eighth wavelength antennas so you would anticipate deflection to be somewhat greater.

By Daniel J. Lynch, W4MNW, 2000-147 N. Meridian, Tallahassee, Florida 32303

table 1. Stationary antenna gains. Antenna gains with reference to the 1/4-wavelength whip. Only two measurements were performed on the DB-702. The ASP-800 is a heavy duty version of the ASP-177 with approximately 0.5 dB more gain.

antennas	stationary average gain
0.046 inch (1mm) stainless 1/4-wavelength whip	0 dB
0.100 inch (2.5mm) Larson 1/4-wavelength whip	—
Antennas Specialists 800 5/8 wavelength 0.125 inch (3mm) whip	3.1 dB
Antennas Specialists 800 5/8-wavelength without spring	3.1 dB
DB Products 702 5/8-wavelength 0.100 inch (2.5mm) whip	2.2 dB
Larson 150 5/8-wavelength 0.100 inch (2.5mm) whip	3.6 dB
Larson 150 5/8-wavelength 0.125 inch (3mm) whip	3.6 dB

Subsequent tests with an antenna cut for 146 MHz indicates approximately the same antenna deflection at vehicle speeds of 70 mph (113km/h).

high speed gain

Tests were then run to check the effect of antenna deflection on performance. **Table 3** shows both the high-speed gain reduction and the gain at high speed with reference to a quarter-wavelength whip. At high speeds the gain degradation is both apparent and dramatic. The five-eighth wavelength antennas with 0.100-inch (2.5mm) whips suffer much greater degradation than the five-eighth wavelength antennas with 0.125-inch (3mm) whips or the quarter-wavelength antennas.

Degradation was not caused by detuning of the antenna or transmitter, since there was only a slight increase in vswr when the antennas were deflected. Although the 0.046-inch (1mm) quarter-wavelength whip and the ASP-800 deflected approximately equal amounts (45 degrees and 50 degrees respectively), the ASP-800 had significantly greater degradation. This greater degradation is caused by the narrower beamwidth of the gain antennas being bent up above the horizon more than the wide beamwidth of the quarter-wavelength antenna.

This was verified in testing of uhf antennas when a 30-degree deflection produced a degradation of 5.5 dB for an antenna that used two vertically phased five-eighth wavelength elements. This compares to a 30-degree deflection producing a 3.0 dB degradation for a single five-eighth wavelength element.

It is apparent that for maximum performance it is necessary to maintain the antenna vertical and still retain immunity to damage from overhead objects. Knowing that the antenna must be kept vertical, placement on the vehicle becomes important. Tests by Antenna Specialists[1] show a 2.5 dB increase in signal when a vhf quarter-wavelength antenna is moved from the trunk lip to the center of the roof. The five-eighth wavelength antenna shows a 1 dB increase when moved from the trunk lip to the center roof.

Since most of my driving is within 10 miles (16km) of the local repeater, a quarter-wavelength whip on the roof is adequate. When traveling out of town a five-eighth wavelength antenna (with a 0.125 inch (3mm) whip) is substituted on the same mount. The quarter-wavelength antenna offers an added advantage around town. Because the quarter-wavelength whip doesn't resemble a CB antenna, the radio is somewhat more immune to theft since stolen amateur equipment doesn't have as large a market as do stolen CB radios. In some areas this aspect may outweigh the performance factor.

table 2. Antenna deflection at high vehicle speed. Speed of approximately 70 mph (113km/h) produced above deflection with antenna cut for 146 MHz.

antenna type	deflection
0.046 inch (1mm) stainless 1/4-wavelength whip	45 degrees
Larson 0.100 inch (2.5mm) stainless 1/4-wavelength whip	20 degrees
Antennas Specialists 800 5/8-wavelength 0.125 inch (3mm) whip	50 degrees
Antennas Specialists 800 5/8-wavelength whip without spring	30 degrees
DB Products 702 5/8-wavelength 0.100 inch (2.5mm) whip	80 degrees
Larson 150 5/8-wavelength 0.100 inch (2.5mm) whip	80 degrees
Larson 150 5/8-wavelength 0.125 inch (3mm) whip	30 degrees

table 3. Antenna gain reduction at high speed and the resultant gain with reference to a 1/4-wavelength whip at high speed. The 5/8-wavelength antennas without the 0.125 inch (3mm) whip actually have a loss with respect to the 1/4-wavelength whip at high speed.

antenna	average gain reduction at high speed	average gain at high speed
0.046 inch (1mm) stainless 1/4-wavelength whip	1.6 dB	0 dB
0.100 inch (2.5mm) Larson 1/4-wavelength whip	0.9 dB	0.7 dB
Antennas Specialists 800 5/8-wavelength 0.125 inch (3mm) whip	4.1 dB	0.6 dB
Antennas Specialists 800 5/8-wavelength without spring 0.125 inch (3mm) whip	3.2 dB	1.5 dB
DB Products 702 0.100 inch (2.5mm) whip	7.6 dB	− 3.8 dB
Larson 150 5/8-wavelength 0.100 inch (2.5mm) whip	7.3 dB	− 2.1 dB
Larson 150 with 0.125 inch (3mm) whip	3.0 dB	2.2 dB

reference

1. D. W. Horn, *Selection of Vehicular Antenna Configuration and Location Through the Use of Radiation Pattern*, 1973 Vehicular Technology Group Conference of the IEEE.

ham radio

More Details? CHECK—OFF Page 150

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JERRY VOGT,
WA2GCF
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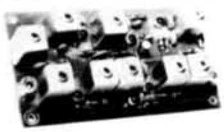

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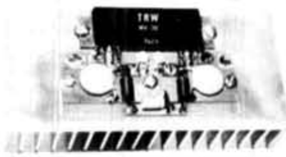

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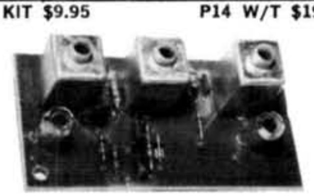

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More Details? CHECK — OFF Page 150

high performance antenna for 80 meters

Simple construction and high performance are two features of this 80-meter phased array

While tuning around the different amateur bands, you can find that the antennas in use fall into a familiar pattern. On 10, 15, and 20 meters, most people are using a Yagi or quad; on 40 meters, the majority are using a vertical or dipole. However, on 80 meters, a wide variety of antennas is encountered, the inverted Vee being the most common. The larger stations do have a wide range of antennas; Rhombics, long wires, long horizontal vees, phased verticals, big loops, collinears, Yagis, quads, occasionally even a Beverage.

At my location in Tennessee, close to the center of the United States, any antenna I install for 80 meters seems to work well for stateside contacts. However, I generally run into trouble busting through the "copper curtain" of the East and West Coasts to DX contacts. This presents no big problem for ordinary hamming and rag chewing. When I decided to climb on the bandwagon and work for 5BDXCC though, I learned quickly that it was going to be a struggle unless I installed an antenna a little better than an ordinary vertical or dipole. I have a conventional horizontal dipole, about 60 feet (18m) above ground, that has been up for several years and works fairly well, but not good enough to stand up under competition for the long-haul contacts or in the pile-ups.

antenna comparison

Not being hampered by a restricted house lot or lack of real estate, I was able to leave up the old dipole and still install other antennas at the same time. The dipole was used as my standard of comparison. As each new type of antenna was erected, I would compare the performance of the new one with the old dipole. In a fairly reasonable period of time this procedure would allow me to determine whether the new antenna was a bomb or a dud.

I've learned that judging the performance of a single antenna in just a couple of contacts, or over a short period of time without some means of comparison, is inconclusive. When band conditions are good, even a short length of barbed wire fencing will give you a few contacts. Conversely, if you check an outstanding antenna system when conditions are poor, you can often be erroneously led to believe that the antenna was a complete waste of time. So over a period of several years, I've spent many weekends installing new antennas for 80 meters and checking them against my old dipole.

The relative performance of the more common antennas surprised me in that several *seemed* to perform beautifully. It wasn't until I compared them to my dipole that I learned they weren't all-round performers, or didn't meet the claimed performance standards.

During the last five years, I've installed and tested verticals, phased verticals, inverted-vees at different heights and configurations, multi-element inverted-vees, horizontal vees up to 650 feet (200m) long, long wires several wavelengths long, loaded rotatable dipoles, discones, sloping dipoles (both single and multi-element and with reflectors) Zepps, loops, shortened quads, collinears and even a small rhombic. I haven't yet gotten around to installing a good full-size rhombic, but this is on the program. Several antennas did outperform the dipole, but their limitations and the small improvement in performance didn't always justify or warrant the extra hardware, weight, and real estate that was involved.

In the course of trying for a better antenna, I attempted to feed in phase a second dipole, identical to the old one, parallel to it and at the same height. This seemed to offer very little improvement. In fact, any improvement of receive or transmit signal strengths were practically indiscernible, in any direction or over any distance.

phased array

Before tearing down this system, I decided to see what would happen if I fed the two antennas 90 degrees out of phase, by very simply inserting a 42 foot (13m) length of coax in the feedline to one of the dipoles. The results were startling in that performance came close to equalling the best multi-element or long wire antennas I had ever used.

I found that by spacing the two dipoles parallel to one another, about 120 feet (36.5m) apart, and at approximately the same height, I was getting about 3-5 dB of forward gain; front-to-back ratio was about 12 dB. Even with some forward gain in either of two directions, my side lobes are broad enough to permit operation off the side with a respectable signal. My two dipoles are

By **Bob Fitz, K4JC**, Route 1, Springfield, Tennessee 37172

oriented north-south, with the gain and front-to-back to the east and west. I could improve the performance by varying the spacing of the two antennas, but the convenience of using trees already present, and the fact that I like my comparatively omnidirectional pattern away from the prime direction discourages my changing the existing spacing. By running the feedlines from the two dipoles to a coax switch, and inserting a 42-foot (12.8m) length of RG-8/U into the feedline of either the east or west antenna, I can switch the directivity to either the east or west (**fig. 1**). Signals from north and south don't seem to be affected very much.

After this antenna installation was made, my total of 50 countries on 80 meters jumped to 140 countries in the next three months. This, without too much effort or more than a casual attempt at DXing on 80-meter ssb and CW.

The only non-conventional aspect of my dipoles is

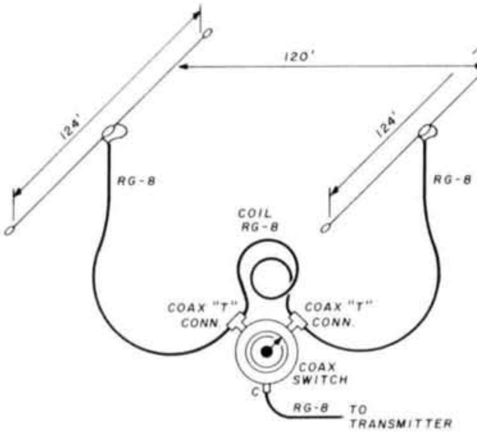


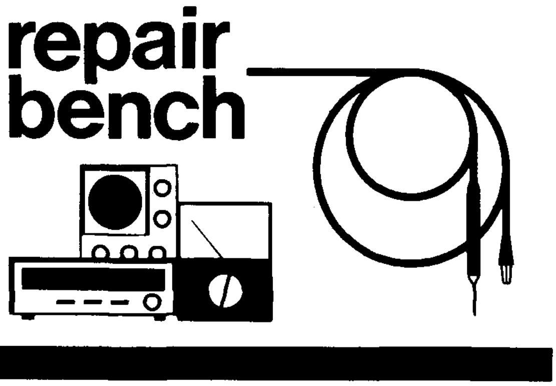
fig. 1. The antennas are fed through identical lengths of coax. By tuning each antenna individually to the same frequency, it is possible to switch directions without retuning the amplifier. The coax switch cannot be self-grounding.

the feedline. Instead of a normal coax feed, I use a standard quarter-wave unbalanced-to-balanced transformer (balun) feed system. The balun seems to improve the performance of the dipoles. The only caution that must be exercised is the exact match of the two feedlines and the two antennas. Otherwise, the transmitter or linear will have to be retuned after changing the direction. I found that antennas of the same length were not entirely satisfactory. The second antenna was affected by several nearby trees, the house, and a slight difference in height. By changing the length to get it to load exactly like the first dipole, I can switch directions without retuning.

The array is broadband enough to permit operation on both the ssb and CW portions of the band without exceeding a swr of about 2.8:1 at the ends of the band. It even permits operation on the Army MARS frequency above the high end of the 7S-meter phone band.

For a simple, easy to install and tune, and inexpensive arrangement that has a minimum of hardware, it's the best all-around antenna I've ever used on 80 meters.

ham radio



Bob Stein, W6NBI

how to use the slotted line for transmission-line measurements

In a **previous article**,[1] several applications of the swr indicator (such as the Hewlett-Packard Model 415B) were described, *excluding* its use in conjunction with a slotted line. Since it was for that specific purpose that the swr indicator was developed, this article will actually be a continuation of the previous one as well as one which will discuss the use of coaxial slotted lines to measure swr, impedance, and transmission-line loss. The frequency range over which coaxial slotted lines are used is typically 400 to 5000 MHz, although it is possible, under certain conditions, to go as low as 100 MHz.

Since the purpose of this series of articles is to popularize the use of test equipment which is often available on the surplus market, let's begin by enumerating some of the coaxial slotted lines which you may run across. Hewlett-Packard Models 805A and 805C and General Microwave Type N200 are slab-type lines, which will be discussed shortly. Conventional coaxial lines, such as the GenRad (formerly General Radio) types 874-LBA and 874-LBB, are also available. Military types IM-24/U, IM-25/U, IM-92/U, and others are usually nothing more than the aforementioned commercial models which have been assigned military nomenclature. One exception to this is the TS-56A/AP, which appears to have been designed originally as military equipment.

By Robert Stein, W6NBI, 1849 Middleton Avenue, Los Altos, California 94022

principles of the slotted line

The principles governing the operation of the slotted line are those which apply to all rf transmission lines, and which will not be repeated here except as they apply directly to using the line. If we consider a section of transmission line which is fed from an rf source and is terminated in its characteristic impedance, Z_o, we know that there will be no reflection from the terminating load and therefore there will be no standing waves on the line. On the other hand, if the line is terminated by an impedance which is different from Z_o, a standing-wave pattern will result, as shown in **fig. 1**.

If the transmission-line section is coaxial, the voltage standing wave will exist as a potential difference or field between the inner and outer conductors. If we probe this field along the length of the line with a detector, and are careful not to disturb the field excessively with the probe, the detector will provide an output voltage which varies as the field intensity or voltage amplitude.

Since adjacent voltage minima or maxima along the line are always a half wavelength apart, the wavelength of the rf source can be determined by measuring the actual distance between adjacent minima or maxima. Furthermore, the detector is able to provide relative amplitudes of the voltage maxima, e_{max}, and minima, e_{min}, enabling us to determine the voltage standing-wave ratio from the following equations:

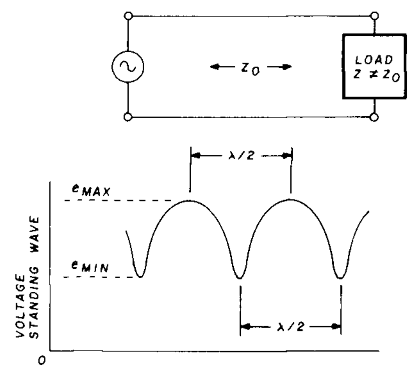


fig. 1. Standing wave on a transmission line terminated by a load impedance which is not equal to its characteristic impedance.

$$swr = \frac{e_{max}}{e_{min}}$$

$$swr\ (dB) = 20 \log \frac{e_{max}}{e_{min}}$$

Knowing the wavelength and the swr, it is also possible to determine the impedance of the load by means of transmission-line relationships. This will be explained later.

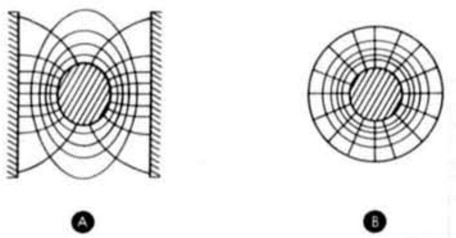


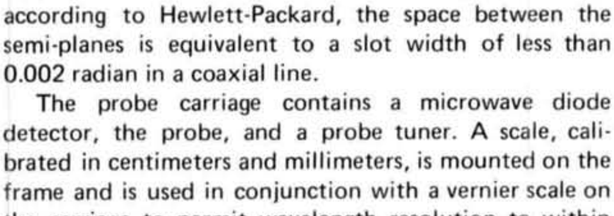
fig. 2. Cross-sections of the slab-type (A) and coaxial (B) slotted lines. The radial lines represent the electric field, the concentric lines the magnetic field. Courtesy Hewlett-Packard Company.

The conventional coaxial slotted line, such as the GenRad Type 874-LBB shown in the photograph, consists of a length of precision 50-ohm coaxial line with a narrow slot cut longitudinally along the outer conductor. A probe, mounted on a carriage which is movable along the length of the slot, extends into the line to sample the rf field. Connected to the probe is a microwave diode; a tuning probe or stub tuner (not shown in the photograph), also connected to the probe and diode assembly, tunes the structure for maximum sensitivity. A scale, graduated in centimeters and millimeters, is attached to the frame so that a pointer on the carriage can be used to measure distances along the line.

A somewhat different line configuration is the slab line used by Hewlett-Packard for their model 805 series and by General Microwave for the Type N200. As shown in the photograph of the Hewlett-Packard Model 805C, the probe carriage is mounted on a box-like structure which is actually two parallel conducting semi-planes separated by about 0.8 inch (20mm) and between which is the center conductor. **Fig. 2** shows cross-sections of the slab line and the conventional coaxial line. The equipotential field lines show that each of the semi-planes of the slab line is equivalent to one-half the outer conductor of the coaxial section. Precision machining results in a 50-ohm characteristic impedance and, according to Hewlett-Packard, the space between the semi-planes is equivalent to a slot width of less than 0.002 radian in a coaxial line.

The probe carriage contains a microwave diode detector, the probe, and a probe tuner. A scale, calibrated in centimeters and millimeters, is mounted on the frame and is used in conjunction with a vernier scale on the carriage to permit wavelength resolution to within 0.1 millimeter (about 0.004 inch).

In both types of slotted lines, the detector is usually a type 1N21 or 1N23 microwave diode, operating in its square-law region. Bolometer elements, such as a Narda



The GenRad (formerly General Radio) Type 874-LLB Slotted Line. An adjustable stub or probe tuner is usually inserted into the left-hand connector on the movable carriage. Photo courtesy GenRad.

Type N821, a PRD Type 610-A, or a selected 10-milliampere instrument fuse, may also be used. Bolometers require less attention relative to square-law operation, but are less sensitive than a diode detector.

For impedance measurements, a precision short must be connected to one end of the slotted line. Because the GenRad line uses hermaphrodite GR874 connectors, the GR Type 874-WN3 Short-Circuit Termination will fit either end. The Hewlett-Packard and General Microwave slotted lines are equipped with type-N connectors, male at one end of the line and female at the other. These lines are supplied with precision male and female shorting terminations.

The low-frequency limit of the slotted line is a direct function of its usable length, that is, the distance over

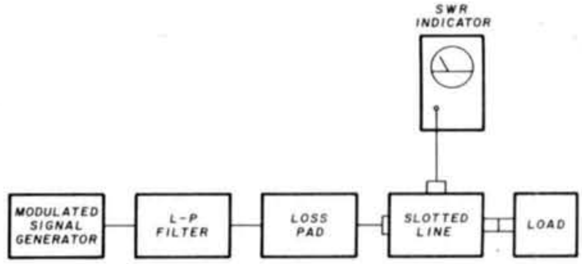


fig. 3. Equipment set-up for measuring swr, using an swr indicator for direct measurement readings.

which the probe carriage can travel. The Hewlett-Packard Model 805A and 805C frequency range is specified as 500 to 4000 MHz, although these lines are usable down to about 400 MHz, since the probe travel is approximately 36.5 centimeters (one-half wavelength at 410 MHz). The GenRad Type 874-LBB is rated from 300 to 8500 MHz, based on its probe travel of 50 centimeters. The earlier Type 874-LBA has a specified upper frequency limit of 5000 MHz.

These slotted lines can be used at frequencies below their specified minima, but such measurements may require the use of additional air-dielectric transmission-line sections or line stretchers. Such applications are beyond the scope of this article, but are covered in reference 2.

connecting the slotted line

The equipment set-up for using the slotted line is shown in **fig. 3**. The swr indicator was discussed in detail in reference 1. The signal generator must be amplitude modulated with a sine or square wave at the same frequency to which the swr indicator is tuned – usually 1000 Hz. Although an output of 1 milliwatt into 50 ohms is recommended for measurement of high standing-wave ratios, an output of 0.2 milliwatt (100 millivolts across 50 ohms) will generally suffice. The generator must supply a constant output which has minimum harmonic distortion and low incidental fm. The modulating voltage must also be stable to minimize measurement errors.

A lowpass filter, connected to the output of the signal generator, is desirable although not absolutely

necessary. Severe harmonic distortion in the signal-generator output can result in erroneous measurements, but these are probably of minor importance for amateur use. A loss pad of at least 6 dB should be used to minimize loading effects of the test set-up on the signal generator.

All of the connections to the input of the slotted line can be made with interconnecting coaxial cables, but the load must be connected directly to the slotted-line connector. In the case of lines having a male connector at one end and a female at the other, connect the load to the end which will permit a direct connection or, only if absolutely necessary, one made with the fewest number of adapters. Otherwise, the swr of the adapter(s) will introduce errors into your readings.

The measurement procedures which follow are, of necessity, abbreviated and generalized so as to be applicable to most slotted lines. That is not to say that they cannot be applied directly to whatever line you may be using, for in fact, they can. But there are much more detailed instructions in the manufacturers' manuals, and I strongly recommend that either the applicable manual

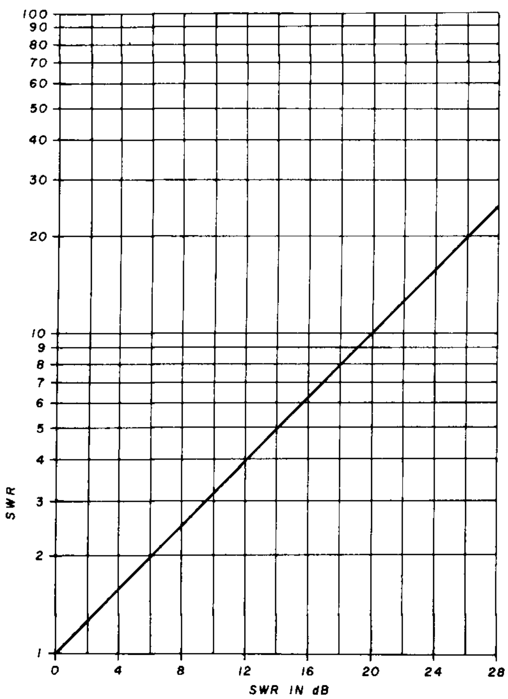


fig. 4. Swr vs swr in dB.

be obtained or that one of those specified in the references at the end of this article be purchased.

measuring swr less than 10:1

Direct method. The direct method of measuring swr is that which is most often used, although the alternate attenuator method will also be described. The procedure for direct measurement of swr is as follows:

1. Connect the equipment as shown in **fig. 3**, except that the load is left unconnected; allow sufficient warm-up time for the signal generator to become stable.

2. On the swr indicator, set the *gain* control fully counterclockwise and the *range* switch to 50.

3. Adjust the probe depth and tuning for a reading on the swr indicator, changing the *range* switch position clockwise, if necessary. If two peaks are obtained as the probe circuit is tuned, use that which results in the higher reading.

4. Connect the load to the slotted line and move the carriage along the line to find a voltage minimum.

5. Retune the probe circuit for a maximum meter reading. Then reduce the probe depth and retune the probe circuit (these adjustments interact) until a stable reading is obtained on the swr indicator with its *range* switch set to 50 or 60. It may also be necessary to adjust the signal-generator output. The main object, however, is to achieve a stable meter indication consistent with *minimum probe insertion*.

6. Move the carriage along the line to find a voltage maximum, and adjust the swr indicator *gain* control and *range* switch to obtain a meter reading of *1* on the swr scale.

7. Move the carriage to obtain a minimum meter reading, without changing any other adjustments or controls on the slotted line or on the swr indicator.

8. Read the standing-wave ratio directly from the swr scale on the meter. If the swr is greater than 3, switch to the next lower (counterclockwise) position of the *range* switch.

9. If the swr is less than 1.3, a more accurate indication can be achieved by setting swr indicator *meter scale* switch to *expand*, and repeating **steps 6** and **7**. In this case, the standing-wave ratio is read from the *expanded swr* scale on the meter.

Attenuator method. The attenuator method of measuring swr eliminates any error which may be introduced by deviation of the detector from true square-law response. It can also be used if an swr indicator is not available or if the signal source is unmodulated.

If the attenuator method is employed in conjunction with a *modulated* signal generator and an swr indicator, the test set-up of **fig. 3** is applicable, except that a precision variable attenuator is used in place of the loss pad. The measurement procedure is as follows:

1. Perform **steps 1** through **7**, described under the direct measurement method, with the variable attenuator set to provide at least 6 dB of attenuation.

2. Adjust the *gain* control and the *range* switch on the swr indicator for a meter reading of 0 dB with the *range* switch set to 50 or 60.

3. Move the carriage along the line to find a voltage maximum; do not readjust the swr indicator controls.

4. Increase the variable attenuator setting until the swr indicator again reads 0 dB, or as close to it as can be obtained on-scale.

5. The swr, in dB, is equal to the variable attenuator

setting plus the meter reading (also in dB), minus the variable attenuator setting used in **step 1**.

6. Swr in dB can be converted to swr by reading the value from the scale on the meter which corresponds to the dB value of swr. This relationship is also plotted in **fig. 4**.

If an swr indicator is not available, or if the signal generator is *unmodulated*, connect the equipment as shown in **fig. 5**, leaving the load initially disconnected. Then proceed as follows:

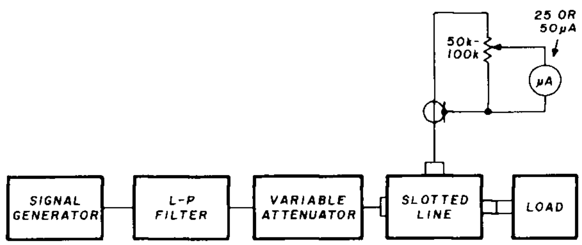


fig. 5. Equipment set-up for measuring swr, using a micro-ammeter for an indicator. The signal generator does not have to be modulated in this arrangement.

1. Set the meter potentiometer to about mid-range and the variable attenuator to provide at least 6 dB of attenuation.

2. Adjust the probe depth and probe tuning for a reading on the meter, readjusting the meter pot if necessary.

3. Adjust the carriage position for maximum meter reading and retune the probe circuit for maximum. If two peaks are obtained as the probe circuit is tuned, use that peak which results in the higher current.

4. Connect the load to the slotted line.

5. Move the carriage along the line again to obtain maximum current.

6. Readjust the probe depth and tuning so that, with the meter pot set for maximum sensitivity, the meter current does not exceed 50 microamperes.

7. Move the carriage to obtain minimum current and note the meter reading.

8. Reset the carriage for maximum current, and increase the setting of the variable attenuator until the current is the same as that recorded in **step 7**.

9. The swr, in dB, is equal to the variable attenuator setting minus the setting used in **step 1**. Swr in dB can be converted to swr by the following expression, or from the curve of **fig. 4**.

$$swr = antilog\ \frac{swr\ in\ dB}{20}$$

measuring swr greater than 10:1

It is extremely unlikely that any amateur will be interested in *accurate* readings if the swr of the device under test is greater than 10:1. The techniques for making such measurements are explained in detail in references 2 and 3, and do not warrant coverage here.

The load impedance on a transmission line can be calculated from a knowledge of the swr present on the line and the position of a voltage minimum with respect to the load. Although this seems complicated, the physical measurements using a slotted line are quite simple. Other than the equipment required to measure swr, a precision (low-inductance) shorting termination is needed.

The measurement procedures involve the precise location of adjacent voltage minima along the line. When the swr is low, the exact location of a minimum is difficult to establish because the minimum-voltage region is quite broad. Improved accuracy in locating the minimum may be achieved by averaging the carriage positions which provide equal voltages on each side of the voltage minimum, as follows.

1. Mentally establish a convenient reference which is approximately the mid-point between the maximum and minimum readings obtained on the swr indicator (or on the microammeter, if the attenuator method of swr measurement is used).

2. Move the carriage to one side of the minimum until the reference level is obtained on the indicating device. Note the carriage position in millimeters on the slotted-line scale.

3. Repeat **step 2**, moving the carriage to the other side of the minimum.

4. Average the positions obtained in **steps 2** and **3** by adding the two position readings and dividing by two. This is the position of minimum voltage.

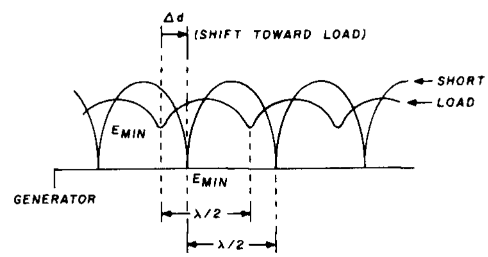


fig. 6. Standing-wave patterns on a slotted line with a capacitive load and with a shorting termination. Courtesy Hewlett-Packard Company.

The following procedures are used to measure the impedance of any load connected to the slotted line.

1. Measure and record the swr of the load, using any of the methods described previously.

2. Note the exact carriage positions in millimeters (from the scale) for two adjacent voltage minima. Record the difference between the two positions, which is equal to λ/2, as shown in **fig. 6**. Also record the position of one of the minima.

3. Replace the load with a precision short.

4. Move the carriage to find a new minimum which is closest to the one recorded in **step 2**.

5. Record the shift, Δd, between the positions recorded in **steps 2** and **4** and note whether the shift is toward the generator or the load.

6. Calculate the electrical length, θ, in degrees, of Δd from the following expression

$$\theta = \frac{180(\Delta d)}{\lambda/2}$$

If the minimum shifted toward the load in **step 5**, θ is considered positive; if the minimum shifted toward the generator, θ is considered negative.

7. Determine the impedance from the following equation (where Z_o equals 50 ohms, the characteristic impedance of the system,

$$Z = Z_o \left[\frac{1 - j(swr)(\tan\theta)}{(swr) - j(\tan\theta)}\right]$$

or by means of a Smith chart, as explained below.

determining impedance from a Smith chart

Solving the equation in **step 7** above involves several rectangular-to-polar and inverse conversions, and is tedious, even with a scientific calculator which incorporates those conversion functions. Fortunately, the ubiquitous Smith chart provides a quick and simple solution to the problem. After proceeding through **steps 1** through **6** under impedance measurements, continue as follows:

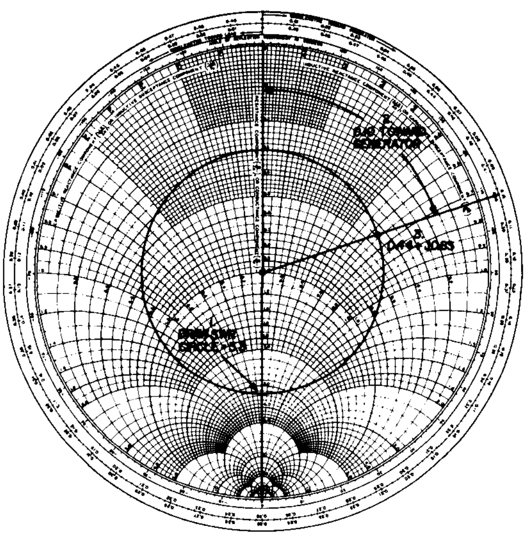


fig. 7. Example of determining impedance by use of a Smith chart. Courtesy Hewlett-Packard Company.

1. Convert Δd to wavelength ($\Delta\lambda$) by means of the expression

$$\Delta\lambda = \frac{\Delta d}{\lambda}$$

where λ is twice the value of $\lambda/2$ recorded in **step 2** of the impedance measurement procedures.

2. Draw a circle, on the Smith chart, whose center is at the origin (1.0) and whose radius is equal to the measured swr.

3. Along the periphery of the Smith chart, mark a point equal to $\Delta\lambda$, the shift in wavelength, either toward the generator or toward the load, as applicable.

4. Draw a radius line from the origin to the point established in **step 3**.

5. Read the normalized impedance at the intersection of the radius line and the swr circle.

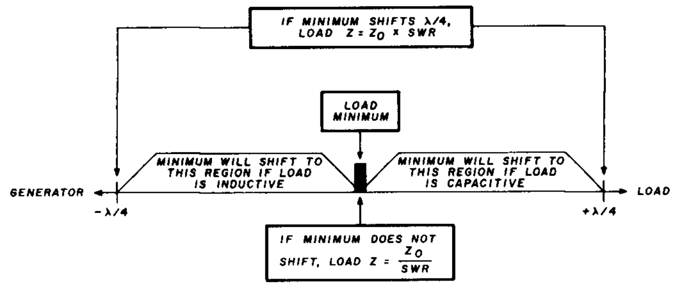


fig. 8. Summary of rules for impedance measurements. Courtesy Hewlett-Packard Company.

6. Multiply the normalized impedance by Z_o (50 ohms) to convert to the actual impedance.

As an example, assume the following values were obtained by measurement:

swr = 3.3
$\lambda/2$ = 150 mm, with one minimum at 220 mm
Δd = 30 mm, toward generator

a. Calculate $\Delta\lambda$

$$\Delta\lambda = \frac{\Delta d}{\lambda} = \frac{30}{2(150)} = 0.10\lambda$$

b. Draw an swr circle with a radius equal to 3.3, as shown in **fig. 7**.

c. Draw a radius line for a shift of 0.10λ toward the generator.

d. **Fig. 7** shows the radius line and circle intersecting at $0.44 + j0.63$, which is the normalized series impedance of the load.

e. Multiply the normalized impedance by 50, giving the actual impedance as $22 + j31.5$ ohms.

rules of thumb for impedance measurements

Some rules of thumb that are helpful when making slotted-line measurements are:*

a. The shift in the minimum when the load is shorted is never more than ± one-quarter wavelength.

b. If shorting the load causes the minimum to move toward the load, the load impedance has a capacitive component.

c. If shorting the load causes the minimum to shift toward the generator, the load impedance has an inductive component.

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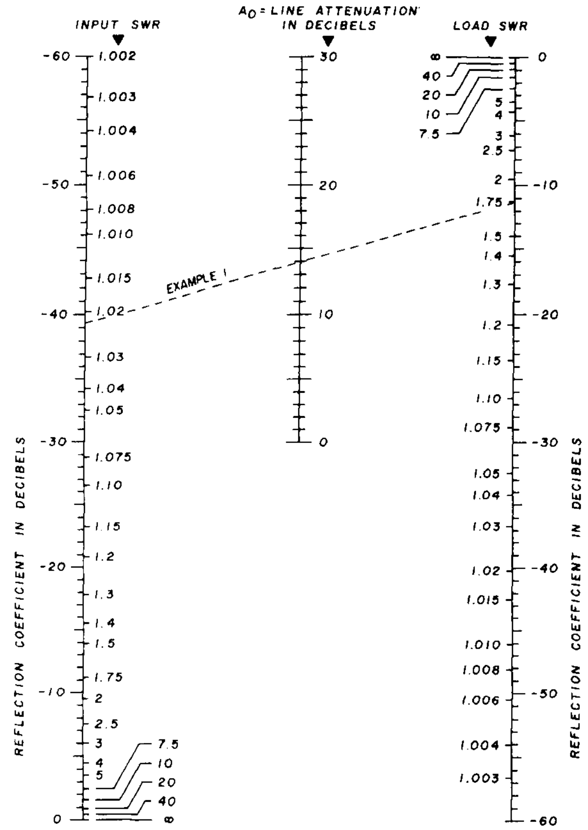


fig. 9. Line attenuation for low input standing-wave ratios. Reprinted from reference 4 by permission of Howard W. Sams & Co., Inc.

d. If shorting the load does not cause the minimum to move, the load impedance is completely resistive and has a value of Z_o/swr.

e. If shorting the load causes the minimum to shift exactly one-quarter wavelength, the load impedance is completely resistive and has a value of $Z_o \times swr$.

f. When the load is shorted, the minimum will always be a multiple of a half wavelength from the load.

These rules are summarized in **fig. 8**.

measuring transmission-line loss

Although the loss in a transmission line can be measured by means of an swr indicator and rf detector, as explained in reference 1, that technique requires that both ends of the line be accessible. This can be inconvenient, especially if the transmission line is connected to an antenna, and you want to find out whether the coax you put up five years ago is still good. Of course you could measure the power between the transmitter and the line, and then measure it between the line and the antenna, but this too has disadvantages (proper impedance terminations, carrying equipment to the roof or up the tower, a second person to energize the transmitter, and so on).

Let's consider how the loss can be measured with a slotted line. We know that the swr, measured at any point along a lossless transmission line, will be uniform and will depend *only* on the load impedance presented to the line. We also know that if the transmission line is lossy, the swr at the input end will appear to be better than that which is actually present at the load end. In fact, if the line is lossy enough, it will look like a pure resistance (equal to its characteristic impedance) at the input end, regardless of the terminating impedance.

Knowing these facts, it stands to reason that if the load impedance or swr is known, and the input swr can be measured, we should be able to calculate the transmission-line loss. The only problem would appear to be that of terminating the line in a known load — an antenna does not qualify — until we realize that a short is a known load with an infinite swr. Theoretically, an open circuit also presents an infinite swr, except that any connections or leads at the open end will bring the swr down.

Thus, the first step is to disconnect any existing load from the transmission line and connect a short in its place. Ideally, this should be a precision shorting termination if there is a connector at the load end of the line. If not, use a short, wide strap between the inner and outer conductors in order to minimize the inductance.

Then measure the swr at the input end of the transmission line. Obivously it should be measured at the frequency of interest because loss increases with frequency. Knowing the input swr and the load swr (∞), the line attenuation can be determined from either **fig. 9** or **fig. 10**. Those nomographs may be used for any known load; for the special case where the load swr is

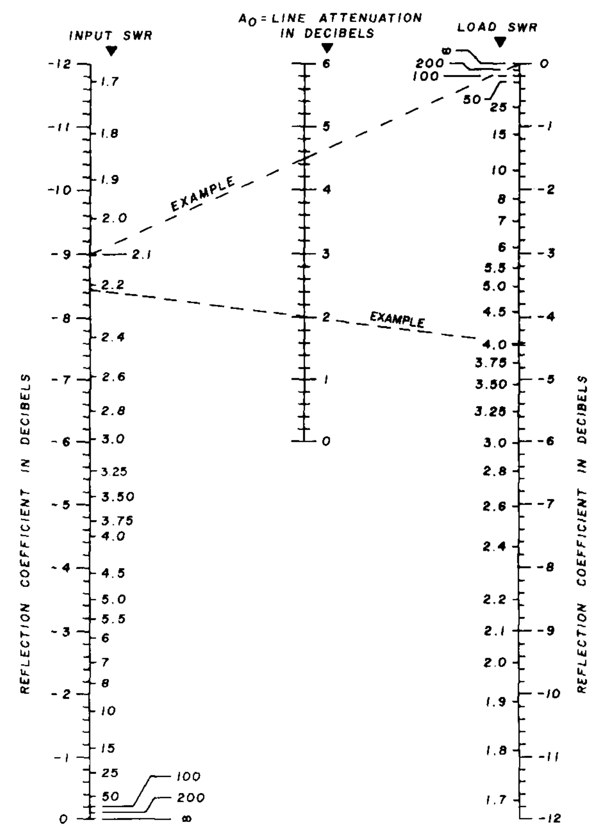
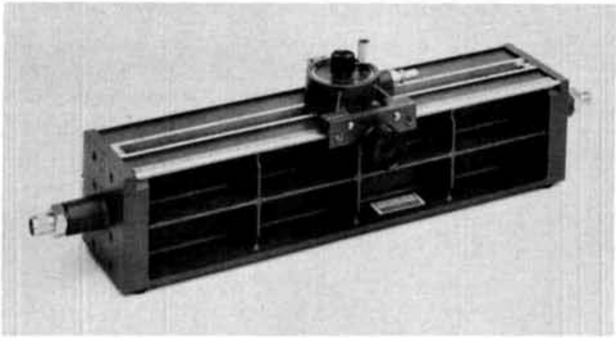


fig. 10. Line attenuation for high input standing-wave ratios. Reprinted from reference 4 by permission of Howard W. Sams & Co., Inc.



The Hewlett-Packard Model 805C Slotted Line utilizes slab-line construction. Photo courtesy Hewlett-Packard Company.

infinite, the following expression will also yield the attenuation, A_o, in dB:

$$A_o = 10\ log\ \frac{swr_{in} + 1}{swr_{in} - 1}$$

As an example, let's assume that you are feeding your two-meter antenna with 60 feet (18.3 meters) of RG-8A/U coaxial cable. The cable attenuation specifications, which have been plotted in **fig. 11**, indicate that the nominal attenuation of 100 feet (30.5 meters) should be approximately 2.3 dB at 144 MHz. However, we cannot normally use a slotted line at 144 MHz, so we must measure the loss at a higher frequency and assume that the measured loss can be translated to 144 MHz.

If we make the swr measurement at 400 MHz, the attenuation of 100 feet (30.5 meters) of RG-8A/U should be nominally 4.1 dB. Since we are concerned with the loss in only 60 feet (18.3 meters), the loss of that length should be about 2.46 dB at 400 MHz and 1.38 dB at 144 MHz.

Continuing with our example, assume that the swr measured at the input end of the coax is 2.1:1 when the load end is shorted. Going to the nomographs, it can be seen that the input swr is read more easily on **fig. 10**. Placing a straight-edge between the input swr of 2.1:1 and the load swr of ∞, we find that it intersects the line attenuation scale at about 4.5 dB.

Since the measured attenuation is more than 2 dB greater than what should be expected at 400 MHz, we can make a worst-case assumption that the coax has seen better days and should be replaced. If you are interested in knowing the actual loss at 144 MHz, it can be extrapolated from the curves of **fig. 11** graphically, as follows.*

1. Convert the measured loss to attenuation per 100 feet (30.5 meters). Since we measured a loss of 4.5 dB for 60 feet (18.3 meters) this becomes $4.5(100/60)$, or 7.5 dB per 100 feet (30.5 meters).

*The extrapolation is based on the following approximations holding true over a *limited* frequency range: (1) the attenuation-vs-frequency characteristic is linear when plotted on log-log coordinates and (2) the attenuation-vs-frequency curve for cable having degraded characteristics varies in the same manner as that for new cable.

2. Using a scale or a pair of dividers, determine the distance between the appropriate curve and the attenuation per 100 feet (30.5 meters) calculated in **step 1**; this is shown as dimension L in **fig. 11**.

3. Lay off dimension L' equal to L, above the curve at 144 MHz; read the actual attenuation. In our case, it is approximately 4.35 per 100 feet (30.5 meters).

4. Determine the loss for the length of transmission line used. For 60 feet (18.3 meters), the loss is approximately 2.6 dB. Since the nominal loss for that length of line is only 1.38 dB, it can be seen that the line has aged sufficiently to cause an additional loss of more than 1.2 dB. Under the most favorable conditions, with a perfect match between the antenna and the coax, only 55 percent of the transmitter output power will reach the antenna, as compared to 72 percent for new line.

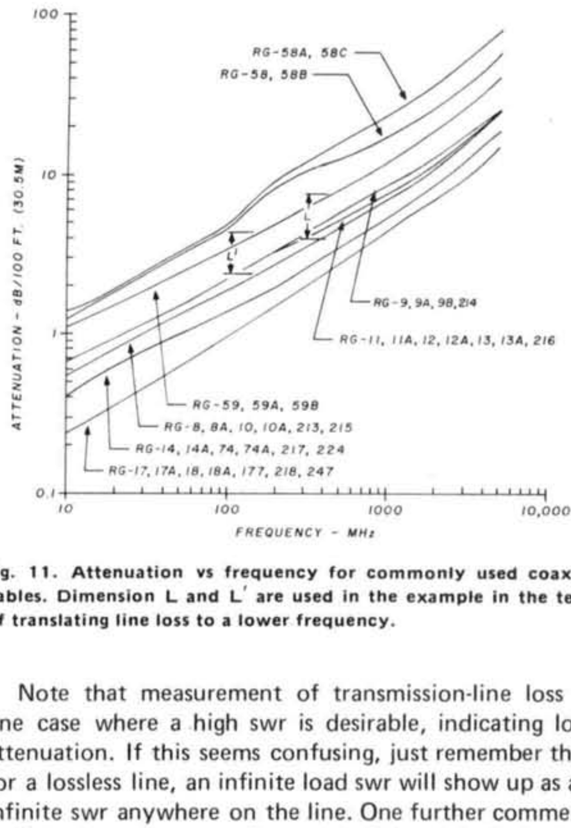


fig. 11. Attenuation vs frequency for commonly used coaxial cables. Dimension L and L' are used in the example in the text of translating line loss to a lower frequency.

Note that measurement of transmission-line loss is one case where a high swr is desirable, indicating low attenuation. If this seems confusing, just remember that for a lossless line, an infinite load swr will show up as an infinite swr anywhere on the line. One further comment – if the input swr actually reads infinity, it is likely that you have a transmission line which is open near the input connector, rather than a lossless line.

references

1. Robert S. Stein, W6NBI, "Using the SWR Indicator," *ham radio*, January, 1977, page 66.
2. *Instruction Manual, Type 874-LBB Slotted Line*, GenRad, West Concord, Massachusetts.
3. *Operating and Service Manual, 805C/D Slotted Line*, Hewlett-Packard Company, Palo Alto, California.
4. *Reference Data for Radio Engineers*, 6th Edition, Howard W. Sams & Co., Inc., Indianapolis, Indiana, Chapter 24, figures 5 and 6.

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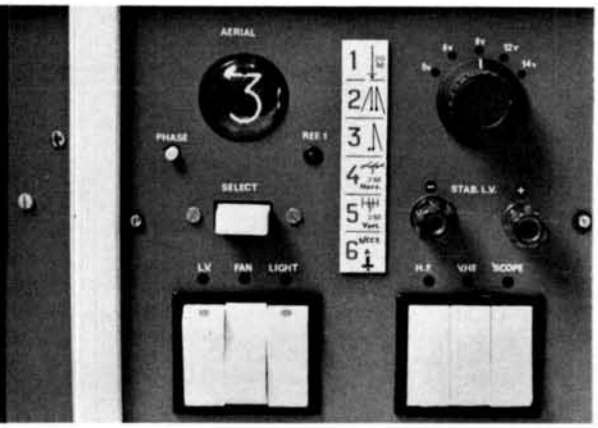

remote switching multiband antennas

Simple remote switching of amateur antennas using surplus components

This article describes a system for remote switching of multiband amateur antennas covering 2 through 10 meters. The antennas include a ten-element 2-meter beam, an inverted-V for 10-80 meters, and a ½-wave vertical for 20 meters.

The distance between my station and the antenna mast is 130 feet (40m). Adding this distance to the height of my antennas makes for a rather long transmission line. While the description of my switching setup centers around an open-wire line, coax cable could also be used, as explained later.

system description

A single open-wire line with ½-inch (12.5mm) spacing was constructed using hard-drawn wire with polyethylene spacers located at 9-inch (230mm) intervals along the line. Near the base of the antenna mast a cast metal box measuring 6 inches (153mm) square by 3 inches (77mm) deep houses the switching circuits between the common transmission line and the antennas (**fig. 1**).

Switching is accomplished by a surplus Ledex rotary solenoid, which is connected to ceramic switch wafers that provide a 2-pole, 11-position arrangement. The circuit is wired to provide two 6-position repeat programs since the Ledex solenoid steps only one way (**fig. 2**).

A slave Ledex solenoid is used in the station to minimize the number of control wires to the switch box and to obtain a positive remote readout of switch position. To ensure synchronization between master and slave, an "indicate at position 1" line is brought into the station in addition to the two lines for energizing the Ledex coils, making three wires in all. If you wish to run an additional five wires to the station, the slave Ledex may be eliminated.

The long length of control wire to actuate the Ledex solenoid introduces a voltage drop, so power to the Ledex coil is taken from a capacitor that is charged through a resistor then discharged through the Ledex coil by a pushbutton switch. Actuating the pushbutton switch about once per second allows the capacitor to recharge; if you need more energy to work the Ledex, either voltage or capacitance must be increased. This

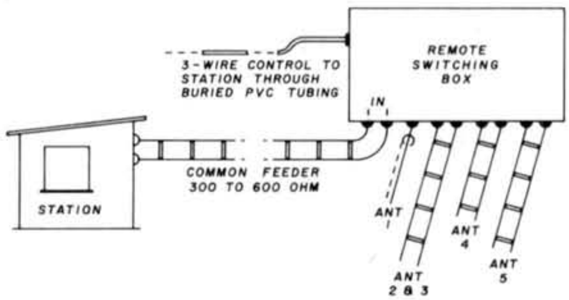

fig. 1. Arrangement of common transmission line and remote switching terminal between amateur station and antennas.

pulse method ensures that any Ledex coil can be used from 6 through 48 volts.

display

To indicate which antenna is in use I use a nixie tube whose numerals are selected by the slave Ledex. A legend is affixed to the panel to show the antenna for each number selected.

The two Ledex solenoids can get out of phase because of an incomplete closure of the select button.

By Maurice Allenden, G3LTZ, 3, Westhill Close, Highworth, Swindon, Wilts., England

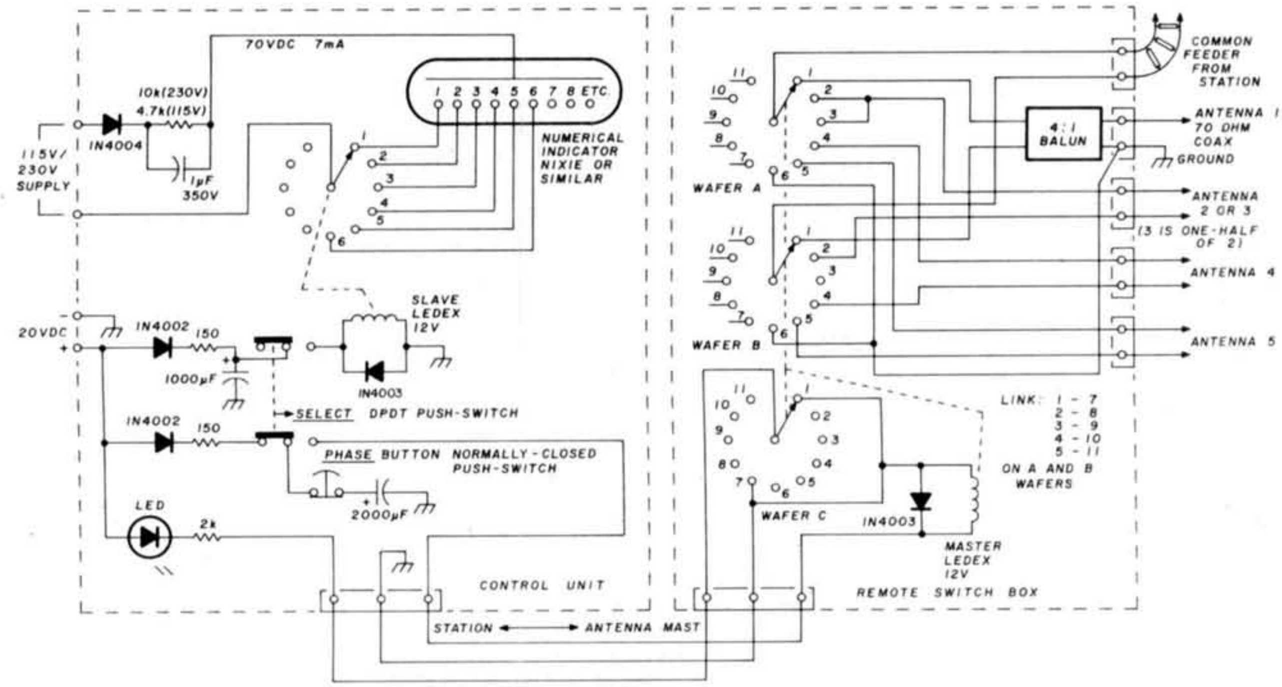

fig. 2. Schematic of the remote antenna switching system. Master and slave Ledex solenoids are used between amateur station and antenna-mast base to minimize number of control wires. NIXIE feature shows selected antenna.

To correct this, one control wire from the master Ledex illuminates an LED (ref. 1 in **fig. 2**) each time antenna 1 is selected. If any discrepancy exists, pressing the **phase button** disconnects the master Ledex while the slave is pulsed to read position 1 also.

construction

The remote-control box is a surplus item. It has a terminal block on one side with feedthrough tabs. The Ledex solenoid is mounted on an aluminum bracket (see photo). Wiring is with polyethylene hookup wire. A 4:1 balun converts the open-wire line impedance (about 300 ohms) to about 70 ohms to feed the half-wave vertical antenna for 20 meters.

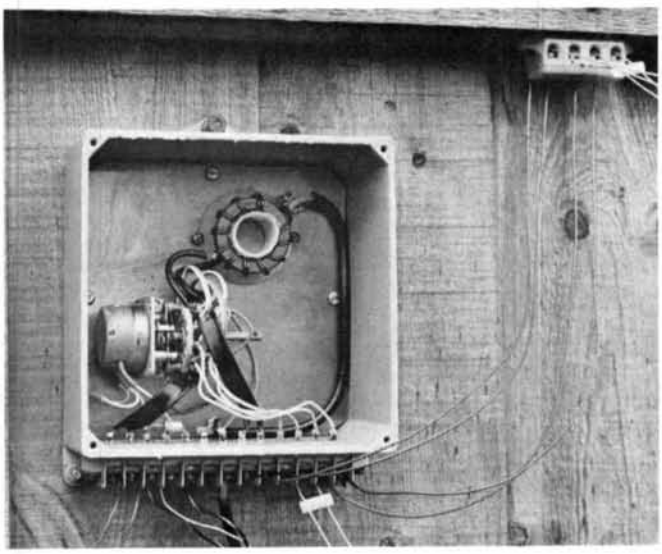

fig. 3. Remote switch box with cover removed. Ledex stepping solenoid is shown at lower left, balun transformer at upper right. Main terminal block is shown at bottom left.

Wiring isn't critical, but the remote box must be weather tight. I sealed all holes and box edges with silicon rubber sealant – the type used around bathtubs and sinks, which is obtainable from most hardware stores. A small amount of silica gel was included in the remote box before sealing.

performance

The system described here has been in constant use for more than 7 years. Weather in England is not noted for its low humidity, but I've had no corrosion problems within the switchbox. I use the open-wire line as a tuned feeder for 10-80 meters and as a flat line for 2 and 20 meters, so the switch wafers are large (1½ inch, or 38mm). If a high-power linear amplifier is used with a tuned transmission line, contact spacing on the switch could be increased by removing alternate contacts. Using a Yaesu FT101 transmitter and tuned lines, I've experienced no problems with this system.

While open-wire line has been emphasized, coaxial cable can be used if resonant antennas are used. The low impedance and low standing-wave ratio of such antennas could be handled easily by the ceramic-switch sections. If long transmission lines are used, a good economic argument exists for the remote switching system described here.

acknowledgement

My thanks to Bob Weston for the photos that illustrate this article.

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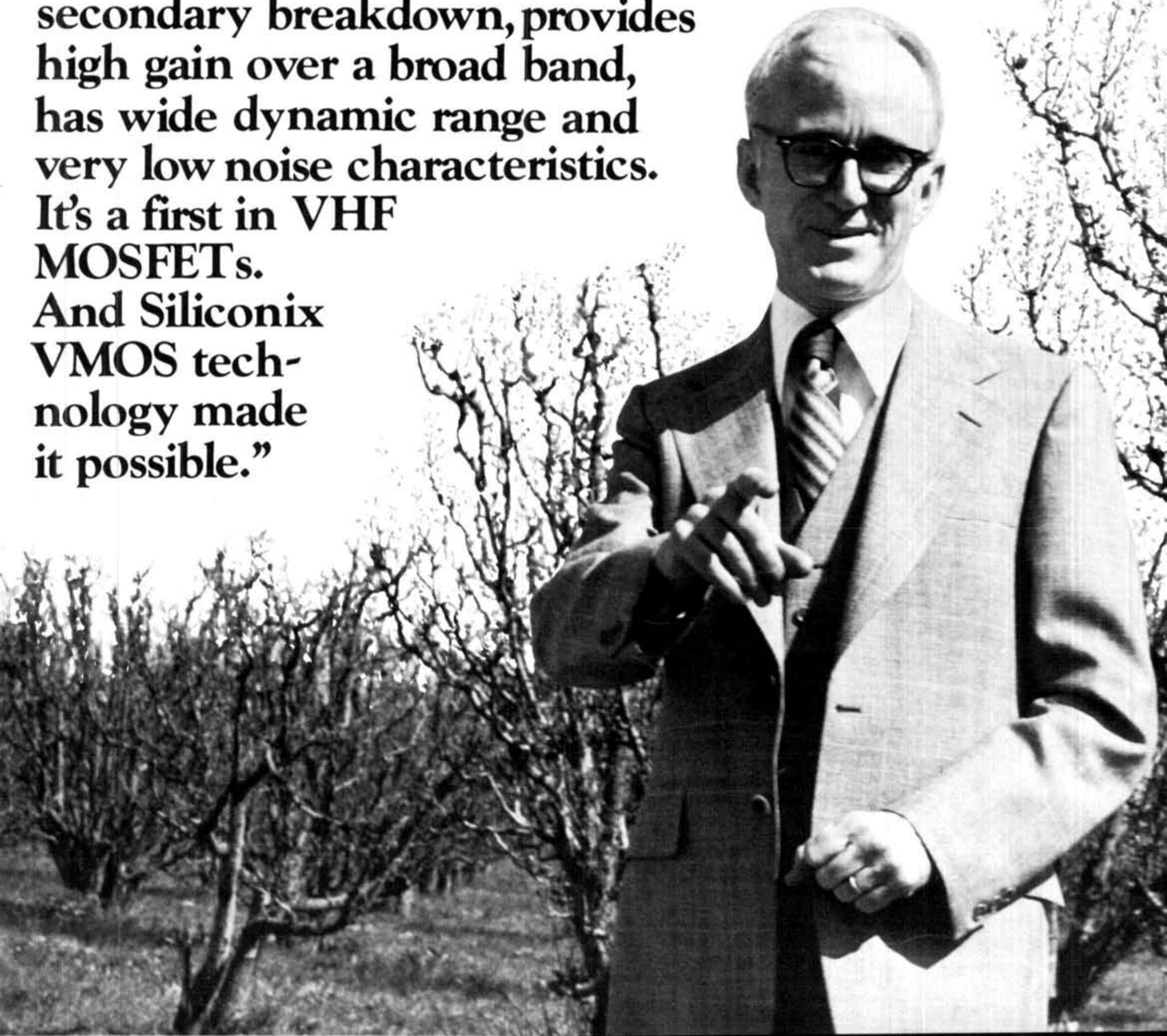

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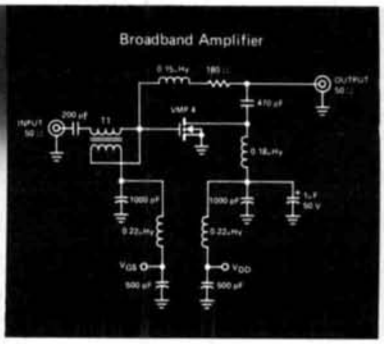

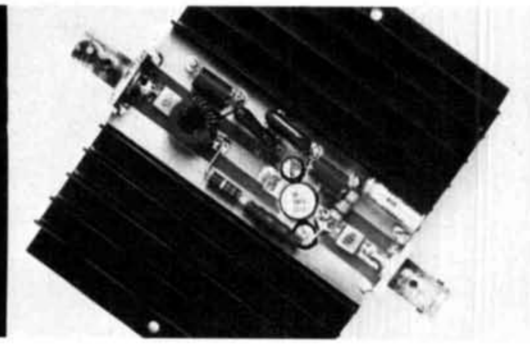

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the gin pole:

a simple lever for raising masts

An easy method for erecting antenna masts using readily available materials

The gin pole is a great help in raising masts. You'll find little information in the amateur radio handbooks on the use of gin poles, so in this article I've included techniques on the proper use of this simple lever to get your antenna mast off the ground and into a position where it will do some good. Information is presented on forces you can expect when using the gin pole, on rigging accessories, and on the correct way to proceed when working with the materials involved.

the mast

A typical example is as follows. The mast butt is to be placed on the ground (or perhaps buried into the ground). If the mast is heavy, certain procedures are in order. Willing helpers can raise the mast to, say 10 feet (3m) or so above ground, then a support, such as a stepladder, can be placed under the mast. The situation is shown in **fig. 1**. A line secured to the point where the mast is supported by the ladder and extended in the direction you want the mast to rise can be used to hoist the mast into place, but this situation also causes some problems.

Assume the mast base is to be located at point X in **fig. 1**; the ladder support touches the mast at a point 25 feet (7.6m) from its base, the ladder is 10 feet (3m) high, and 100 pounds (45 kg) of weight rests on the ladder. Also assume the line is 200 feet (50m) long and attached to a tractor (or a team of helpers). A force of about 256 pounds (1139 newtons) should start the mast rising. Considering the coefficient of friction between tractor (or willing helpers) and ground surface, considerable more than this force would be required, since the force would have to be exerted nearly horizontally.

At the same time, a force of about 279 pounds (1241 newtons) acts to compress the mast between point X and the point where the line is secured. Unless the mast is blocked against movement toward the pulling force, the mast will probably be pulled off the support. To keep the mast at rest until the lift starts and to keep it from swaying later, it's best to have guy wires already attached, with helpers holding the wires to keep the mast steady.

If the mast has been properly blocked, but the mast is flexible, you may suffer the agonies shown in **fig. 2** depending on where the line is secured to the mast. This effect is called buckling and the unhappy result is that the mast will suffer a permanent kink, or you'll hear a loud snap. Buckling is the most common cause of failure of long, thin masts. The answer: use a gin pole.

gin pole number 1

There seem to be as many kinds of gin poles as people who have heard the term, and there seem to be even more ways to use them. The *ARRL Antenna Book*[1] isn't particularly helpful, and I can name at least 20 dictionaries, encyclopedias and technical handbooks (including the *Bluejacket's Manual*) that never mention the word. One reference[2] on gin poles and ropes I've found may be available only in trade school and public libraries.

All this variety means that perhaps we'd better talk

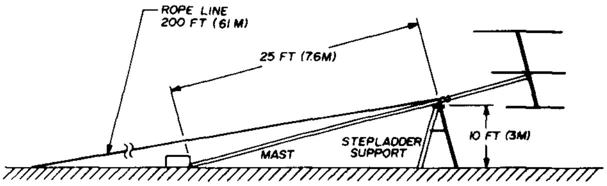


fig. 1. A typical problem — a mast is to be erected at point X. The mast is temporarily propped with a stepladder or other support. Rope is secured to the mast as shown and extended in the direction to which the mast is to rise. Forces involved can be tremendous and the mast may buckle.

By David T. Geiser, WA2ANU, RD 2, Box 787, Snowden Hill Road, New Hartford, New York 13413

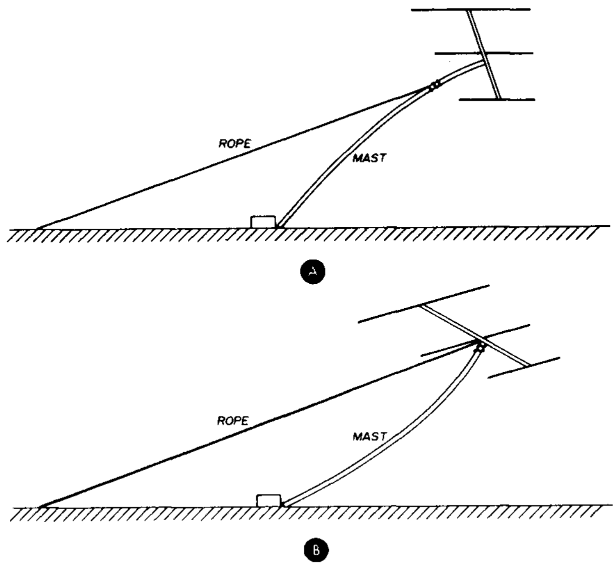


fig. 2. The buckling problem. In sketch (A) a single rope is secured above the mast balance point, which allows the mast to sag, as does a single rope secured to the top of the mast (B). In either case the mast may buckle.

about a few of the more successful kinds of gin poles so you can adapt the material you have to the job when it's time for the antenna-raising party.

Rossnagel[2] credits the American Standards Association with defining a gin pole as shown in **fig. 3**. (In Rossnagel's text, both weight to be lifted and pulling forces were directly below the pulley, or block). If we take the previous example but use a 20-foot-long (6.1m) gin pole located at the mast butt (point X), the required vertical force on the line would be 250 pounds (1112 newtons). The backstay would have to support 324 pounds (146 kg) and the gin pole 579 pounds (251 kg), assuming a 45-degree angle for the backstay. As the mast rises more than 53 degrees from horizontal, other people pulling on the mast guys (in the direction of the backstay) would have more effect than people pulling the gin pole line; however, the possibility of buckling still exists. Buckling would be less if one line went to our previous intermediate attachment point on the mast and another to the top of the mast. Pulling two lines at different speeds through the same block at the same time is a little like trying to pass someone when you're both going down the same playground slide. However, the two lines could be run through different blocks at the same point. (Another solution would be to run the two lines over a U-shaped bracket mounted on top of the gin pole; but the friction – and therefore needed pull – would be increased tremendously and the possibility still exists of the lines interfering with each other.

Before discussing other varieties of gin poles, something must be said about ropes and working with ropes. Rope is convenient, but the character of rope and the forces involved are dangerous to careless people.

A new Manila rope of ½ inch (12.5mm) diameter has a breaking strength of over 2600 pounds (1179kg). However, the safe working load for such rope[2] is only 265 pounds (116 kg). Such a rope would be marginal for the direct pull in the example of **fig. 1** and the mast line of **fig. 3**. Its use as a backstay in **fig. 3** would result in an overload. Doubling the rope is acceptable if both halves can be made to take the same stress. A rope should be used at about 10 per cent of its breaking strength (**table 1**).

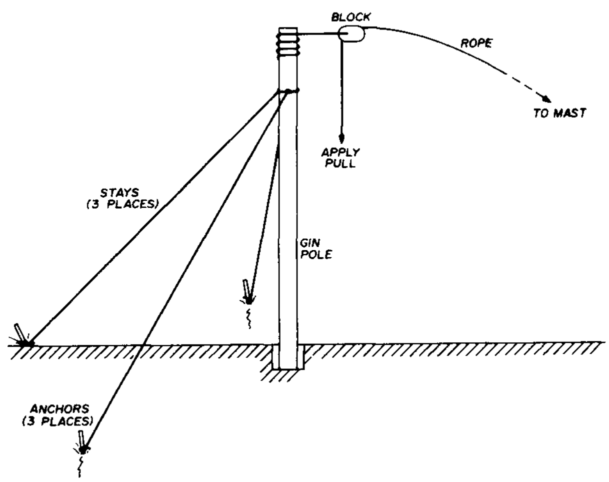
Ropes that are old, rotted, kinked, wet, or frozen should be distrusted. (A wet rope or a wet splice is strong, but a wet rope kinks.) The old rules of the sailor apply: never step across a rope, never step inside a rope loop, and never wrap a rope around your hand or arm unless you want the rope to pull you. Always use heavy gloves when working with rope lines; old ropes; particularly used ones, can produce nasty burns.

table 1. Safe working loads for Manila rope (from reference 2). Data is based on no. 1 Manila rope, 3 strands, with a safety factor of 10.

diameter		working load	
inches	(mm)	pounds	(kg)
0.375	(9.5)	135	(61)
0.5	(12.5)	265	(120)
0.625	(16.0)	440	(200)
0.75	(19.0)	540	(245)
0.875	(22.0)	770	(349)
1.0	(25.5)	900	(408)

gin pole number 2

By now it should be apparent that the gin pole is shorter than the mast. The gin pole should be 1/3 to 1/2 the height of the mast. There is an advantage (but not an



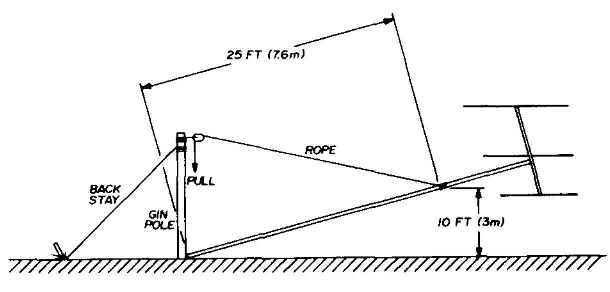


fig. 3. Gin pole no. 1: a fully guyed gin pole whose butt is located at the butt of the mast to be raised.

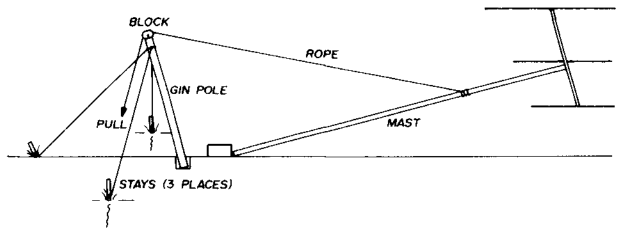


fig. 4. Gin pole no. 2: a fully guyed gin pole located some distance from the mast.

overriding one) in having the gin pole as high as the balance point on the mast.

In the first discussion it was assumed that the mast butt rested on the ground when the ladder support was used. If the support had been too close to the mast butt, the butt would have swung into the air, and the top of the mast would have crashed to earth. It's important that the gin-pole rope be fastened to a free mast *above* the balance point. This is what I meant when I said the butt end of the mast was supposed to be against the ground.

If the mast butt end is hinged to a heavy weight (such

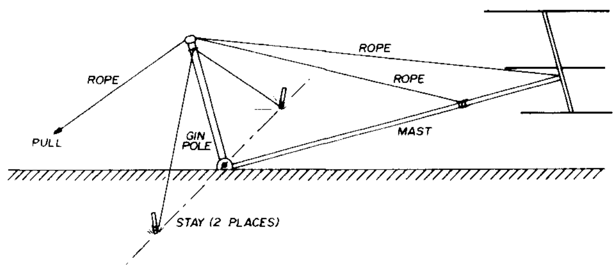


fig. 5. Gin pole no. 3: a swinging gin pole with mast and pull ropes secured at the gin-pole top. Gin pole swings vertically. Side sway is prevented with guys or stays.

as a foundation for the mast), the gin-pole rope line may be attached to (or even slightly below) the balance point, although I wouldn't consider that a very good idea. If the mast is of uniform cross section and the mast carries no extra load on top, the balance point is in the center. **Table 2** shows how the balance point moves on the mast as n changes. (n is the ratio of mast to top load, such as an antenna and rotator.) Thus if the mast weighs 4 times as much as the antenna and rotator, the balance point would be 60 per cent of the mast height. If the mast butt is larger than the top (and of the same general type of construction), the balance point would tend to be lower.

In the discussion of gin pole no. 1, pulling the rope is less effective when the mast rises to more than a certain angle. The reason is that the gin-pole rope tends to pull the mast down toward the gin pole rather than up into the air. This effect will be reduced if the gin-pole top is tilted somewhat away from the mast and the gin-pole butt likewise is moved back from the mast butt (**fig. 4**). The change of gin-pole position makes the first part of the mast raising harder but the last part easier. It does not cure the possibility of buckling, however.

While it's apparent that it's desirable to tie gin-pole ropes both at the top and slightly above the mast balance point, it may not be obvious what would be lifted by a single rope at each point in turn. On a perfectly stiff and uniform mast, a rope at the top would

table 2. Ratio of mast weight to top-load weight as a function of balance-point location of mast height.

mast weight / top-load weight (n)	balance point location (% of mast height)
0.5	83.4
1	75.0
2	66.7
3	62.5
4	60.0
5	58.3
6	57.1
7	56.3
8	55.6
9	55.0
10	54.5

have to lift the top load and half of the mast weight. A rope at the balance point would lift the total weight of top load and mast. Thus the rope at the top may be considered to make up for the flexibility of the mast.

gin pole number 3

The swinging gin pole (**fig. 5**) has its bottom end pinned very close to the mast butt so that the top can swing downward as the rope is pulled. If the pull rope and two mast ropes are tied to the top of the gin pole, the mast will rise as the top of the gin pole is pulled down. The pulls at the top and slightly above the mast balance point will remain in good proportion so long as the mast butt is blocked so that the mast butt can move no further in the direction of the gin pole. (The ideal condition is when the mast butt and the gin-pole butt rotate around the same pin.) If the angle of the gin pole to the mast is 90 degrees (or a little less), the mast becomes vertical as the gin pole approaches the horizontal.

Note that the gin pole needs side strays anchored in line with the pin. This helps the gin pole to remain in a vertical plane. If the gin pole is narrow in the direction of the plane of movement, several sets of side stays along its height may help the gin pole bear much heavier loads.

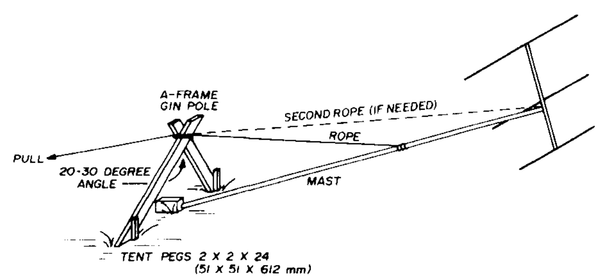


fig. 6. Gin pole no. 4: A-frame swinging gin pole. The spread legs provide help against side sway and allow mast and gin-pole butts to line up. Tent pegs are used to butt mast and gin-pole assembly.

Remember this as in the other procedures: helpers prevent *mast* sidesway by controlling the mast guy wires.

This technique is somewhat idealized as it isn't easy to use a single pin for mast and gin pole, and the forces on the pin can be fierce. (Since both butts can't be in the same place at the same time, the pin is subjected to bending as well as shear.)

gin pole number 4

My preference (because of a short mast, heavy rotator, and heavy beam antenna) is the A-frame swinging gin pole of **fig. 6**. Here, two pieces of 2x4-inch (5x10cm) lumber are pinned together with a bolt, and the bottom ends of the pieces are spread into a 20 to 30 degree X. The rope is tied in the manner shown in **fig. 7**.

The A-frame legs are blocked with 2x2 inch (5x5cm) tent pegs. The tent pegs are driven into the ground in line with the pin on the hinged mast. The mast butt is likewise blocked. Each butt (mast and A-frame) should be in line with, and at right angles to, the plane of the gin pole and mast movement.

Using the swinging gin poles, the longer the pull rope (within reason), the easier will be the job of rasing the mast. From experience I recommend that the pull-rope length, from the gin pole to helpers, be two or three times the length of the gin pole. If a tractor (or an auto) is available to do the pulling, there's an advantage in having more rope length because of the better traction.

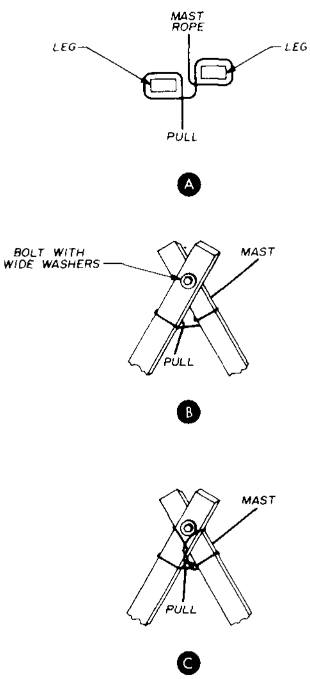


fig. 7. Rope ties at A-frame cross. Basic method is shown in (A) and (B). Rig at (C) is preferred to minimize slipping and bind the joint.

An auto (or any other conveniently located anchor) is more useful standing still if a long rope is available. The auto need only be moved to a location where the rope is snug. Then the pulling crew can raise the antenna by walking toward the antenna while pressing down on the rope (**fig. 8**). This procedure can bend or pull off an auto bumper, so it's best to anchor the pull rope to the auto frame.

This "walking-in" procedure is necessary at some time when raising a mast with any swinging gin pole. If the angle between gin pole and pull rope becomes more than 90 degrees, some of the pull force will tend to lift the gin-pole butt from its pivot. The last few degrees of swing should be easy while pulling down on the rope – perhaps *too* easy! The weight of a heavy gin pole, without any pulling during the last few degrees of swing, may be enough to swing the mast to the vertical position and beyond. As the mast approaches the vertical, helpers on the mast guys away from the gin pole should keep their guys under tension so that the mast won't get out of control.

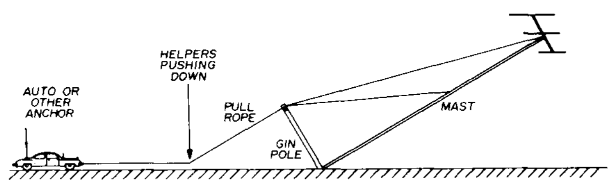


fig. 8. The "walking-up" procedure. With pull rope tight and anchored, the pulling crew walks toward the gin pole, pushing down on the pull rope. As the mast rises, crew pulls rope during the last few feet of rise (see text).

gin pole strength

A 20-foot (6.1m) length of 2x4 inch (5x10cm) lumber isn't very strong. A finished 20-foot (6.1m) length of 4x4 inch (10x10cm) lumber will safely bear about five times the load of a finished piece of 2x4 inch (5x10cm) lumber. The larger the pole, in thickness and width, the more load it will bear. It doesn't do much good to increase one dimension of the gin pole without increasing the other, although sometimes (as with the side stays discussed for gin-pole no. 3) lateral guys will help on the narrow side.

removing the ropes

When the mast is erect, the strain can be taken off the ropes and the gin pole can be removed. If the mast can be climbed, a helper can remove the ropes (don't forget the safety belt and its proper use). I prefer to use a heavy knob at the lift points while the mast is on the ground and use a doubled rope line from the gin pole to the lift points and looped over the knob. Thus the rope doesn't have to be tied to the pole. With two ends of the rope loose at the gin pole, one loose end is merely pulled over the knob, and the rope is down.

references

1. *The ARRL Antenna Book*, 1st edition, 1939, page 117, or 11th edition, page 259, ARRL, Newington, Connecticut.
2. W. E. Rossnagel, *Handbook of Rigging*, 1st edition, McGraw-Hill, New York, 1950.

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using a programmable calculator to design your own phased array

How to use the hand-held programmable calculator to compute the radiation pattern of phased vertical arrays

Did you ever see those antenna pattern diagrams for an array of vertical antennas? Kraus[1] and Jasik[2] have them, and they can be found in a lot of the books the broadcast engineers have on directive arrays. Usually the books show a group of polar plots depicting what happens to the pattern when you vary the spacing and phasing of the elements. But it's not too often that they'll tell you what happens when you change the amplitudes of the element currents or lay the elements out in anything other than in a straight line. Smith's book is a noteworthy exception.[3]

You say the geometry of your back yard forces you to position your elements like a convoluted *kolbassi* sausage, and the way you want to lay your elements out doesn't look like anything in the books? How can you predict the antenna pattern? Discussed here is a little program for the HP-25 Programmable Calculator.

the technique

A number of years ago an article appeared in the *IEEE Transactions on Broadcasting* showing how to compute broadcast array patterns when the individual towers were fed with arbitrary amplitudes and phases and were arbitrarily located in space.[4] It looked like a nice way to go if you knew FORTRAN and had an IBM 360/65 computer lying around. Now, with the advent of programmable pocket calculators, you too can crank out phased array antenna patterns – and from the comfort of your own hamshack.

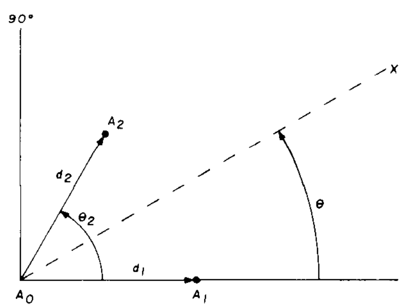

fig. 1. Element positions for an antenna array, showing the terms used in the formula for calculating the radiation pattern. A_0 is the reference element.

Suppose you lay out the elements as shown in **fig. 1**, choosing A_0 as the reference element (with current amplitude I_0 and phase $0°$). The magnitude and phase of the currents in antennas A_1 and A_2 will be specified as $K_1 I_0 \angle \alpha_1$ and $K_2 I_0 \angle \alpha_2$ where the K and α values are

By Jim Corum, K1AON, Box 213B, Route 6, Morgantown, West Virginia 26505

HP-25 Program Form

Title: PHASED ARRAYS

Switch to PRGM mode, press [f] [PRGM], then key in the program.

Display Line	Display Code	Key Entry	X	Y	Z	T	Comments
00							FIX 3 display
01	2306	STO 6					
02	2401	RCL 1					
03	41	-					
04	1405	f Cos					
05	2401	RCL 1					
06	1501	gFRAC					
07	2407	RCL 7					
08	61	x					
09	61	x					
10	2400	RCL 0					
11	41	-					
12	2400	RCL 0					
13	1501	gFRAC					
14	1409	f →R					
15	5104	STO+4					
16	21	x⇆y					
17	5105	STO+5					
18	2406	RCL 6					
19	2403	RCL 3					
20	41	-					
21	1405	f Cos					
22	2403	RCL 3					
23	1501	gFRAC					
24	2407	RCL 7					
25	61	x					
26	61	x					
27	2402	RCL 2					
28	41	-					
29	2402	RCL 2					
30	1501	gFRAC					
31	1409	f→ R					
32	5104	STO+4					
33	21	x⇆y					
34	5105	STO+5					
35	74	R/S					Stop
36	2406	RCL 6					
37	1302	GTO 02					
38	2405	RCL 5					
39	2404	RCL 4					
40	1509	g→ P					
41	2407	RCL 7					
42	61	x					
43	1409	f→ R					
44	01	1					
45	51	+					
46	1509	g→ P	P(θ)	Phase			
47	00	0	0	P(θ)			
48	2304	STO 4	0	P(θ)			R4 Cleared
49	2305	STO 5	0	P(θ)			R5 Cleared

Registers	
R0	$\alpha_1 \cdot K_1$
R1	$\theta_1 \cdot \beta d_1$
R2	$\alpha_2 \cdot K_2$
R3	$\theta_2 \cdot \beta d_2$
R4	Used (cleared)
R5	Used (cleared)
R6	θ
R7	1000

HP-25 Program Form

Title: PHASED ARRAYS   Page ___ of ___

Programmer ___

Step	Instructions	Input Data/Units	Keys				Output Data/Units
1	Load Program						
2	Switch to RUN						
	and store element						
	information	$\alpha_1 \cdot K_1$	STO	0			
		$\theta_1 \cdot \beta d_1$	STO	1			
		$\alpha_2 \cdot K_2$	STO	2			
		$\theta_2 \cdot \beta d_2$	STO	3			
3	Store normalizing						
	constant	1000	STO	7			
4	Enter angle at						
	which P(θ) is to						
	be evaluated	θ	f	PRGM	R/S		Partial Sum
5	If N≤3 Continue	N≤	GTO	3	8	R/S	0
	(If N>3 go to						
	step 7)						
6	Roll Down*		R↓				|P(θ)|
7a	If N>3 store						
	element information						
	on next 2 elements	$\alpha_3 \cdot K_3$	STO	0			
		$\theta_3 \cdot \beta d_3$	STO	1			
		$\alpha_4 \cdot K_4$	STO	2			
		$\theta_4 \cdot \beta d_4$	STO	3			
7b	Repeat		R/S				Partial Sum
8	Continue		GTO	3	8	R/S	0
9	Roll Down*		R↓				|P(θ)|
*	Now repeat Step 4						
	at the next value						
	of θ						

table 1. HP-25 program for calculating the radiation pattern of phased arrays. Examples for its use are given in the text.

the amplitudes and phases relative to the reference element. The antenna pattern is calculated from the phasor sum

$$P(\theta) = \left| 1 + \sum_{n=1}^{N-1} K'_n \, e^{j\psi n} \right| \qquad (1)$$

where

$P(\theta)$ = the antenna pattern as a function of θ

K'_n = the relative amplitude of the n[th] element

N = the total number of elements in the array

$\psi n = \beta d_n \cos(\theta_n - \theta) - \alpha_n$

α_n = the phase of the n[th] element relative to the reference element in degrees (+ for lagging phase, – for loading phase)

βd_n = the electrical distance (in degrees) from the driven element to the n[th] element

θ_n = the spatial angle between $A_0 A_1$ line and A_n

Because of the format which must be used with the smaller programmable calculators, **eq. 1** is modified to the form

$$P(\theta) = \left| 1 + 1000 \sum_{n=1}^{N-1} K_n \, e^{j\psi n} \right| \qquad (2)$$

where $K_n = \dfrac{K'_n}{1000}$. This may look like double talk, but it makes the program fit into the 49 steps available in the HP-25.*

The program is loaded into the memory by keying in the strokes listed in the Program Form, **table 1**. Next you've got to put your element data into the memory registers. We're going to put in the phase and amplitude information as a decimal number of the form $\alpha_n \cdot K_n$ (with α_n positive). We'll also store the element position in the form $\theta_n \cdot \beta d_n$. Punch in a θ and we're ready to go. Not yet clear? Well, let's try an example.

Suppose you want to find the pattern for the array in **fig. 2**. Load in the program. Element 1 (A_1) has current $5I_o$ with phase $-180°$. Consequently $K_1 = 5/1000$ and we'll store the number $\alpha_1 \cdot K_1 = 180.005$ in register 0. Element 1 is along the reference axis so that $\theta_1 = 0°$, and it's spaced out $\lambda/3$ so that $\beta d_1 = (2\pi/\lambda)\,(\lambda/3) = 120°$. Therefore, store the number $\theta_1 \cdot \beta d_1 = 0.120$ in register 1 of the calculator. Next, we'll take care of element 2 (A_2). It's current is $2I_o \angle -90°$ so $\alpha_2 \cdot K_2 = 90.002$ is stored in register 2. Finally, $\theta_2 \cdot \beta d_2 = 45.180$ is stored in register 3. (Don't forget to put 1000 in register 7). Now you're ready to run. If you have an HP-25, preset the calculator at the program start. Let's find the value of the antenna pattern at 0° and then work our way around in 5° increments. Plug in zero, press R/S, and watch the display blink away. This program will stop at **step 36** to see if you want to compute a pattern for more than three elements (more on this in the next example). Since we're looking at a 3-element array, press GTO 38 R/S.* When the program

*Though it may not be immediately obvious, the K_n values are stored as fractional parts, thereby effectively doubling the memory capacity of the HP-25. This results in some skew in the calculated antenna patterns, but represent only a small percentage error. **Editor**

*If you are working with three elements or less, you can save computational time by deleting **steps 35, 36,** and **37** from the HP-25 program, and add stack rolldown (R↓) and GTO 01 at the end of the program. This will provide direct readout of the answer without the intermediate operation as **step 36**. **Editor**

stops you're at **step 49** and the display reads 0. Now rolldown the stack and read the magnitude of the field pattern at 0° *[P(0°) = 5.984]*. Now plug in the next value of θ, say 5°. If you repeat in 5° increments and plot on polar graph paper, you should get the pattern shown in **fig. 3**.

five-element array

Next, let's calculate the pattern of an antenna with five elements. For simplicity, assume one of the arrangements you can look up in a book. Kraus provides an example on page 94 of *Antennas*: an array of five sources spaced $\lambda/2$ apart along a line. All elements are fed in phase but the relative magnitudes of the separate currents are 1, 4, 6, 4, 1, respectively (this is called a binomial array). Load the data:

$$a_1 \cdot K_1 = 0.004 \text{ (Register 0)}$$
$$\theta_1 \cdot \beta d_1 = 0.180 \text{ (Register 1)}$$
$$\alpha_2 \cdot K_2 = 0.006 \text{ (Register 2)}$$
$$\theta_2 \cdot \beta d_2 = 0.360 \text{ (Register 3)}$$

(We're using the same normalizing constant.) Plug in $\theta = 0°$ and start the program. The display stops blinking with a partial sum displayed. Since $N > 3$, go to **step 7a** of the procedure (**table 1**) and load the last two elements:

$$\alpha_3 \cdot K_3 = 0.004 \text{ (Register 0)}$$
$$\theta_3 \cdot \beta d_3 = 0.540 \text{ (Register 1)}$$
$$\alpha_4 \cdot K_4 = 0.001 \text{ (Register 2)}$$
$$\theta_4 \cdot \beta d_4 = 0.720 \text{ (Register 3)}$$

Press R/S. When the display stops blinking, you've got a partial sum on all five elements. Now press GTO 38 R/S. When the lights stop, you should have 0.000 across the display. Now roll down the stack, and read off the value, $P(0°) = 0.00008727 \approx 0$. Repeat the process in 5° increments and you should get the pattern of **fig. 4**. This sure beats using a slide rule! If you're not convinced, take these 5 elements, lay them out at random and calculate the array pattern.

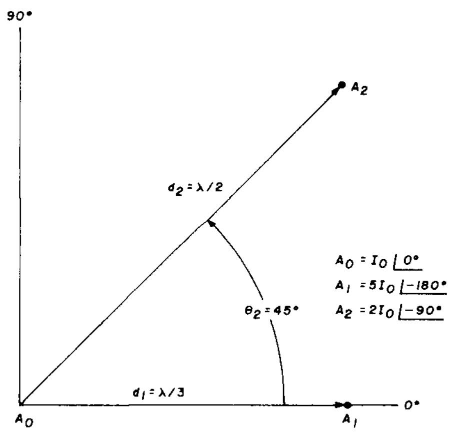

fig. 2. Three-element antenna array used as an example in the text. Radiation pattern of this array is plotted in fig. 3.

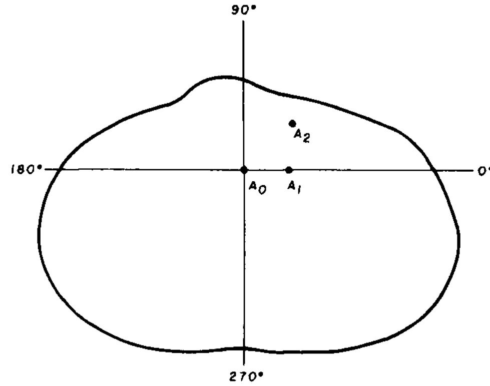

fig. 3. Radiation pattern for a 3-element array shown in fig. 2.

You can use this same program for an array as large as you like — just keep repeating **steps 7a** and **7b** (life would be simpler if there were four more registers on the HP-25).* By the way, you can get more accuracy by letting the normalizing constant be a million. Then $R_7 = 1{,}000{,}000$; $K_n = K'_n \times 10^{-6}$; and $R_1 = \theta_1 \cdot (\beta d_1 \times 10^{-6})$.

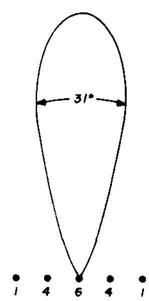

fig. 4. Radiation pattern for a 5-element binomial array calculated with an HP-25 programmable calculator. Only the upper half of the pattern is shown.

Remember that this gives the array pattern when the elements are fed with the *specified* amplitudes and phases. Actually, getting these on the antenna farm is no simple trick — even for two elements it can be non-trivial (see W1CF's article in *QST*)[5] and you may need some cute matching networks.

A special thanks to Bazile Pinzone of stations WCLG and WELW for several antenna sessions at the kitchen table.

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3. Carl E. Smith, *Directional Antennas*, Cleveland Institute of Radio Electronics, Cleveland, Ohio, 1946.
4. E. D. Alton and L. G. Groe, "A Computer Calculation of the Far Field Radiation Pattern of an Antenna Array", *IEEE Transactions on Broadcasting*, March, 1970, pages 8-20.
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* The new HP-67 and HP-97 programmable calculators have sufficient storage for up to 12 elements. **Editor**

all-band bobtail curtain array

In addition to its effectiveness as a DX antenna, the bobtail curtain serves as a useful all-band antenna

By Bill Wildenhein, W8YFB, 41230 Butternut Ridge, Elyria, Ohio 44035

The problem of antenna height restrictions is not new to amateurs. Though, having to keep them virtually below surrounding ground can be frustrating. First the State took most of my high ground for a highway and then the FAA imposed an antenna height restriction. The tops of my new antennas varied from a point only level with surrounding terrain to about 15 feet (4.6m) above the ground level. After trying to find an effective antenna to overcome the problem, I surely felt that signals that originate in the valley, tend to stay in the valley.

My next thought was to build an antenna with enough gain to overcome the losses due to my location. Previous work with a bobtail curtain indicated it would be an effective antenna, particularly since the high current points occur at the top of the array. At the same time, the thought occurred to split the center leg into an open-wire section. The antenna could then

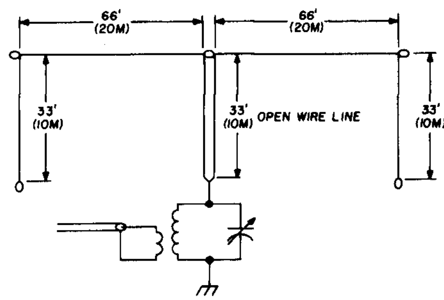


fig. 1. Layout of the all-band bobtail curtain array. The center leg has been split into an open-wire line providing a feed system for 80, 20, 15, and 10 meters. A normal bobtail curtain is one wavelength long on the top portion, with the vertical legs being one-quarter wavelength. The normal feed is through a single wire.

be fed on other bands, as a symmetrical center-fed antenna. On 80 meters, the current points would again be at the top of the array. The result is shown in **fig. 1.** I was happy to find that on 40 meters it performed exceptionally well to Australia with the temporary

25-watt rig in use. The quoted gain of 7 to 10 dB for this antenna is realistic – primarily for DX stations. For ragchewing around the United States, it is less effective. effective.

On 80 meters the tuner was wired as in **fig. 2**, with the antenna current distrubution shown in **fig. 3**. Signal reports Stateside, again, tend to be lower than reports, for instance, from the Carribean. Not enough time has been available to thoroughly investigate its properties on 80 meters.

On 160 meters the bobtail can be fed the same as on 80 and tuning will be relatively non-critical, but, the radiation angle will be higher. As a local ragchew antenna it would be quite adequate. Instead, I decided to try it working against a radial ground system. Since the resonant frequency was approximately 1.6 MHz, the antenna was "shortened" as shown in **fig. 4** with about 1300 pF series capacitance. The only drawback with this arrangement is that the antenna becomes quite narrowband, requiring resetting of the series capacitor if the frequency is changed more than about 25 kHz. Radiation resistance is only 15 ohms, but this can be transformed to 60 ohms with a wideband 4:1 transformer. In my case, I used a 2-inch (5cm) diameter toroid bifilar wound with 22 turns and then connected as a 2:1 autotransformer. Using a home-made impedance bridge, the transformer looks essentially "flat". With the series capacitor resonated, the input side of the transformer measures 60 ohms. **Fig. 5** is a schematic of the complete tuner, while **fig. 6** shows the normal patching arrangement for 40 meters.

Although I hardly felt a 20 meter setup would be worthwhile, I arranged the tuner for 20 meters by dis-

The complete tuning unit is installed inside of the paint pail. A tight fit prevented damage during a recent flood. The 160-meter radials are secured to the vertical support pipe by a hose clamp.

connecting the 90 pF mica shunt capacitors and used the 40 meter tap on the link coil. This configuration of the bobtail begins to exhibit a pattern similar to a center-fed longwire, but also seems to produce unusually high angle lobes that may be due to interaction from the vertical ends. Since the characteristics may be partly due to the site, I would hesitate to make any definite claims regarding the various lobes, but feel it is

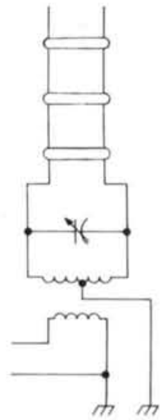


fig. 2. A single-band bobtail curtain can be fed across a parallel-tuned circuit, since the input is a high impedance. To provide a balanced feed, for bands other than 40 meters, a split secondary was used on the inductor.

a worthwhile addition – even if only as a secondary antenna. One unusual advantage at this location is the hillside to the south of the antenna effectively shields the antenna. When static from southern thunderstorms becomes severe, this antenna discriminates against the noise and provides solid contacts when the comparison antenna mounted on high ground is useless.

Since my transmitter does not cover 15 or 10 meters, it was not possible to run more than comparative listening tests. Indications are that the antenna begins to behave as a long wire on these bands, with lobes more closely aligned to the plane of the top portion. Tuning and loading were checked by using a temporary network configured the same as 80 meters, a crystal-controlled source, and a few measurements with an impedance bridge.

The antenna tuning is not critical on all bands from 80 to 10 meters. If the tuner is set for 3.6 MHz, swr does not exceed 1.5:1 over the range 3.5 to 3.8 MHz. If tuned to the center of 40 meters, the swr remains within 1.4:1 across the entire band. The higher bands follow the same pattern. With a 2-inch (5cm) graduated dial on the tuning capacitor, I can accurately preset the antenna coupler on all bands without resorting to on-the-air tuning. Thus, it is possible to have an antenna that is a solid performer on 40, but useful on all other bands with a minimum of extra effort. If 160 meter operation is not intended, no extensive ground system is necessary. A 10-foot (3m) length of pipe can be driven into the ground to act as a ground as well as to support the network. In my case, a stainless hose clamp secures the 160 meter radials to the pipe.

The network cover is a discarded plastic paint pail. The plywood disc was carefully fitted into the paint pail forming a skirt to guard the patch board from rain. This care in fitting paid off when an unexpected flood covered the tuner. As soon as the river was low enough, I examined the tuner and found very little

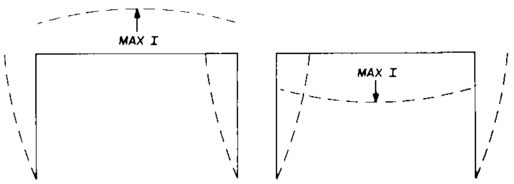


fig. 3. Current distribution when the modified bobtail curtain is used on 80 meters.

leakage, — only a soaked coax line. The patch board is made from a piece of plexiglass obtained as scrap. Since the input end of the feed line is a high-voltage point, this precaution is advisable. For the same reason, it is wise to "child-proof" the feed system and also the ends of the antenna. The aluminum tab

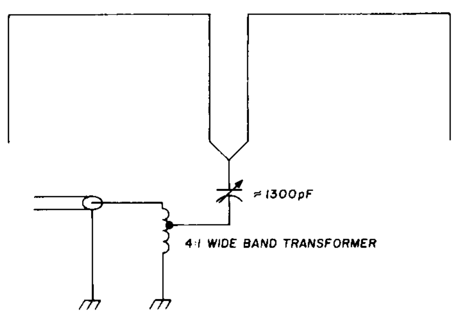


fig. 4. Method of feeding the bobtail curtain on 160 meters. Instead of using the balanced feeders, the antenna can be fed against a system of ground radials.

extending down from the lower edge of the plywood disc and a similar one at the rear are drilled and tapped to receive wing bolts that secure the paint pail to the disc.

As can be seen, most of the components were from a military surplus TU-5 or TU-6 tuning unit. Plate spacing is adequate for about 200 watts. As a rough guide to selection of capacitors, assuming 5000-ohm feed impedance, the following may be helpful:

watts output	volts p-p	plate spacing
50	1500	0.04 inches (1mm)
100	2000	0.05 inches (1.3mm)
250	3000	0.07 inches (1.8mm)
500	4500	0.125 inches (3.8mm)
1000	6500	0.225 inches (6mm)

The following hints from an inveterate antenna tinker may help reduce the costs and make construction easier. Before you spend money on expensive wire, visit your nearest farm supply. Copperweld electric fence wire is cheap, light, and very strong. If you purists are turning up your noses, consider this: rf penetrates to a depth commonly given by:

$$depth = \frac{2.63 \times 10^{-3}}{\sqrt{F(MHz)}} \text{ inches or } \frac{6.68 \times 10^{-3}}{\sqrt{F(MHz)}} \text{ cm}$$

Hence, at 2 MHz, penetration is only 1.8 mils (.05mm) and becomes progressively less as frequency increases. We are then, no longer concerned with the usual cross sectional area, but more nearly with the circumference of the wire.

wire size	circumference	radius
18 AWG (1mm)	0.126 inches (3.2mm)	0.020 inches (0.5mm)
12 AWG (2.1mm)	0.253 inches (6.4mm)	0.040 inches (1mm)
10 AWG (2.6mm)	0.320 inches (8mm)	0.051 inches (1.3mm)

The copper coating extends to a depth of typically 10 per cent of the radius. Using this fact, no. 18 AWG (1mm) would be sufficient down to 2 MHz. Thus, two strands of no. 18 AWG (1mm) are equivalent to no. 12 AWG (2.1mm) and three strands become no. 10 AWG (2.6mm).

In its basic form Copperweld is very springy, snags and kinks easily, and is difficult to twist into strands unless you use a little common sense. First, have your tools ready at the place where they will be used. A pair of trees, posts, or other supports, located the proper distance apart, will hold the wire during preparation for stranding. Be aware of the fact that when these wires are twisted you will find the group becomes several feet shorter. Fasten the end of the wire to one tree or support. Use a dowel or rod through the spool to prevent further twisting of the wire as you pay off the wire. Walk with the spool to the other tree or post, around it, and back to the start. Keep tension on the spool at all times. Your electric drill should be ready to go, with a husky hook already

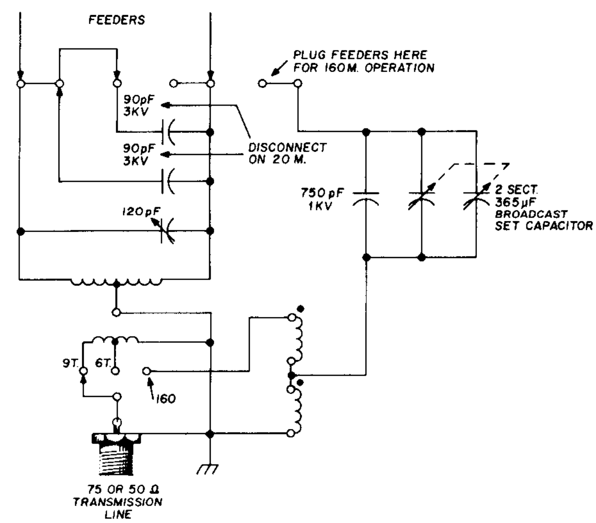


fig. 5. Schematic diagram of the complete tuner that will permit a 40-meter bobtail curtain to be used on all bands. The feedline is plugged into the appropriate jacks for each band. The coil is 2 inches (5cm) in diameter with 17 turns (center tapped) wound to be 3 inches (7.6cm) long. The link for the input is 1-3/8 inches (3.5cm) in diameter centered inside the secondary. It should be 3/4 inch (2cm) long and wound with no. 16 AWG (1.3mm) wire. The capacitors across the coils must have adequate plate spacing to prevent arcing.

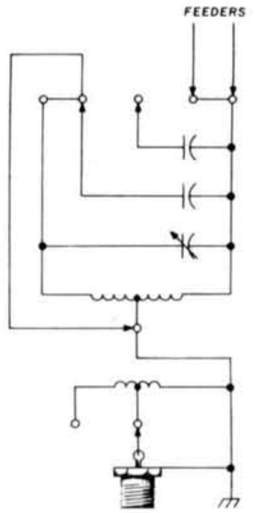
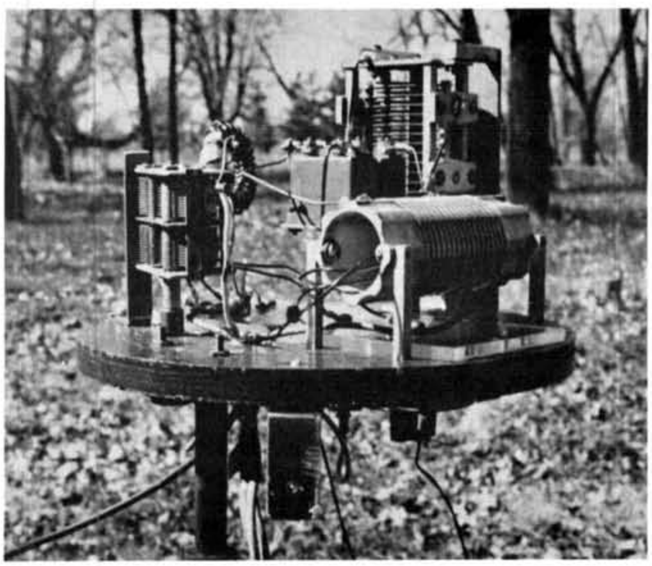


fig. 6. Patching the tuner for 40-meter operation.

in the chuck, and your cutters handy. Grasp all the strands securely and cut them free from the post. Secure the strands to the hook in the chuck. Firmly hold the drill, keeping tension on the strands to prevent them from tangling in the grass as the drill twists them. After they are twisted, and the drill shut off, you will notice the chuck rotating backwards. This is fair warning that you have made a dandy spring. If let go now, you and your lawn will be consumed by a whirling dervish, resulting in a very unhappy mess. So grasp the hook with one hand and release the chuck with the other. The added leverage from the hook will allow you to let the excess twist unwind in a controlled manner. At all times keep that wire under tension! When the wire is unwound you will have the pleasant surprise of seeing a docile, nail-straight length



Most of the components for the tuner were obtained from surplus TU tuning units. A dial on the bottom permits setting the capacitors for the different bands. The metal bracket on the bottom is used to hold the pail securely.

of wire, with no tendency to spiral or become unmanageable.

With two lengths of wire completed, you can prefab the entire antenna as shown in **fig. 7**. Before raising the antenna, give it a heavy coating of an acrylic spray. The best way is to make a spray guard out of tin metal stock as shown in **fig. 8**. Without a guard you get a light, uneven coating, and you need several cans of clear spray to do the job. The spray guard is hooked around the wire so that the rear of the guard rides on the wire. Let the wire dry thoroughly before putting the antenna up.

If you haven't priced feeder spreaders lately, get ready for a shock! However, they can be made very easily from scrap plexiglass. If just rough sawn to size, they will accumulate dirt rapidly and may arc in wet weather. I found the easiest way is to file them smooth with a sharp file, removing all saw marks. Then play the flame of a Bernzomatic torch over them. The

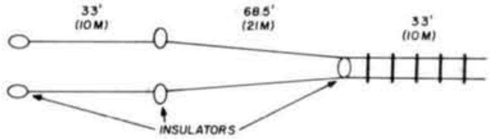


fig. 7. The entire antenna can be fabricated by installing the insulators and spreaders with the wires suspended a short distance above the ground. This will allow the feeders to hang straight.

torch will melt just the surface, leaving them glass-smooth. For powers to about 200 watts, 2 inch (5cm) feeder spacing is adequate, with spreaders spaced a foot apart. For higher power I would recommend 6 inch (15cm) spacing of feeders, and 18 inches (46cm) between spreaders. I use solid no. 22 AWG (0.6mm) wire to strap the spreaders in place and then secure these wraps to the feeders with a drop of solder. (Obviously, before spraying the wires with the acrylic spray.) By assembling the system under tension between posts or supports, the open-wire line section can be accurately made so it will hang straight.

If the array is supported between trees, you don't want the feeders bumping the ground during high winds, so your best investment is a good quality, free running pulley at one end, and an adequate counterweight. My 40 meter model, with two strands of wire, rides very steady using one half of a cement block for weight. The far end of the antenna is secured to a 55-foot (17m) tall locust tree that is about 8 inches (20cm) in diameter at the base. During high winds the point where the antenna attaches to the tree has a total swing of 8 to 10 feet (2.5-3m), yet the antenna rides very well. For inexpensive halyards on such lightweight antennas, Sears' heavy duty plastic clothesline (without the steel core) is very usable.

If you haven't worked with plastic materials, you may feel that drilling is no problem. A twist drill with a conventional grind does have a tendency to grab as it breaks through the far side. If you use too much feed pressure it will practically screw through to the far side.

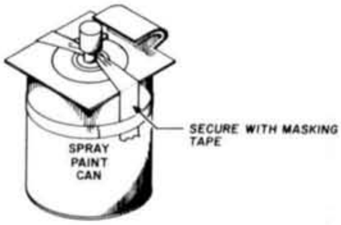


fig. 8. The guard for the spray can is fabricated from light metal stock. By using the guard, the spray will cover the wire and not dissipate in the air.

Your drill press may suddenly sport a propellor. In many cases the plastic piece will shatter or crack. An even worse hazard is present in a piece that has been squared up with a sander. The sander imparts an edge like a fine toothed saw. Let that spin on a drill press and you get an ugly slash. So break the corners and edges with a file. To prevent the drill from grabbing, modify the drill point with a brass grind. **Fig. 9** shows a conventional point, a point modified with a brass grind and the simple way to obtain the brass grind. This grind produces clean holes

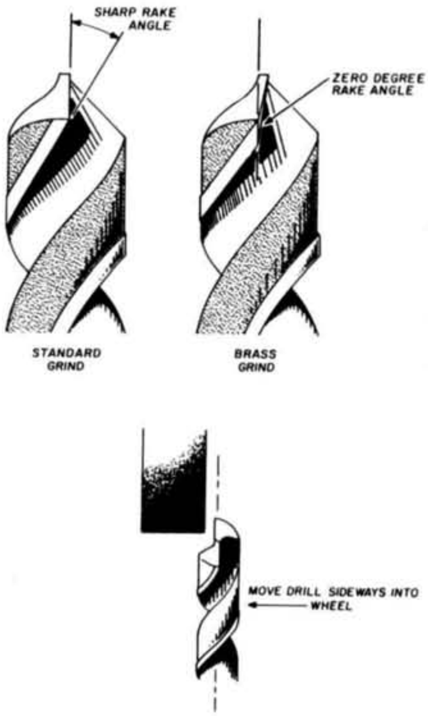


fig. 9. Normal drills can be converted to a brass grind by changing the rake angle at the tip. This alleviates problems with cracking and chipping when drilling plastics.

with far less tendency to grab unless you feed too heavily or don't retract the drill to clear chips on thicker pieces.

In conclusion, this antenna has at least gotten me back in the running! If you need a cheap, all-band antenna that can be hung from fairly low supports, is inobtrusive, and gives excellent performance for 40 meter DX, this could be one solution.

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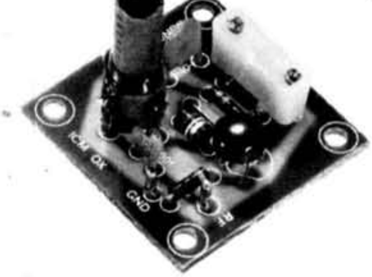

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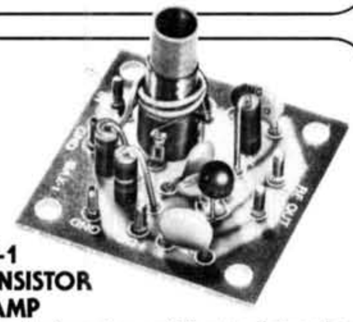

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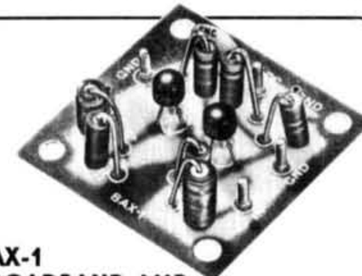

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146.40	147.39
146.43	147.60
146.61	147.63
146.64	147.66
146.67	147.69
146.70	147.72
146.73	147.75
146.76	147.78
146.79	147.81
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146.85	147.87
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the ham notebook

converting a low-band mobile antenna for two-meters

If you are a low-band mobile operator, and would like to give two meters a try without investing in a new antenna or replacing the old one, you might like to try my solution to the problem. I can

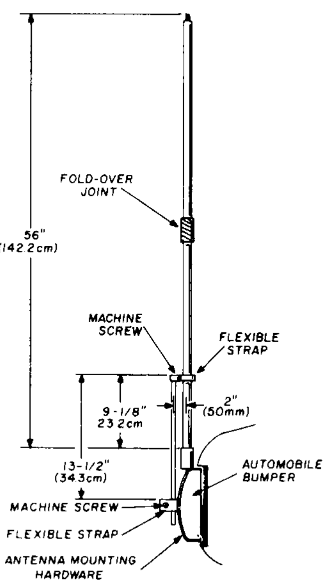

fig. 1. Illustrates simple modification of a low-band mobile antenna to permit use on two meters. Newtronics Hustler **is shown.**

convert back and forth in minutes, vswr on 2 meters is almost 1:1, and operation – either simplex or through the local repeaters – has been very satisfactory. Low-band operation is unaffected as soon as the modification is removed.

The mast portion of my *Hustler* mobile antenna is used as the 2-meter radiator. A matching stub is made from a two-foot piece (61cm) piece of ½-inch (12.5mm) diameter aluminum tubing, a short length of flexible metal strap (plumber's tape) and two nuts, washers and bolts. The aluminum tubing serves as a matching stub held in place by the metal strap, as shown in **fig. 1**.

First, flatten the tubing for about five inches (12.5cm) at one end and bend the flattened section around the *Hustler* mast for a tight fit. Allow sufficient overlap to permit drilling the flattened portion to receive a bolt. After attachment, the tubing may be bent parallel with the mast and spaced about 2 inches (50mm) from it. Secure the bottom of the tubing to the antenna mounting hardware on the bumper by the flexible strap and a bolt, nut and washer. Adjust the distance between attachment points to about 13½ inches (34.3cm).

Dimensions for a car other than a 1973 Chrysler Newport may be a little different, but a simple adjustment of length by sliding the tubing up and down should make a good match possible.

Herb Ash, K7ARR

vhf frequency measurement with an hf receiver and scaler

The combination of a high-frequency receiver and scaler cannot compare with a frequency counter having one Hz resolution and a scaler to measure vhf or uhf frequencies. However, if accuracy of several hundred Hz in the two-meter band is acceptable, try this.

Inject a small sample of, let's say, a 145.000 MHz signal into a 10-to-1 digital scaler. The scaled-down frequency will be exactly 14.5000 MHz. This signal, coming out of the scaler, is rich in harmonics. With the hf receiver connected to the output of the scaler, tune to the second harmonic, or 29.0000 MHz, to be compatible with the 10-meter band coverage of the receiver. In effect, this uses a divide-by-five scale-factor (10÷2=5). If the receiver dial calibration is accurate, it will measure 29.0000 MHz, showing that the vhf frequency was exactly 145.000 MHz.

The vhf frequency determination will be as accurate as the accuracy to which the hf receiver can read, times a multiplying factor of five (as in the foregoing example). My receiver dial readout error is no more than 200 Hz at midpoint between 100-kHz marker points, and about 100 Hz as it approaches the marker frequencies. This would produce vhf frequency measurements with errors of only 1000 Hz (200 x 5) and 500 Hz (100 x 5), respectively. If you are lucky enough to have the divided vhf frequency falling extremely close to a marker frequency, so that the audible beats can be counted and the marker set to a near-zero beat with WWV, an extremely good vhf frequency accuracy can be obtained – probably better than 100 Hz.

With good modern communications receivers and scalers and reasonably careful manipulation, you can obtain 500 to 1000-Hz accuracy in the two-meter band. Other combinations of scaling factors, and hf receiver frequencies, may be used to measure different portions of the vhf and uhf bands. The accuracy can be no better than the hf receiver readout times the scaling factor, but this may be accurate enough and eliminates the need for an expensive frequency counter.

Louis D. Breetz, W3LB

boosting bargain regulators

Have you ever purchased a "bargain" 3-terminal, 5-volt, voltage regulator only to find that its output voltage was below

the manufacturer's specifications? Many of these devices provide excellent regulation, but their output voltage is marginal for TTL.

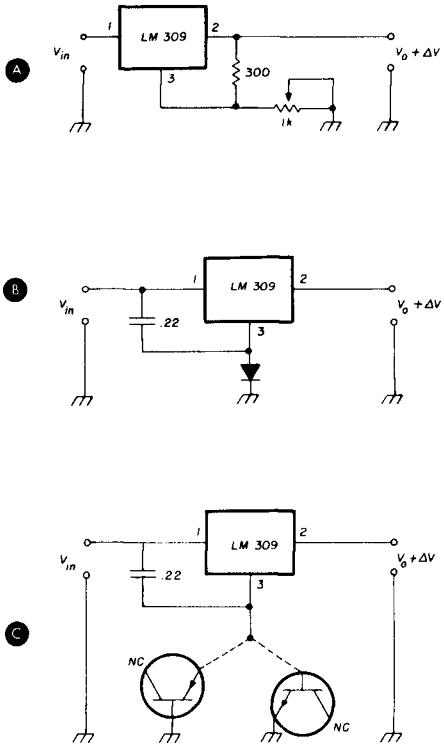

fig. 2. Voltage-regulator circuits. (A) illustrates poor means of obtaining other than characteristic output voltage from LM309 regulator (not recommended). (B) shows a simple way to obtain a different output voltage from the LM309 while maintaining good load regulation. (C) illustrates use of a transistor to increase the output voltage of the LM309 regulator.

The circuit of **fig. 2A** is suggested by at least one manufacturer as a way to obtain output voltages different from the device's characteristic output. Because the output voltage is dependent upon the load current, this circuit suffers diminished load regulation.

A common germanium or silicon diode as used in **fig. 2B** is a simple way to raise the output voltage while maintaining excellent load regulation. The current through the diode is less than 10 mA so a 1N270 germanium diode can be used to increase the output voltage by 0.4 volt. Any silicon diode such as a 1N4001 will raise the output voltage by 0.7 volt. The 0.22 μF capacitor is necessary to prevent oscillation when the regulator's ground terminal is raised above the circuit ground.

If you happen to have a zapped transistor on hand whose base-emitter junction is still functional, it can be used as in **fig. 2C** to boost the output voltage. Germanium or silicon transistors, npn or pnp, may be used for 0.4 or 0.6 volt increases, respectively.

Remember that the minimum input voltage to the regulator is increased by the added voltage, and the regulator case must now be electrically isolated from the chassis.

George Shankland, WA7VVC

step forward in vhf circuits

Fig. 3 illustrates a typical vhf rf stage circuit diagram, except that all of the rf circuits have been isolated from the chassis. This technique has the advantage that smaller-than-ordinary values of dc blocking capacitance can be used, helping to prevent stray out-of-band signals from reaching the mixer stage and reducing unwanted reaction between input and output circuits.

It is necessary, however, to build the rf amplifier stage and the mixer stage in separate boxes. The copper tubes which form part of the input and output coupling circuits provide a low-impedance return for rf to the coax braid, heretofore a very weak point in vhf receiver design.

All components are attached to standoff insulators mounted on each side of the central screen. The input and output coupling coils are spaced about 1/8 inch (3.0mm) from the input and output coils, respectively, to reduce their mutual capacitance to as low a value as possible while still retaining adequate coupling. Both positive and negative supply leads have high rf impedances and are bypassed to the metal box by feedthrough capacitors.

I believe that all vhf circuits should be isolated from the chassis to prevent signal coupling, and every attempt should be made to attenuate parallel currents flowing through containters (chassis, etc.) of vhf circuits. Such currents can reduce the attenuation of out-of-band signals by allowing them to bypass amplifier tuned circuits and reach the mixer stages.

Perhaps in the future parallel currents may be attenuated by painting all vhf rf chassis and containers with some form of rf-resistance paint. My copper tubes could also be covered on the outside with such paint. Although I have not tried this, it seems reasonable that higher gains, narrower bandwidths, and improved stability in all vhf rf circuits could result.

My present amplifier is similar to that shown in **fig. 3**, but has slightly larger values of dc-blocking capacitance and higher value rf-decoupling resistors in the supply leads. I also use a higher supply voltage of approximately 70 volts. The standoff insulators are about 1½ inches (3.8cm) long and are made from nylon. The holes through the center screen are about 3/8 inch (9.5mm) in diameter.

These techniques are also useful in reducing feedthrough of local oscillator signals to rf stages, a condition that can cause all sorts of additional problems.

Peter W. Hazlett, G3IPV

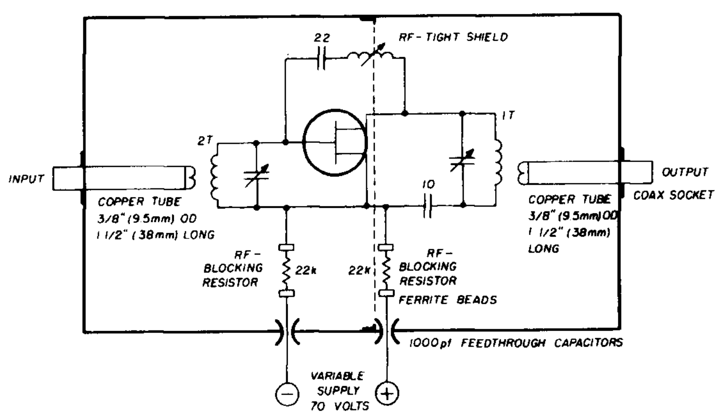

fig. 3. Vhf rf amplifier which has been designed to eliminate problems of coupling unwanted signals into the circuit through parallel current paths.

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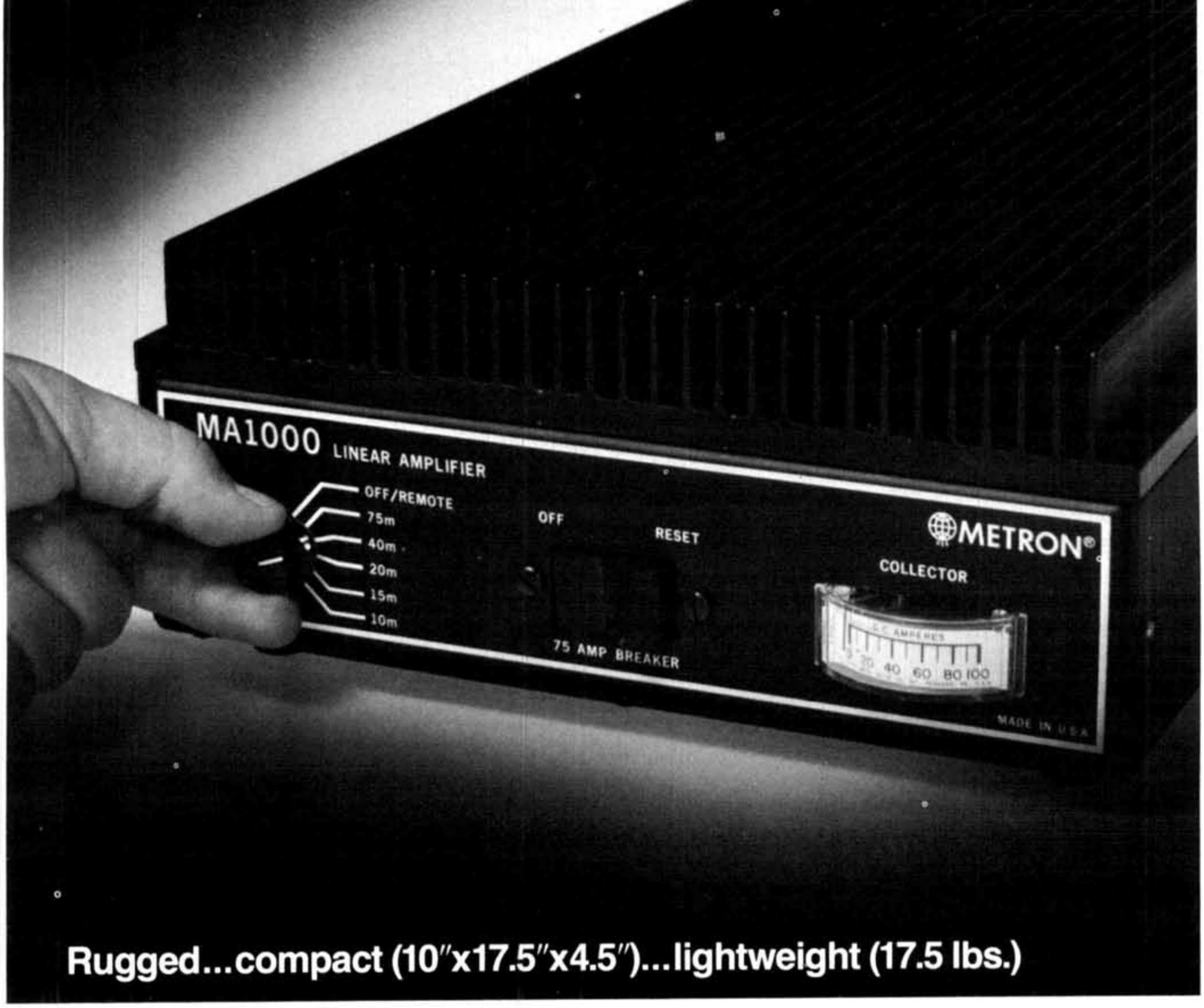

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short circuits

simple computing vswr indicator

Several errors crept into the WB9CYY article on the simple computing vswr indicator, in January, 1977, *ham radio*. In **fig. 2** (page 60), C9, .001 μF, should be inserted between the junction of R17 and R19. U3 is an LM301 (748), as noted in the text, while CR5 is a 1N914. The formula for calibrating the front of a junk-box meter should read:

$$swr = \frac{I_{fs} + I}{I_{fs} - I}$$

where I_{fs} is the full-scale meter deflection and I is the indicated meter reading. A new printed-circuit board layout is shown in **fig. 1**. As with all parts placement diagrams from *ham radio*, the board is shown from the component side.

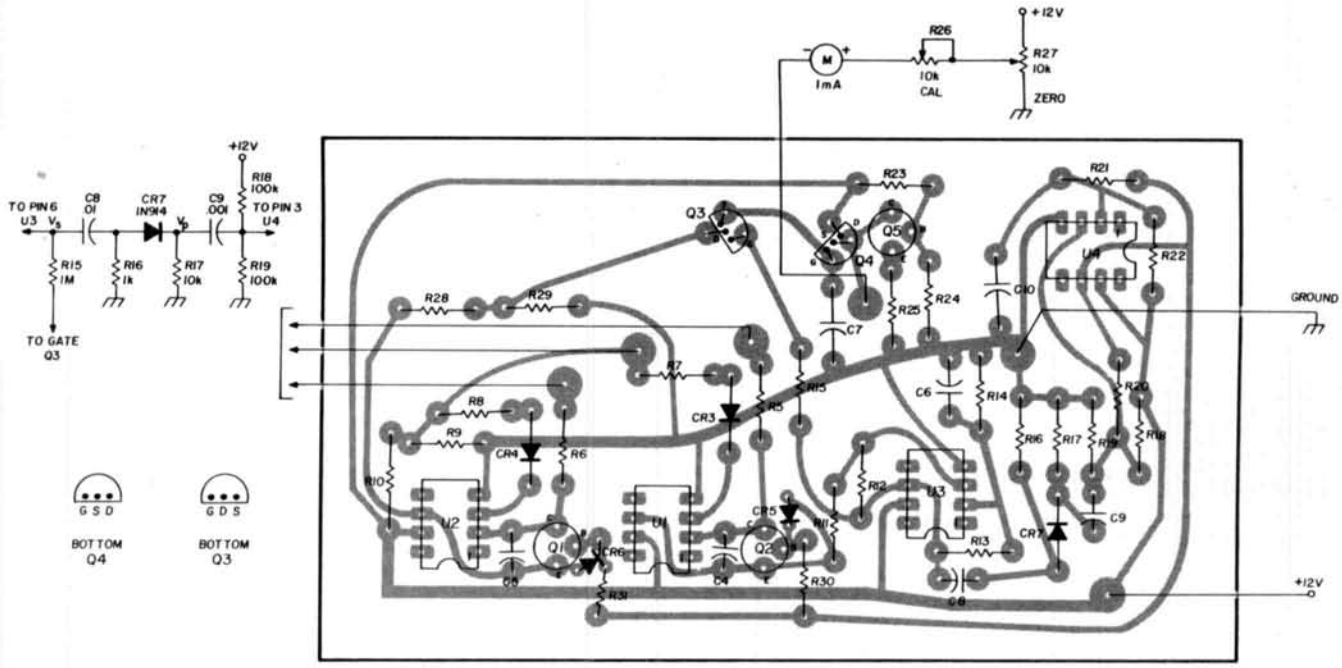

fig. 1. Parts placement and corrected board layout for the simple computing vswr indicator by WB9CYY.

table 1. Changes required to the schematic for operating frequencies other than standard mark and space.

jumper	afsk use	Y1 (MHz)	Y2 (MHz)	R5 (ohms)	R6 (ohms)	R7 (ohms)	mark (Hz)	space (Hz)
15-A	RTTY	4.352	4.700	47k	228	91k	2125	2295
15-A	ASCII comp	4.557	4.147	47k	228	91k	2225	2025
1-A	ASCII term	5.202	4.383	47k	228	91k	1270	1070

$$R7 = \frac{2Q}{f_o C3} \qquad R5 = \frac{R7}{2A} \qquad R6 = \frac{R5R7}{4Q^2R5 - R7} \qquad f_o = \frac{f_{mark} + f_{space}}{2}$$

Where, $f_o > 1800$ Hz and f_o = desired center frequency, $Q = 10$ and $f_o < 1800$ Hz, $Q = 5$. The actual value used for R6 should be chosen to allow variation over the desired range. Gain (A) is normally set to be = 1 (unity gain). Values in the table above were selected using these parameters.

digital afsk

In the improved digital afsk (March, 1977, *ham radio*) several design changes were inadvertently overlooked by the author. **Table 1** reflects these additions. The parts list should be changed as follows: C3 and C4 are .1μF mylar or polystyrene capacitors while R6 is a 500-ohm trimpot (CTS X201-R501B).

repeater up/down mode circuit

In the PC-board layout for the up-down repeater-mode control circuit, January, 1977, *ham radio*, page 41, the interconnection between pins 3 and 4 of each IC was inadvertantly left out.

i-f amplifier design

The noise blanker for high-performance operation (**fig. 2**) shown in *ham radio*, March, 1977, page 11, was suggested by Siemens and developed by Michael Martin, DJ7VY.

milliwatt portable counter

In the schematic diagram (**fig. 2**) of the portable milliwatt counter, *ham radio*, February, 1977, page 24, the coil shown between the output of the 40673 transistor and the input of U1 should be deleted. The network is a 330-ohm resistor in parallel with the 100-pF capacitor.

vestigial sideband transmitter for ATV

In **fig. 6** of the vestigial sideband transmitter (*ham radio*, February 1976, page 24) the input has been incorrectly shown going to pin 7 instead of pin 8. For normal operation, pin 7 is open and the video information goes to pin 8. All other connections remain the same.

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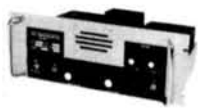

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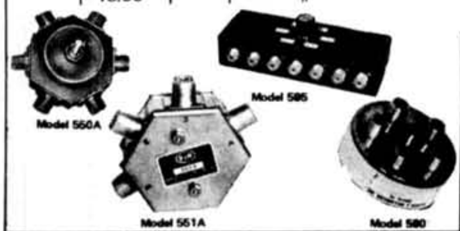
592	16.50	2	Axial	
595	18.50	6	In-line	Grounds all except selected output circuit.



MODEL 104R

NPC 6 Amp Power Supply Regulated.
Solid State. Dual Overload Protection.

Converts 115 volts AC to 13.6 volts DC ±200 millivolts. Handles 4 amps continuous and 6 amps max. Ideally suited for applications where excellent DC stability is important, such as CB transmission, small Ham radio transmitter, and high quality eight-track car stereos. Can be used to trickle-charge 12 volt car batteries.

	MAXIMUM	TYPICAL
Output Voltage	13.6 ± 2 VDC	13.6 ± 3 VDC
Line/Load Regulation	20 mV	50 mV
Ripple/Noise	2 mV RMS	5 mV RMS
Transient Response	20 uSec	
Current Continuous	4 Amp	
Current Limit	6 Amp	
Current Foldback	2 Amp	

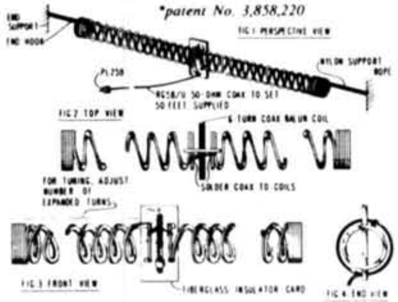
$49.95

Case: 3½'' (H) x 5½'' (W) x 6½'' (D). Shipping Weight: 6 lbs.

SLINKY!® $39.95 kit

A LOT of antenna in a LITTLE space
New Slinky® dipole* with helical loading radiates a good signal at 1/10 wavelength long!

**patent No. 3,858,220*



• This electrically small 80/75, 40, & 20 meter antenna operates at any length from 24 to 70 feet • no extra balun or transmatch needed • portable—erects & stores in minutes • small enough to fit in attic or apartment • full legal power • low SWR over complete 80/75, 40, & 20 meter bands • much lower atmospheric noise pickup than a vertical and needs no radials • kit includes a pair of **specially-made 4-inch dia. by 4-inch long coils**, containing 335 feet of radiating conductor, balun, 50 ft RG58/U coax, PL259 connector, nylon rope & instruction manual • now in use by US Dept. of State, US Army, radio schools, plus thousands of hams the world over

talk power by TPL

TPL for an Economy Price?
THAT'S RIGHT!
introducing the ECONO-LINE

Model	Input	Output	Typical	Frequency	Price
702	5-20W	50-90W	10 in/70 out	143-149 MHz	$139.00
702B	1-4W	60-80W	1 in/70 out	143-149 MHz	$169.00

Now get TPL COMMUNICATIONS quality and reliability at an economy price. The new Econo-Line gives you everything that you've come to expect from TPL at a real cost reduction. The latest mechanical and electronic construction techniques combine to make the Econo-Line your best amplifier value. Unique broad-band circuitry requires no tuning throughout the entire 2-meter band and adjacent MARS channels. See these great new additions to the TPL COMMUNICATIONS product line at your favorite amateur radio dealer.

For prices and specifications please write for our Amateur Products Summary! FCC type accepted power amplifiers also available. Please call or write for a copy of TPL's Commercial Products Summary.

DENTRON

160-10AT SUPERTUNER™
Want an antenna tuner to match everything between 160 and 10 through balanced line, coax line and random line. Supertuner™ is the one for you at just $129.50

160-10AT-3K SUPER SUPERTUNER™
Designed and engineered to be compatible with the full-power highly efficient modern amplifiers now available to the amateur. In our opinion the finest tuner on the market today. $229.50

80-10AT SKYMATCHER™
Here's an antenna tuner for 80 through 10 meters, handles full legal power and matches your 52 ohm transceiver to a random wire antenna. 80-10AT is yours for only $59.50

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More Details? CHECK—OFF Page 150

ATLAS 210x/215x

5 BAND—200-WATT—ALL SOLID STATE HF SSB/CW TRANSCEIVER

With its exclusive Plug-in-and-go MOBILE MOUNT, light weight, and compact size, the Atlas 210x/215x transceiver is the perfect mobile rig . . . the King of the Road in Amateur Radios.

To go mobile, just slip the 210x into the mobile mount and all connections are made automatically. In just 10 seconds you're on the air mobile!

OTHER FEATURES INCLUDE:

- All solid state design.
- 200 watts power rating and no transmitter tuning.
- Full 5 band coverage (210x covers 10-80 meters, 215x covers 15-160 meters).
- Weighs just 7 pounds and is only 3½″ high x 9½″ wide.
- Plug-in circuit boards.
- Phenomenal selectivity with exclusive 8 pole crystal ladder filter
- Exceptional immunity to strong signal overload and cross modulation.

Model 210x or 215x Transceiver . . . . **$679.**
(With noise blanker installed add $40.)

ACCESSORIES:

Portable AC Supply 110/220V . . . . **$100.**
Plug-in Mobile Kit . . . . **$ 48.**
Model DD6-C Digital Dial only . . . . **$229.**
Mobile Antenna Matching Transformer MT-1 . . . . **$ 27.**
DL 200 Dummy Load, 200 watt intermittent or 60 watt continuous power rating . . . . . . **$ 9.**

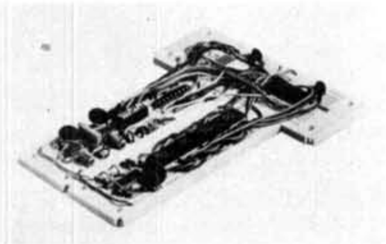
For complete details see your Atlas dealer, or drop us a card and we'll mail you a brochure with dealer list.

ATLAS RADIO INC.

417 Via Del Monte • Oceanside, CA 92054
Phone (714) 433-1983
Special Customer Service Direct Line (714) 433-9591

NEW products

interlocking solderless breadboards from CSC



Continental Specialties Corporation, a leading manufacturer of electronic breadboarding equipment, test equipment and accessories has announced two new professional-quality solderless breadboarding sockets which combine a number of highly desirable features. Designated *Experimentor*™ *300* and *Experimentor 600*, the new one-piece sockets both provide 94 five-point terminals, plus two 40-point bus strips, for a total of 550 solderless tie-points. Experimentor 600, priced at $10.95 suggested list, has a 0.6″ (15mm) center channel, making it the only socket on the market with full 4-terminal fan-out for microprocessors, clock chips, RAM's, ROM's and other larger DIP packages. Experimentor 300, priced at $9.95 suggested list, has a 0.3″ (7.5mm) center channel that is perfect for smaller DIP's.

Like CSC's other popular breadboarding products, both Experimentor sockets also accept transistors, LED's, resistors, capacitors, pots — virtually all types of discrete components, as well as lengths of # 22-30 solid hookup wire for interconnection — with plug-in ease. CSC Experimentor sockets also feature a unique interlocking system that permits sockets to be snapped together, mixed or matched, vertically or horizontally, to provide optimum configurations for almost any type of circuit. And instantly disconnected or reconnected, without tools, to meet requirements.

CSC Experimentor sockets are molded of durable abrasion-resistant material, and feature CSC's non-corrosive, prestressed nickel-silver contacts for positive connection and longer life. Both sockets measure 0.325″ (9.5mm) deep and 6″ (15cm) long — but the Experimentor 600 measures 2.4″ (6cm) wide (as opposed to 2.1″ (5.3cm) for Experimentor 300), because of the wider center channel that accommodates microprocessor type DIP IC's. Both sockets also feature alphanumerically designated tie-points, aiding in circuit design and testing, as well as circuit tracing. Vinyl-backed to prevent accidental shorts, CSC Experimentor sockets can be used free-standing or conveniently screw-mounted, either with 4-40 flat-head screws from the front, or 6-32 self-tapping screws from the rear.

CSC Experimentor sockets are available now from CSC distributors and dealers, or directly from CSC's East- or West-Coast offices. For more information, contact CSC at 44 Kendall Street, Box 1942, New Haven, Connecticut 06509, or 351 California Street, San Francisco, California 94119.

digital multimeter

This new battery/ac portable 4-1/2 digit, five-function digital multimeter from Hewlett-Packard has a unique *touch-hold* probe (available as an accessory) that lets the user "freeze" the reading on the display — a convenience when probing closely-packed circuit boards.

Called the Model 3465B, the digital multimeter has a dc voltage measurement range from 1 microvolt to 1 kilovolt with a mid-range accuracy of ±(0.02 per cent reading + 0.01 per cent of range) for one year. Ac measurement range is 10 microvolts to 500 volts with a mid-range accuracy of ±(0.15 per cent of reading + 0.05 per cent of range) over a 40 Hz to 20 kHz bandwidth.

Ac and dc current measurement range is from 10 nanoamps to two amps. Dc current accuracy for the 10 mA range is ±(0.1 per cent of reading + 0.01 per cent of range). Ac current measurements are made over a frequency band of 40 Hz to 20 kHz with a mid-band accuracy of ±(0.25 per cent of reading + 0.25 per cent of range).

Resistance range is 10 milliohms to 20 megohms with a mid-range accuracy of ±(0.02 per cent of reading + 0.01 per cent of range). Open circuit voltage on the *ohms* terminal, when set to its lowest range does not exceed 5 volts, preventing damage to most solid-state devices.

Input protection is provided to 1kV on any dc range, 500 V rms on any ac range, and 350 V peak on any resistance range. A front-panel fuse protects the instrument from overload when measuring current.

The HP 34112A touch-hold probe accessory provides greater utility by allowing the operator to focus his attention on the point of measurement in hard-to-reach circuits. The touch-hold probe, which plugs into the front panel input connectors, holds the displayed reading at the touch of a button.

A high efficiency LED display has the advantage of longer battery life, and instrument reliability is improved because of low internal temperature rise.

Input terminals are recessed to meet safety requirements, and the input terminal for current also contains a fuse. International symbols as well as voltage limits are shown on the front panel.

More Details? CHECK — OFF Page 150

The standard 3465B DMM comes with an internal ac power supply and rechargeable nickel-cadmium batteries.

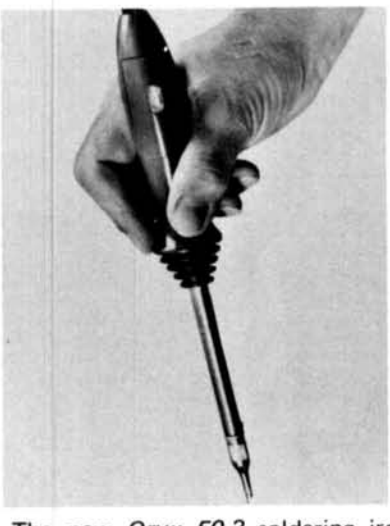
U.S. price of the Hewlett-Packard Model 3465B with rechargeable nickel-cadmium batteries is $500. U.S. price of the Model 34112 Touch-Hold Probe is $40. For more information write Inquiries Manager, Hewlett-Packard Company, 1501 Page Mill Road, Palo Alto, California 94304.

Hamtronics catalog

Hamtronics announces publication of a new catalog featuring, among other products for the vhf enthusiast, a new miniature vhf receiver preamplifier, a receiver multi-coupler allowing two receivers to be used on a single antenna, and a low-cost fm signal generator. Previous products from *Hamtronics* listed in their new catalog include vhf and uhf fm receivers and transmitters in kit form and various adapters for use with vhf and uhf equipment, such as scanner adapters, multi-channel adapters, and a full line of preamps.

The new 16-page catalog is yours in exchange for a self-addressed stamped envelope. Write Hamtronics, Inc., 182 Belmont Road, Rochester, New York 14612.

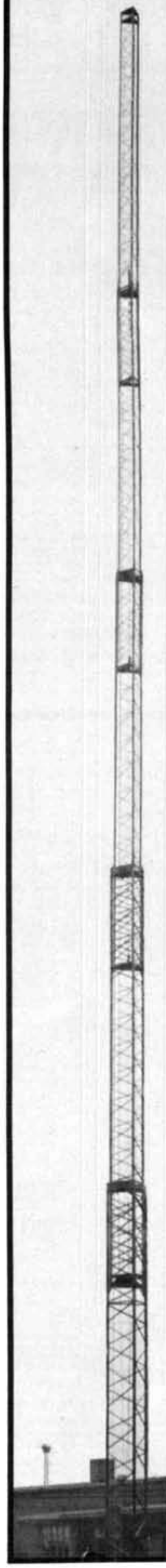
temperature-controlled soldering iron



The new *Oryx 50-3* soldering iron has a thermostatic control built right into the handle. It keeps the temperature constant regardless of speed of soldering, or line voltage variations. Operating temperatures can be adjusted in seconds to any setting between 400° and 750° F (204° and 399° C) while the iron is running. An indicator light in the handle serves as a visual guide to the control system, as a temperature-setting aid, and as a safety feature by indicating clearly when the iron is left on. The *Oryx 50-3* comes complete with a long-life, iron-coated tip and a four-foot, 3-wire cord for 100-130 Volts ac. Other style tips and a safety stand are offered as optional accessories. For more information, write: Oryx, 4115 North 44th Street, Phoenix, Arizona 85018.

More Details? CHECK—OFF Page 150

More Details? CHECK—OFF Page 150



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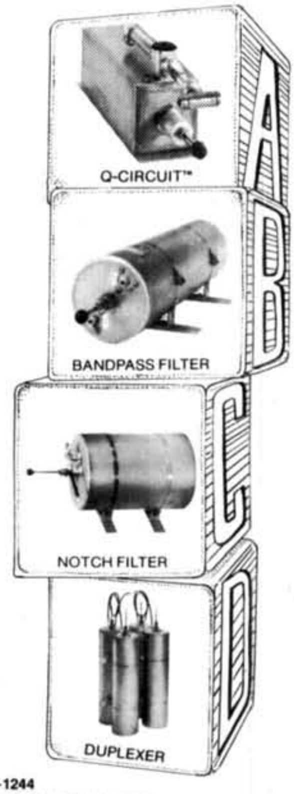
Fact: Better communications systems start with SINCLAIR building blocks.



For over 25 years, Sinclair's cavity filters have set the pace in two-way radio communications.

These building blocks provide optimum performance coupled with rugged, long-life construction □ Bandpass filters – field tunable, rotatable loops for variable selectivity □ Notch filters – optimum rejection of specific frequencies □ Q-circuit™ filters – unique, patented broad isolation notch for rejecting multiple frequencies. These innovative temperature-compensated, cavity filters are also used to build the industry's finest duplexers. To reduce the cost of combining transmitters, Sinclair cavity and cavity-ferrite combinations are the answer.

With these building blocks and help from Sinclair's communication specialists, you can build a system matched to your needs. Send today for new All-product Digest.

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- ACCURATE
- VERSATILE
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MODEL 85

4 RANGE WATTMETER SERVICES EVERYTHING FROM PORTABLES TO BASE STATIONS

MODEL 85 HAS 15 FEATURES, HERE ARE A FEW

• Frequency range 20-512 MHz • Power ranges, 0-3/15/50/150 watts • Accuracy ± 5% of full scale • Temperature compensation • Easily recalibratable in the field • Dry load, no coolant, PLUS over 10 accessories available.

You can buy a Wattmeter for less but if you want quality send for data on the Model 85 or call 216-267-2233. Available for immediate delivery.

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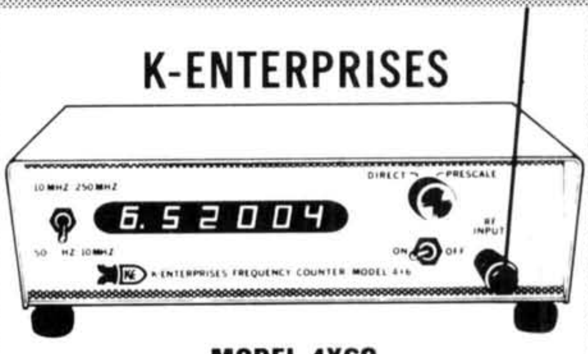

MODEL 4X6C
50 HZ—250 MHZ $270.00

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SEE YOU IN ATLANTA — HAMFESTIVAL JUNE 18 & 19

New from Info-Tech:
An AFFORDABLE, SILENT, RTTY System

New Model 150
RTTY Keyboard

Features:

4 speeds (60,66,75,100 wpm)
Built-in AFSK with 3 shifts (170, 425, 850 hz)
Automatic CR & LF at end of 64 or 72 character line
Built-in low shift CW ID provision

Priced at **$289.50**
F.O.B. St. Louis

New Model 75
RTTY to Video Converter

Features:

4 speeds (60, 66, 75, 100 wpm)
Built-in T.U. with 3 shifts (170, 425, 850 hz)
32 character x 16 line video output with scrolling
Connects directly to receiver audio & video monitor

Priced at **$324.95**
F.O.B. St. Louis

- Send for data sheets on these products
- Video monitors available
- Master Charge welcome

INFO-TECH INCORPORATED *Specializing in Digital Electronic Systems*

20 Worthington Drive, St. Louis, Missouri 63043 Phone: 314-576-5489

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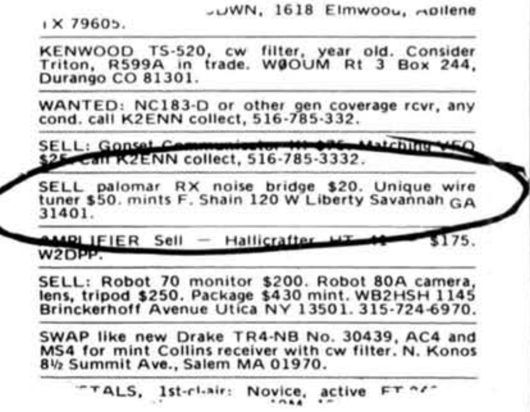
NEW R-X NOISE BRIDGE OFFER!

IF YOU BOUGHT THIS

Fake Palomar Engineers Noise Bridge

FROM THIS AD



...DWN, 1618 Elmwood, Abilene TX 79605.

KENWOOD TS-520, cw filter, year old. Consider Triton, R599A in trade. WØOUM Rt 3 Box 244, Durango CO 81301.

WANTED: NC183-D or other gen coverage rcvr, any cond. call K2ENN collect, 516-785-332.

SELL: Gonset ... Matching VFO $25 call K2ENN collect, 516-785-3332.

SELL palomar RX noise bridge $20. Unique wire tuner $50. mints F. Shain 120 W Liberty Savannah GA 31401.

AMPLIFIER Sell — Hallicrafter ... $175. W2DPP.

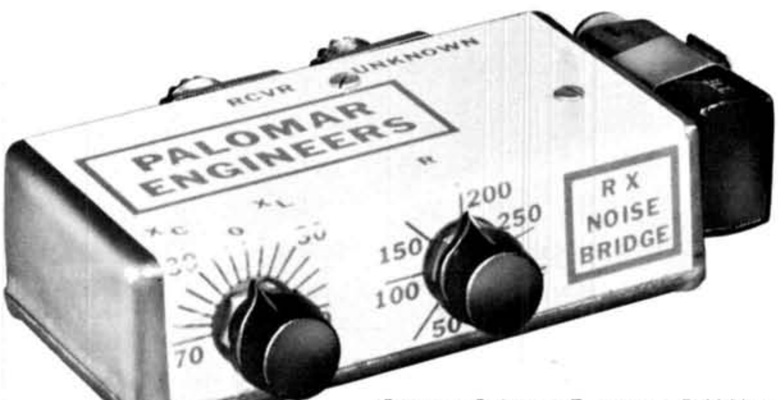
SELL: Robot 70 monitor $200. Robot 80A camera, lens, tripod $250. Package $430 mint. WB2HSH 1145 Brinckerhoff Avenue Utica NY 13501. 315-724-6970.

SWAP like new Drake TR4-NB No. 30439, AC4 and MS4 for mint Collins receiver with cw filter. N. Konos 8½ Summit Ave., Salem MA 01970.

...TALS, 1st-class: Novice, active ...

Reproduced from September 1976 QST Page 164

EXPECTING TO GET THIS



Genuine Palomar Engineers R-X Noise Bridge

CHEER UP!

TAKE ADVANTAGE of our great new trade-in offer. $1.00 off on a genuine Palomar Engineers R-X Noise Bridge when your order is accompanied by a fake R-X noise Bridge.

EVEN IF YOU DON'T HAVE A FAKE R-X NOISE BRIDGE you can take advantage of our usual low price of only $39.95.

The Palomar Engineers R-X Noise Bridge tells you if your antenna is resonant or not and, if it is not, whether it is too long or too short. All this in one measurement reading. And it works just as well with ham-band-only receivers as with general coverage equipment because it gives perfect null readings even when the antenna is not resonant. It gives resistance and reactance readings on dipoles, inverted Vees, quads, beams, multiband trap dipoles and verticals. No station is complete without this up-to-date instrument.

Why work in the dark? Your SWR meter or your resistance noise bridge tells only half the story. Get the instrument that really works, the Palomar Engineers R-X Noise Bridge. Use it to check your antennas from 1 to 100 MHz. And use it in your shack to adjust resonant frequencies of both series and parallel tuned circuits. Works better than a dip meter and costs a lot less.

Send check or money order for $39.95 (or $38.95 and your imitation Palomar Noise Bridge) for postpaid delivery anywhere in U.S. or Canada. California residents add sales tax.

Italy write i2VTT, PO Box 37, Cantu. Elsewhere send $42 (U.S.) for air parcel post delivery worldwide.

Fully guaranteed by the originator of the R-X Noise Bridge. ORDER YOURS NOW.

PALOMAR ENGINEERS

P.O. Box 455, ESCONDIDO, CA 92025 – Phone: (714) 747-3343

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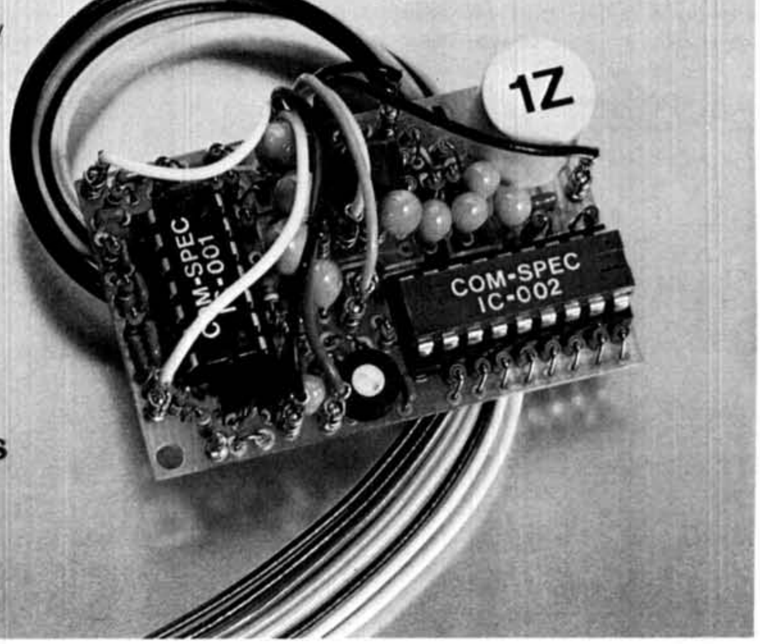

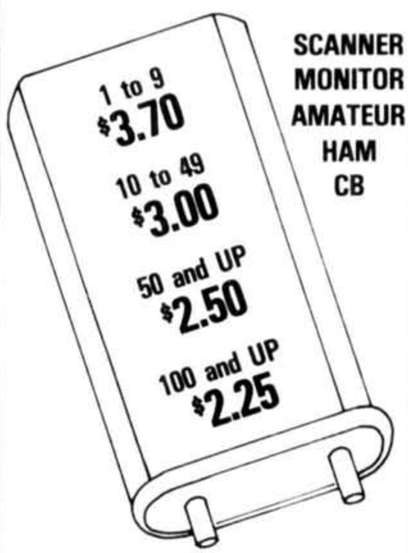

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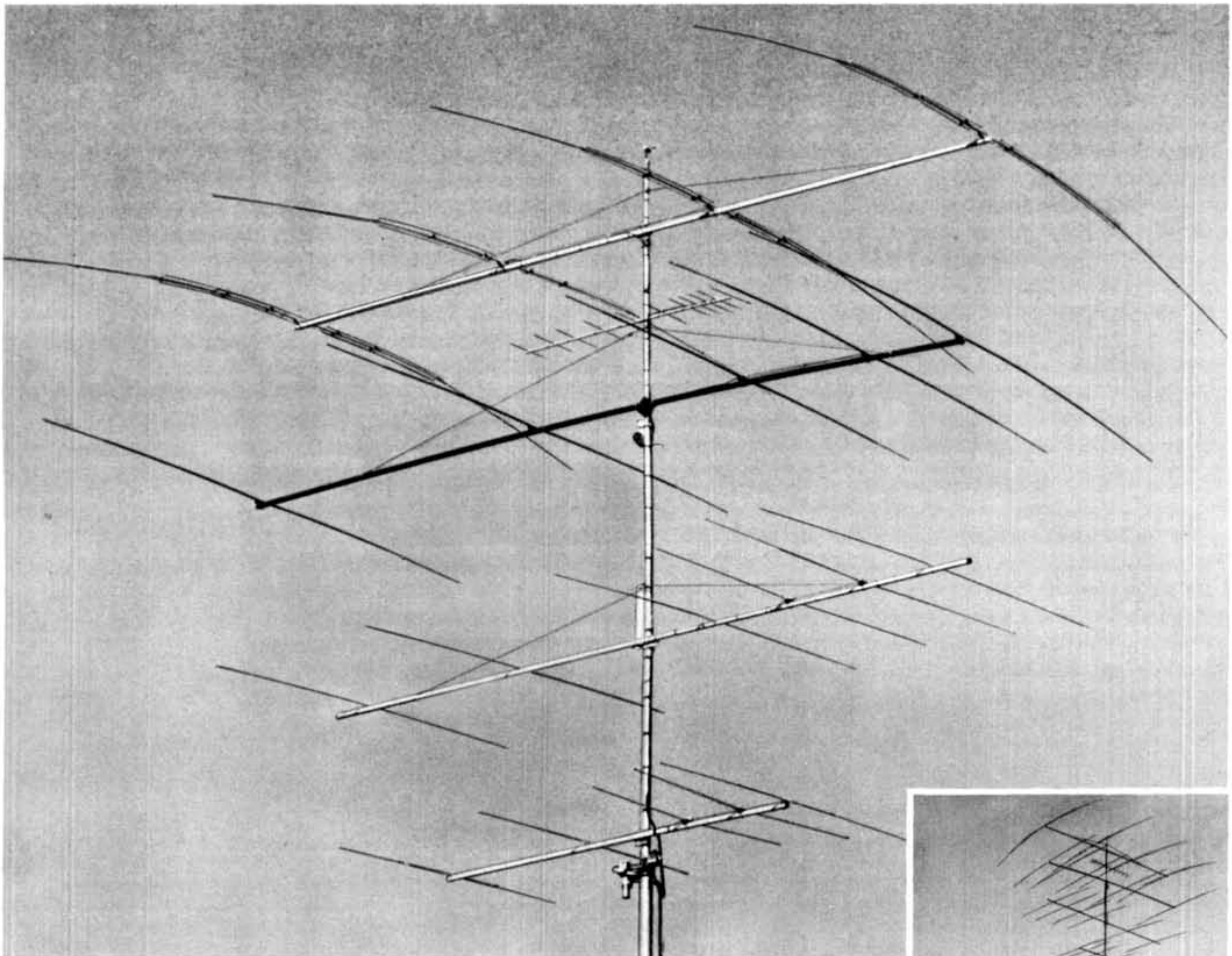

KLM beams...

mechanical excellence...
peerless performance...
top to bottom.

The outstanding antenna system of well known DXer Don Schliesser, W6MAV/K6RV, is shown in the above close-up photograph. A full view of the complex is shown in the smaller right-hand photograph of Don's beautiful, high-on-a-hilltop home.

After careful consideration, Don chose KLM monobanders, top to bottom; **five beams**, topped by a 4 element 40, a 5 element 20, a 6 element 15, a 5 element 10 and an 11 element 2 meter beam. Mel and Mike of KLM are indeed proud that their high performance antennas were selected on a merit basis over others considered by Don Schliesser.

The KLM product line also includes HF, VHF and UHF antennas in a very wide variety of configurations, log periodic types for commercial and military applications plus the rotors pictured.

See your KLM dealer and pick up a catalog before making any antenna decision.

KLM 1500-HD Heavy duty rotator

KR-400 azimuth rotator

KR-500 elevation rotator

KLM electronics

17025 Laurel Road, Morgan Hill, California 95037 (408) 779-7363

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Drake Accessories

designed for convenience and accuracy

Drake Directional RF Wattmeters

W-4 1.8-54 MHz **WV-4** 20-200 MHz

Drake directional, through line wattmeters, using printed circuits, toroids, and state of the art techniques, permit versatile performance and unsurpassed accuracy, yet at a lower cost.

In contrast to VSWR measuring devices of the past, Drake wattmeters are frequency insensitive throughout their specified range, requiring no adjustments for power or VSWR measurements.

Negligible insertion loss allows continuous monitoring of either forward or reflected power for fast accurate tune up and checking of transmitter-antenna performance.

Indirectly measure radiated power (forward power minus reflected power) and VSWR by means of a plastic nomogram included.

Each wattmeter makes possible quick, accurate adjustments of antenna resonance and impedance match, when placed between transmitter and matching network.

High accuracy; ideal as laboratory instruments.

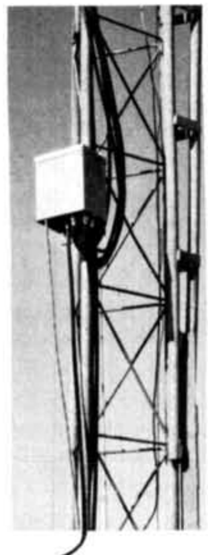
Removable coupler allows remote metering.

Specifications	W-4 $72.00	WV-4 $84.00
Frequency Coverage	1.8-54 MHz	20-200 MHz
Line Impedance	50 ohm resistive	50 ohm resistive
Power Capability	2000 W continuous	1000 W continuous
Jacks, Removable Coupler	Two S0239 input and output connectors	Type N input and output connectors.
Semiconductors	Two 1N295 power meter rectifiers	Two 1N695 power meter rectifiers
Accuracy	± (5% of reading + 1% of full scale)	

Drake RCS-4

Remote Coax Switch

- **Remotely Selects One of Five Antennas**
- **Grounds All Unused Antennas**
- **Grounds All Antennas in Gnd Position for Lightning Protection**
- **Front Panel Indicator Monitors Antenna Selection Interval**
- **Protected Against Adverse Weather Conditions**
- **SO-239 Connectors Provided for Main Coax Feed-Line and Individual Antenna Feed-Lines**
- **Handles 2000 Watts PEP**
- **Available in 120 V-ac or 240 V-ac 50/60Hz Versions**



$120.00

• Control unit works on 110/220 V-ac, 50/60 Hz, and supplies necessary voltage to motor. • Excellent for single coax feed to multiband quads or arrays of monobanders. The five positions allow a single coax feed to three beams and two dipoles, or other similar combinations. • Control cable (not supplied) same as for HAM-M rotator. • Selects antennas remotely, grounds all unused antennas. Gnd position grounds all antennas when leaving station. "Rain-Hat" construction shields motor and switches. • Up to 30 MHz, insertion of switch changes VSWR no more than 1.05:1. • From 30 MHz to 150 MHz, insertion changes VSWR no more than 1.5:1. • Motor: 24 V-ac, 2 amp. Lubrication good to −40°F. • Switch Rf Capability: Maximum legal limit.

Drake MN-4 & MN-2000 Matching Networks

- **80-10 Meters**
- **Antenna Selector and By-Pass Switches included**

MN-4 (300 Watts)
$110.00

MN-2000 (2000 Watts)
$220.00

A Drake matching network is a worthwhile addition to any amateur station where peak performance is desired. Basically identical, except for power handling capabilities, the MN-4 and MN-2000 enable feedline SWR's of 5:1 to be matched to the transmitter. If input impedance is purely resistive, even higher SWR's can be handled. • Besides presenting a 50 ohm load to the transmitter, the Matching Network's built in rf wattmeter allows accurate and continuous power measurement and VSWR indication. The advanced wattmeter circuitry yields frequency-insensitive readings from 2 to 30 MHz, and accuracy until now obtainable only in expensive wattmeters.

To receive a FREE Drake Full Line Catalog, please send name and date of this publication to:

All prices (suggested amateur net) and specifications subject to change without notice.

R. L. DRAKE COMPANY DRAKE®

540 Richard St., Miamisburg, Ohio 45342
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JUST ASK ANY HAM ABOUT A Wilson RADIO . . .

WE-800
2 METER PORTABLE SYNTHESIZED RADIO
$399.00 LIST

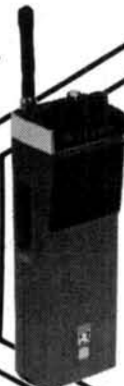
. . . we're known by the thousands who use us!!!

SPECS. 1405SM

- 6 Channel Operation
- Individual Trimmers on all TX/RX Crystals
- All Crystals Plug In
- 12 KHz Ceramic Filter
- 10.7 and 455 KHz IF
- .3 Microvolt Sensitivity for 20 dB Quieting
- Weight: 1 lb. 4 oz. less Battery
- Battery Indicator
- Size: 8 7/8 x 1 3/4 x 2 7/8
- Switchable 1 & 5 Watts Minimum Output @ 12 VDC
- Current Drain: RX 25 MA TX 400 MA (lw) 900 MA (5W)
- Microswitch Speaker Mic
- Unbreakable Lexan® Case
- Furnished with Flex Antenna and Simplex Xtal Frequency 52/52 installed.

ACCESSORIES:

- Battery Chargers
- Touch Pads
- Tone Options
- Speaker Mics
- Leather Cases
- Mobile Amplifier and Battery Charger



1402SM
HAND HELD 2.5 WATT TRANSCEIVER
144-148 MHz
$192.95 LIST

SPECS. 2202SM

FREQUENCY RANGE 220-225 MHz

- 6 Channel Operation
- Individual Trimmers on all TX/RX Crystals
- All Crystals Plug In
- 12 KHz Ceramic Filter
- 10.7 and 455 KHz IF
- .3 Microvolt Sensitivity for 20 dB Quieting
- Weight: 1 lb. 4 oz. less Battery
- Battery Indicator
- Size: 8 7/8 x 1 3/4 x 2 7/8
- Switchable 1 & 2.5 Watts Output @ 12 VDC
- Current Drain: RX 25 MA, TX 400 MA
- Microswitch Speaker Mic
- Unbreakable Lexan® Case
- Furnished with Flex Antenna and Simplex Xtal Frequency 223.50 MHz installed
- Uses the same accessories as 1405.

$259.95 2202SM

1405SM
5 WATT TRANSCEIVER
144-148 MHz
$259.95

Wilson 2 meter Hand-Held radios . . . The dependable ones . . . proven performance for the discriminating Ham who insists on quality and value.

Two models are available: the 2.5 watt model 1402SM, and the switchable 1 watt or 5 watt model 1405SM . . . options include Touch-Tone Pad, Battery Charger, Battery Packs Speaker Mike, Leather Case, and Tone Options.

Join the thousands of amateurs now using Wilson . . . the radio that goes where you do.

1402 SPECS

- 6 Channel Operation
- Individual Trimmers on all TX/RX Crystals
- All Crystals Plug In
- 12 KHz Ceramic Filter
- 10.7 IF and 455 KHz IF
- .3 Microvolt Sensitivity for 20 dB Quieting
- Weight: 1 lb. 4 oz. less Battery
- S-Meter/Battery Indicator
- Size: 8 7/8 x 1 7/8 x 2 7/8
- 2.5 Watts Minimum Output @ 12 VDC
- Current Drain RX 25 MA TX 500 MA
- Microswitch Speaker Mic
- High Impact Plastic Case

4502SM SPECS.

FREQUENCY RANGE 420-450 MHz

- 6 Channel Operation
- Individual Trimmers on all TX/RX Crystals
- All Crystals Plug In
- 12 KHz Ceramic Filter
- 21.4 and 455 KHz IF
- .3 Microvolt Sensitivity for 20 dB Quieting
- Weight: 1 lb. 4 oz. less Battery
- Battery Indicator
- Size: 8 7/8 x 1 3/4 x 2 7/8
- Switchable 1 & 1.8 Watts Output @ 12 VDC
- Current Drain - RX 25 MA, TX 500 MA
- Microswitch Speaker Mic
- Unbreakable Lexan® Case
- Furnished with Flex Antenna and Simplex Xtal Frequency installed, 446.00 MHz
- Uses same accessories as 1405.

$324.95

WILSON ALSO HAS DYNAMITE LINES OF ANTENNAS, CRANK-UP TOWERS, AND ROTORS . . .

MORE ABOUT THE WE-800:

Wilson's New Portable 800 Channel 2 Meter Synthesized Radio that can go anywhere with you • Switchable 1 and 12 watt output • 1 watt output with internal Ni-cad battery pack (takes regular 10 "AA" Ni-cads) • Low current drain CMOS synthesizer: Rx45 MA, TX 350 MA at 1 watt • 12 watt output mobile • Covers frequency range 144-148 MHz in 5 kHz steps, 600 kHz off-set up or down • Two positions available for other than 600 kHz off-set • Five pre-set channels • On-off switch control for meter light in rear for power saving use • Size 8-1/4" x 6-3/4" x 1-7/8" • Weight 1 lb. 5 oz.

ALL WILSON HAND-HELD RADIOS FEATURE:

- Performance
- Dependability
- Rugged Construction
- Versatility

Prices effective May 1, 1977 and are subject to change without notice.

FOR ADDITIONAL LITERATURE, CONTACT YOUR NEAREST AMATEUR DEALER OR:

Wilson Electronics Corp.

4288 SO. POLARIS • P. O. BOX 19000 • LAS VEGAS, NEVADA • 89119 • TELEX 684-522

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RATES Non-commercial ads 10¢ per word; commercial ads 40¢ per word both payable in advance. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing). Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (not all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N.H. 03048.

THE BEST HANDBOOK in Amateur Radio. The Radio Communication Handbook from the RSGB in 2 volumes $31.90, from *ham radio's* Communications Bookstore, Greenville, NH 03048.

HELP CELEBRATE VERMONT'S BICENTENNIAL (1777-1977), work 10 Vermont stations on HF bands, get beautiful VTCC award. For info write VTCC AWARD, Burlington Amateur Radio Club, PO Box 312, Burlington, VT 05402.

HAM RADIO HORIZONS, a super new magazine for the Beginner, the Novice and anyone interested in Amateur Radio . . . What it's all about. How to get started, The fun of ham radio. It's all here and just $10.00 per year. HURRY! HURRY! Ham Radio HORIZONS, Greenville, NH 03048.

QRP TRANSMATCH with Preamp for HW7 Ten-Tec. Send stamp for details to Peter Meacham Associates, 19 Lorreta Road, Waltham Mass. 02154

CANADIANS 1,000,000 surplus parts. Bargains galore. Free catalog. Etco-HR. Box 741, Montreal, H3c 2v2.

WANTED: Ham Radio Magazine, all issues thru 1976. State condition, price. K7PPC, 160 N. 6th, Laramie, WY 82070.

PORTAPAK the accessory that makes your mobile really portable. $67.50 and $88.00. Dealer inquires invited. P.O. Box 67, Somers, Wisc. 53171.

RADIO MUSEUM now open. Free Admission. 15,000 pieces of equipment from 1850 telegraph instruments to amateur and commercial transmitters of the 1920's. Amateur station W2AN. Write for information. Antique Wireless Assn., Main St., Holcomb, N. Y. 14469.

TELETYPE EQUIPMENT for beginners and experienced operators. RTTY machines, parts, supplies. Beginner's special: Model 15 Printer and demodulator $139.00. Dozen black ribbons $6.50; case 40 rolls 11/16 perf. tape $17.50 FOB. Atlantic Surplus Sales, 3730 Nautilus Ave., Brooklyn, N. Y. 11224. Tel: (212)372-0349.

BUY — SELL — TRADE. Write for free mailer. Give name, address and call letters. Complete stock of major brands new and reconditioned equipment. Call for best deals. We buy Collins, Drake, Swan etc. SSB & FM. Associated Radio, 8012 Conser, Overland Park, Ks. 66204 913-381-5901.

QSL — BROWNIE W3CJI — 3035B Lehigh, Allentown, Pa. 18103. Samples with cut catalog 50¢.

WANTED: (4) Spectrum International 70/MBM48 J-Beams. 1330 Curtis, Berkeley, CA 94702.

RTTY DEMODULATORS — New ST-5's with auto-start and AK-1 AFSK audio oscillator $185 or $25 and balance UPS COD. David Tancig, 618 W. White St., Champaign, ILL. 61820.

WANTED: ARRL Handbooks. Quote W9DDL, 5006 North Second, Loves Park, Illinois 61111.

NEW 4-Varactor, 3-transistor UHF TV tuner. Tunes thru 440 MHz for ATV or repeater applications. $7.95 ppd. Workshop, Box 393H, Bethpage, NY 11714.

TV-2B SWAN Two Meter Transverter. Two units for sale, one 28 MHz IF and one 50 MHz IF. $200 each. Hallicrafters PS-500, 500 watt tranceiver power supply. $50. K3RYL, 2750 Belaire Rd., Bethlehem, Pa. 18017.

CRYSTALS — S.A.S.E. my list. K8LJQ, 355 Mower Rd., Pinckney, Mich. 48169.

PRESCALER BOARD for 650 MHZ 11C90. Includes instructions and parts source, 3.00. Also CSJ counter boards 15.00 (see 76 ads). RTC Electronics, P.O. Box 2514, Lincoln, Nebr. 68502.

RECONDITIONED TEST EQUIPMENT for sale. Catalog $.50. Walter, 2697 Nickel, San Pablo, Ca. 94806.

RTTY: E-51 AFSK generator — wide/narrow shift — wired/tested — $34.95 — kits available. Stamp for info. Com — Tech Electronics, P.O. Box 73, Rensselaer, N.Y. 12144.

WANTED: old keys, Navy,RR etc., also old microphones. K4NBN, Del Powpell, 1946 Sweetbriar, Jacksonville, Fla. 32217.

DISCOUNTS — KLM, Larsen, Brimstone, Stereo Systems, Police Monitors, etc. Catalog available. Bankamericard & Mastercharge. 201-962-4695 Narwid Electronics, 61 Bellot Road, Ringwood, N.J. 07456.

TRAVEL PAK QSL KIT — Send call and 25¢; receive your call sample kit in return. Samco, Box 203, Wynantskill, N.Y. 12198.

2-METER CRYSTALS, $3.50 each, for all popular rigs. In stock. Immediate delivery. Send cash or money order, we pay postage. Rolin Distributors, P.O. Box 436, Dunellen, N.J. 08812.

TRANSMITTING TUBES, HV and filament xfmrs, rotary inductors, transmitting capacitors. Send stamp for flyer. T.S. Marinich Electronics, 102 Bell St., Weirton, W. Va. 26062.

SAVE! BEARCAT SCANNERS. $259.95. New. E.R. Brooks Guns, 6612 Eastern Ave., Bell Gardens, CA 90201 (213) 773-5193.

MOBILE IGNITION SHIELDING provides more range with no noise. Available most engines. Many other suppression accessories. Literature, Estes Engineering, 930 Marine Dr., Port Angeles, WA 93862.

300 MHz B&K counter, and prescaler. Price breakthrough! $191 postpaid. Portable. Factory built. Details, catalog free. Spacetron-J, 948 Prospect, Elmhurst, ILL. 60126.

MOTOROLA HT220, HT200, and Pageboy service and modifications performed at reasonable rates. WA4FRV (804) 320-4439, evenings.

B&K TEST EQUIPMENT. Free catalog. Free shipping. Dinosaur discounts. Spacetron-"D", 948 Prospect, Elmhurst, ILL. 60126.

QSL's, CATALOG 30¢. RTTY paper 4½ inch rolls white, case of 12 $25.00 plus shipping. P. O. Box 11184, Phoenix, Arizona 85061.

MODEL 28 Consoles, RO's — $135.00, KSR's — $175.00, ASR's — $325.00. Goodman, 5454 South Shore Drive, Chicago, ILL. 60615 (312) 752-1000.

OLD TIMERS TOO rave about Ham Radio HORIZONS, amateur radio's exciting, new, fun magazine! Join in the action. 12 issues for $10.00. Ham Radio HORIZONS, Greenville, NH 03048.

AMECO TX62 (55.00). 1330 Curtis, Berkeley, CA 94702 (415) 526-7345.

MOBILE BONDING STRAPS under 50¢ each. Literature. Estes Engineering, 930 Marine Drive, Port Angeles, Wash. 98362.

FOR SALE Hallicrafter SR 150 AC supply D-104 MIC. Good condition $250.00, WB4KIZ, John P. Rentz, P.O. Box 284, Twin Lakes, CA 31605.

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DEALERS, Stock HAM RADIO and Ham Radio HORIZONS in your store. Call 800-258-5353 for complete details.

FERRITE BEADS: w/specification and application sheet - 10/$1.00. Assorted PC pots - 5/$1.00. Miniature mica trimmers, 3-40 pf. - 5/$1.00. Postpaid. Includes latest catalog. Stamp for catalog alone. CPO Surplus, Box 189, Braintree, MA 02184.

COILS WANTED: Need complete set of B & W kilowatt HDVL plug-in coils with jack bar and link assembly. Same style in E.F. Johnson would be acceptable. All replys answered. Wayne N8MS, Rt. 2, Box 305, Fairmont, West Virginia 26554.

VERY In-ter-est-ing! Next 4 issues $1. "Ham Trader" Yellow Sheets, Sycamore, IL 69178.

HAMMARLUND HQ 170, Hammarlund HX 50 with manuals, good working & looking cond., new tubes. $300.00. WB4FSN, 708 Holston, Elizabethton, Tennessee 37643 615-543-2830.

ETCH IT YOURSELF PRINTED CIRCUIT KIT, Photo-Positive Method — All the supplies for four P.C. boards, direct from magazine article in less than 2 hours. Only $19.95 S.A.S.E. for details. Excel Circuits, P. O. Box 891, Troy, Michigan 48099, 313-549-0440.

475 TEKTRONIX portable scope. Early model, used very little. $1375.00, includes all necessary accessories. Call 503-642-1088 or write: Jim Lowe, 19699 SW Wright, Aloha, OR 97005.

MODERN CODE PRACTICE. 0-22wpm on four 60 min. cassettes, $10. Royal, P. O. Box 2174, Sandusky, Ohio 44870.

FOUR SCHOLARSHIPS for the academic year 1977-78 are being offered to licensed Amateurs — General class or higher — by the Foundation for Amateur Radio. Requirements for the scholarships, two for $750 each and the others for $250 each, differ; full details and application forms should be requested from FAR Scholarships, 8108 Hampden Lane, Bethesda, MD 20014.

EXCLUSIVELY HAM TELETYPE 23rd year, RTTY Journal, articles, news, DX, VHF, classified ads. Sample 35¢. $3.50 per year. Box 837, Royal Oak, Michigan 40868.

FIGHT TVI with the RSO Low Pass Filter. For brochure write: Taylor Communications Manufacturing Company, Box 126, Agincourt, Ontario, Canada. MIS 3B4.

RUBBER STAMP, name/call/QTH $2.50 ppd. (CA residents add tax). LWM Press, Box 22161, San Diego, CA 92122.

FOR SALE: Heathkit RF Generator. Mint condition. $45.00. Please write. Eric Bartlett, 20 Park St., Fitchburg, Mass. 01420.

TELETYPEWRITER PARTS, gears, manuals, supplies, tape, toroids. SASE list. Typetronics, Box 8873, Ft. Lauderdale, FL. 33310. Buy parts, late machines.

TECH MANUALS for Govt. surplus gear — $6.50 each: SP-600JX, URM-25D, OS-8A/U, TS-173/UR. Thousands more available. Send 50¢ (coin) for 22-page list. W3IHD, 7218 Roanne Drive, Washington, DC 20021.

MANUALS for most ham gear, 1939/70. List $1.00. Send SASE (or 25¢) for one specific model quote. Hobby Industry, WØJJK, Box H864, Council Bluffs, Iowa 51501.

RTTY — NS-1A PLL TU — Due to continued interest and demand we are resuming production. Board $3.00, parts kit (no board) $15.00, wired/tested $24.95 all postpaid. SASE for info. Nat Stinnette Electronics, Tavares, FL 32778.

STAINLESS AND GALVANIZED STEEL antenna guy wire our specialty. Wilcox Electronics, Box 1331, S. L. C. Utah 84110.

VARIABLE AND TRIMMER CAPACITORS — RF chokes — Miniductors; stocked for immediate shipment. First class stamp for flyer. D & V Radio Parts, Rt.#2, Freeland, Michigan 48623.

HELP FOR YOUR NOVICE, general, advanced ticket. Recorded audio-visual theory instruction. Free information. Amateur License Instruction, P. O. Box 6015, Norfolk, Va. 23508.

TRANSISTORS, IC's, Communications — CB Save — Save — Low Cost — Direct 2SC1307 — $3.85, 2SC1306 — $2.95. Send for dealer confidential price list — Get Free Transistor. B&D Enterprizes, Box 32 Dept. 2, Mt. Jewett, PA 16740.

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NEW FROM HY-GAIN 2-METER BEAMS THAT LAST LONGER. WORK HARDER. AND COST LESS.

Introducing a whole new generation of Hy-Gain 2-Meter beams.

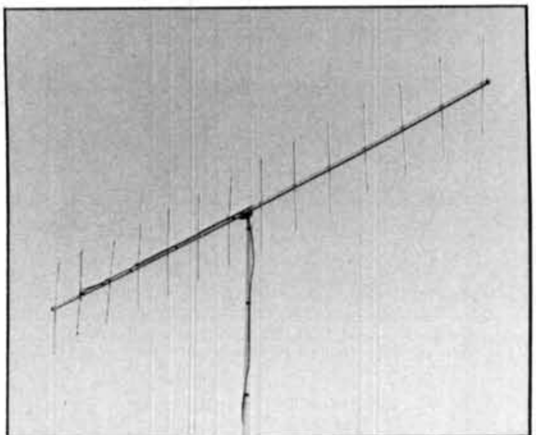
Completely redesigned for greater strength and corrosion resistance. So they last longer.

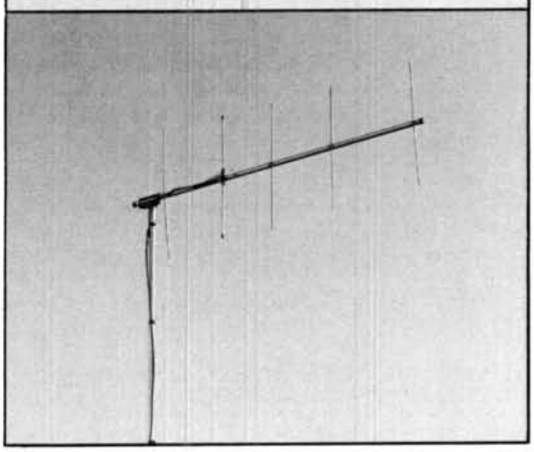
Newly engineered for greater performance and maximum efficiency. So they work harder, your transceiver works better.

And built better. So you pay less for the performance you want.

Our new 2-Meter beams give you the kind of performance you expect from the world's largest manufacturer of quality antennas. Yet, thanks to Hy-Gain technology, they weigh less, have lower wind loading and are UPS shippable.

They use an exclusive new element to boom mounting system that's mechanically stronger and electrically more efficient. All can be vertically or horizontally polarized. And all are constructed of the finest aluminum and ZMI hardware.





Hy-Gain 214 14-element close spaced beam with extremely high forward gain and narrow beam width. **$26.95**

Also available with 8-element optimum spacing, **Hy-Gain 208. $19.95**

Hy-Gain 205 5-element optimum spaced end mount beam with high forward gain and broad frequency response. **$16.95**

Also available with 3 elements, **Hy-Gain 203. $12.95**

See the new generation of Hy-Gain 2-Meter beams at your amateur radio dealer. Or write Hy-Gain; 8601 Northeast Highway Six; Lincoln, NE 68505.

hy-gain®

WE KEEP PEOPLE TALKING.

Hy-Gain reserves the right to change prices, designs and/or specifications at any time without notice.

SPECIFICATIONS	214	208	205	203
Mechanical				
Boom length	186″	148 ¾″	75″	43½″
Longest element	39½″	40¼″	39 ⅝″	40¼″
Turning radius	95″	75 ⅛″	73″	43½″
Wind survival	80 mph	80 mph	80 mph	80 mph
Mast diameter	1¼-1⅝″ O.D.	1¼-1⅝″ O.D.	1¼-1⅝″ O.D.	1¼-1⅝″ O.D.
Boom diameter	1¼″ O.D.	1¼″ O.D.	1¼″ O.D.	1¼″ O.D.
Wind load area	1.65 ft^2 max.	1.26 ft^2 max.	.740 ft^2 max.	.496 ft^2 max.
Net weight	5.5 lbs	4.1 lbs	2.9 lbs	2.2 lbs
Electrical				
Forward gain	13.0 dBd*	11.8 dBd*	9.1 dBd*	6.1 dBd*
Front-to-back ratio	20 dB	20 dB	20 dB	20 dB
Maximum SWR	2:1	2:1	2:1	2:1
Band width	2 MHz	2 MHz	4 MHz	4 MHz
Maximum power	250/500 PEP	250/500 PEP	250/500 PEP	250/500 PEP
Impedance w/balun	52 ohms	52 ohms	52 ohms	52 ohms
½ power beam width	35° vertical 35° horizontal	43° vertical 36° horizontal	60° vertical 45° horizontal	95° vertical 60° horizontal
Stacking distance	82″ min.	82″ min.	82″ min.	82″ min.

*Hy-Gain antennas are gain rated against a standard dipole antenna (dBd) instead of a theoretical isotropic source (dBi). This is a more honest and realistic means of comparing forward gain.

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STOP LOOKING for a good deal on amateur radio equipment — you've found it here — at your amateur radio headquarters in the heart of the Midwest. We are factory-authorized dealers for Kenwood, Drake, Collins, ICOM, Ten-Tec, Atlas, Tempo, Regency, Swan, Midland, Alpha, Standard, Dentron, Hy-Gain, Mosley, Cushcraft, and CDE, plus accessories. For the best deal around on HF or VHF gear, write or call us today for our low quote and become one of our many happy and satisfied customers of HOOSIER ELECTRONICS, P.O. Box 2001, Terre Haute, Indiana 47802. (812)-238-1456.

ROHN 25/45 Tower sections wanted. Pick-up, take-down, W1/W2 areas preferred. Need only few for final setup. M.S. Pride, 603-472-5000.

FREE CATALOG. Solar Cells, Nicads, Kits, Calculators, Digital Watch Modules, Ultrasonics, Strobes, LEDS, Transistors, IC's, Unique Components. Chaneys, Box 27038, Denver, Colo. 80227.

JANEL 6 meter F.E.T. converter, I.F. 285 MHz $60.00. James Gysan, W1VYB, 53 Lothrop St., Beverly, MA 01915.

WANTED: 4CX-250B/4CX 250K (W6RGZ), 1330 Curtis, Berkeley, CA 94702.

NEW TV Cameras $150.00, video tape $3.00 per hour. D.G. Trimble, 5835 Herma, San Jose, Ca. 95123.

POWERFUL, ADJUSTABLE, REGULATED, THREE OUTPUT POWER SUPPLY and 900 easily removable parts in complete Cartrivision television recorder electronic assembly with documentation. Perfect for Microprocessor, IC, transistor, television, CB radio applications. $21.45. Free brochure. Madison Electronics, Incorporated, 369, D77, Madison, Alabama 35758. Satisfaction Guaranteed.

DIGITAL ELECTRONICS: Your Ham headquarters in New Orleans. Representing Drake, Ten-Tec, Atlas, KLM, Hy-Gain, Tri-Ex, Rohn, Regency, Midland, Wilson, CDE, Dentron, Larsen, Nye-Viking, New-Tronics, Standard, Swan, B&W, Millen, Amidon, and W2AU. Call or write Chuck, W5VJG for quotes. Trade ins accepted. BankAmericard & Mastercharge. Digital Electronics, Inc., P.O. Box 30566, New Orleans, 70190. (504)-568-9879.

DEALERS, Stock HAM RADIO and Ham Radio HORIZONS in your store. Call 800-258-5353 for complete details.

Coming Events

W6LS 12th Los Angeles Amateur Radio Convention. Saturday and Sunday, May 21 & 22. 2814 Empire Ave., Burbank, CA 91605.

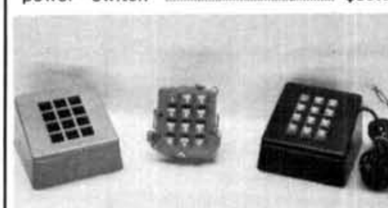
ROME HAM FAMILY DAY, June 5, 1977. Bring the XYL and kids and spend a great day at the Beeches, Rt 26, Rome, NY. We have over 5000 square feet of indoor display area and a giant flea market. For the family we offer a free tour of Ft. Stanwik. For the ham we have interesting programs, contests, door prizes, equipment displays, exhibits, and technical presentations. At the end of the day relax and treat the family to the famous Beeches buffet. For info write PO Box 721, Rome, NY 13440. (Exhibitors are urged to reserve free display area now).

COME TO CANADA this summer for Ontario Hamfest 77. July 8-10 1977, sponsored by Burlington Amateur Radio Club. Weekend camping, fleamarket, auction, many displays. Write Box 836 Burlington Ont. L7R3Y7 for descriptive brochure.

MEMPHIS IS BEAUTIFUL IN OCTOBER! The Memphis ARRL-sponsored Hamfest, bigger and better than the 4,500 who attended last year, will be held at State Technical Institute, Interstate 40 at Macon Road, on Saturday and Sunday October 1 and 2. Demonstrations, displays, MARS meetings, flea market, ladies flea market, too! Hospitality room, informal dinners, XYL entertainment, many outstanding prizes. Dealers and Distributors welcome. Contact Harry Simpson W4SCF, PO Box 27015, Memphis, TN 38127 for further information.

STARVED ROCK RADIO CLUB HAMFEST — June 5. S.A.S.E. after 4/1/77 for details. SRRC/W9MKS, RFD #1, Oglesby, Ill. 61348.

WEST VIRGINIA: THE TRI STATE AMATEUR RADIO ASSN. W8VA (TARA) 15th. annual Hamfest, Sunday, June 5th. 11:30 a.m. Camden Park, Rte. West, Huntington. Talk-in on 04/64, 16/76 and 34/94. For info and tickets write: TARA, P.O. Box 1295, Huntington, W. Va. 25715.



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PREASSEMBLED **COMPLETE KIT**

Crescomm Frequency Counters Features:

1 High Sensitivity VHF pre-scaler (built-in). 100mv RMS @ 50Ω @ 300MHZ. Frequency range DC through 600MHZ Model 600.

2 Excellent temperature compensation crystal controlled time base, yielding ±1 part/ 10^6 stability per hour after 10 min warm-up, ± 10PPM worst case, from 0^o to + 55^oC!, at 100Hz @ 450MHZ is attainable, typically if calibrated to WWVL. This is approximately 2 parts in 10^7!

3 7 digit display, resolution 100Hz with 10m Sec. gate interval, pre-scaled! 10Hz resolution with 1 Sec. pre-scaled, 1Hz resolution with 10 Sec. gate interval pre-scaled!

4 Built-in 5VDC regulator; input to 3-terminal regulator is accessible for use with 12VDC out-board PS. **You can use this counter mobile.**

5 Easy 6 hour assembly; all circuit broad tracks are pre-tinned, have drilled holes and are plated through! All I.C. sockets included - Makes trouble shooting a breeze.

6 Cabinet, plexy window and all necessary components included for easy, trouble-free assembly.

7 90-Day full coverage warranty.

Optional accessories TCXO time base yielding ½ PPM stability. $79.95

Optional 10 Sec. time gate resolution to 1Hz. $15.00. (Free with purchase of above TCXO)

Optional 12VDC power recepticle and cord assembly $15.00 (on preassembled counter only)

"HAVE IT YOUR WAY"

Complete kit or preassembled, burned in, and environmental chamber tested unit available for the commercial shop or modern ham shack.

KIT Model 600K 179.00 ea. PREASSEMBLED & TESTED Model 600 AT 249.00

Bank Americard and Master Charge accepted. Please include account number with order.

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STREET ______________________

CITY ____________ STATE ____________ ZIP ________

CALL SIGN ______ SEND CHECK OR MONEY ORDER TO:

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SEE YOU AT THE ATLANTA HAMFESTIVAL, JUNE 18-19

Bldg. 13 Euclid Avenue, Newark New Jersey 07105 (201) 589-4647

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flea market

KENTUCKY HAM-O-RAMA — Sunday, May 29 (Memorial Day Weekend) at Boone County Fairgrounds, Burlington, Kentucky. 10 minutes south of Cincinnati, 2 miles west of I-75 South, Burlington exit. Prizes, refreshments, exhibits, flea market. NKARC, Box 31, Ft. Mitchell, Kentucky 41017.

PERKIOMEN VALLEY ARC Hamfest June 5, 1977 at the Perkiomenville Sale and Auction Ground, Rt. 29 Perkiomenville, Pa. Tables available for flea market. Talk-in on 28/88. Also channel 14. Site is located south of Green Lane on Rt. 29 in the scenic hills of Pennsylvania. For information and reservations contact Bob Bosch, WA3EBX, 215-679-5143.

CADILLAC MICHIGAN 17th Annual Swap-Shop will be held Saturday, May 21st 1977 at the National Guard Armory, Cadillac, Michigan. Free parking, everyone welcome. Tickets $2.00. Talk-in on 146.37/97.

ANN ARBOR, Michigan, Arrow Repeater Hamfest, June 5, Chelsea Fairgrounds, I-94 at exit 159. Nearby overnight camping. Table and truck sales. Tickets $2 gate, $1.50 advance. Write Arrow, Box 1572, Ann Arbor, MI 48106.

18TH ANNUAL STARC HAMFEST May 7, Binghamton, NY. Flea market, snack bar, tech talks, hourly door prizes. Admission $2.00, banquet reservation $6.00. Indoor exhibit reservation $5.00/table. Contact STARC, P.O. Box 11, Endicott, NY 13760.

NEW YORK CITY. The 4th annual Hall of Science A.R.C. Flea Market and Hamvention. 111th Street and 48th Ave. Corona-Queens. Refreshments, Zoo Museum. Dealers booths, test bench. Family fun Sunday June 12 (rain date June 19) 9 AM-3. Admission $2.00 door prizes. Talk in .34/94. Information (212) 699-9400.

BETTER THAN EVER-1977 EDITION GOLDEN SPREAD HAMFEST AND FLEA MARKET-Holiday Inn West-Amarillo, Texas Aug. 12, 13 & 14. Six big tech sessions. Commercial exhibits. Family recreation. Two Hospitality Hours. Big pre-registration prize and super Grand Prize, others. $3.00 advance, $4.00 at door. For info. pre-registration packet, P. O. Box 10221, Amarillo, Texas 79106.

HAMFESTERS 43rd Annual Picnic and Hamfest. Sunday August 14, 1977, Santa Fe Park, 91st and Wolf Road, Willow Springs, Illinois, Southwest of Chicago. Exhibits for OM's and XYL's, Famous Swappers Row. Tickets at gate $2.00, advance $1.50. For advance tickets send check or money order to Bob Hayes W9KXW 18931 Cedar Ave., Country Club Hills, Ill. 60477.

K1FCO, members of the 143 Communications Flight (Spt), Rhode Island Air National Guard, plan to be operating on Armed Forces Day, May 21, 1977. Anyone working our club station, K1FCO, will receive a commemorative certificate from our unit provided a S.A.S.E. and QSL card is sent to us. Our mailing address is: K1FCO, 143 Communications Flight, Rhode Island Air National Guard, T.F. Green Airport, Warwick, R. I. 02886. We will be operating on the following frewquencies: 21.385 MHz 1400Z to 1800Z, 14.330 MHz 1400Z to 1800Z, 7.280 MHz 1400Z to 1800Z, 50.700 MHz, 1400Z to 1800Z.

NEW JERSEY: The Irvington Radio Amateur club hamfest, Flea-Market will be held at the P.A.L. building, 285 Union Ave., Irvington, N.J. May 15, 1977 from 9 A.M. to 4 P.M. Prizes, refreshments. The PAL Building Borders the Garden State Parkway at exit 143. Talk-in 34-94 and 52. Tables $3. Info. write Radio Club, P.A.L. 285 Union Ave., Irvington, N.J. 07111 or call evenings WA2MYZ Ed 201-687-3240.

THE EASTERN CONN. AMATEUR RADIO ASSOC. — K1MUJ — will hold their 4th annual Flea Market on May 22, 1977 at Point Breeze Rest, Webster, Mass. Time will be from 10:00 AM to whenever. Dealer fee will be $5.00. Admission for buyers will be 50¢ per person. Free parking. Take Rt. #52 to Exit 1 in Webster then South on Rt. 193 one mile. Look for signs. Talk-in on 52 direct, 16-76, 10-70, 825-225, CH. 14. Need more info? Call Dick, K1MUJ, 617-943-4420 after 7 or Mike WA2RLV, 203-774-2854 anytime. Food & refreshments available.

HOSSTRADERS Fourth Annual Tailgate Swapfest, Sat. May 7, all day, at the Deerfield NH Fairground, under covered buildings. Admission only 75¢. No commission or percentage, dealers welcome at same rate. Excess revenues to benefit Shriners Hospital for Crippled Children in Boston. (Last year our Seabrook Swapfest sent $206.75 to March of Dimes.) For more info, SASE to Norm, WA1IVB, Box 32, Cornish, Maine 04020, or Joe K1RQG, Star Rd., Box 56, Bucksport, Maine 04416.

More Details? CHECK—OFF Page 150

The DRAKE TR-33C

$229.95

Amateur VHF FM Transceiver

- **Hand Held Convenience, 12 Channel Capability**
- **SCPC** *(Single Crystal Per Channel)* **Frequency Control**
- **Lower Receiver Battery Drain**
- **Expanded Portable Antenna Choice**

• 12 Channels—only one crystal per channel provides simplex OR repeater operation on ANY channel. 2 channels supplied. 5 transmit offset positions, 3 supplied. • All FET front-end crystal filter for superb receiver intermod rejection. • Small convenient microphone included. • New lower power drain circuit on squelched receive. • Nicad rechargeable batteries supplied. • Built-in battery charger. • Ac and dc power cords supplied. • Telescoping screw-on antenna supplied, rubber helix optional. • Channel indicator light when using external dc supply. • Carry strap supplied. • Meter Indicates receive strength, xmit output, or battery voltage. • External speaker jack on rear panel. • Auxiliary jack on rear panel—may be used for tone-pad connections, etc. • Traditional R.L. Drake service backup.

DRAKE TR-33C SPECIFICATIONS

GENERAL: • **Frequency Coverage:** 146-148 MHz, 12 channels (2 supplied: 146.52 and 146.94). Crystal determines receive frequency. • Transmit frequency offset for repeater operation determined by 5-position switch: Simplex, +600 kHz, and −600 kHz supplied; any two additional offsets available with accessory crystals. • **Power requirements:** 13.0 volts dc ± 15% external supply OR internal battery supply. • **Current Drain (Batteries):** Squelched receive: 30 mA; transmit: 400 mA. External supply: above plus 45 mA for channel switch indicator lamp. • **Antenna:** 50 ohm external antenna through SO-239 connector OR screw-on telescoping whip antenna supplied, may be replaced with rubber helix antenna. • **Dimensions:** 5.5" x 2.8" x 8.5" (13.8 x 5.8 x 21.6 cm). • **Weight:** 4.4 lbs (2 kg).

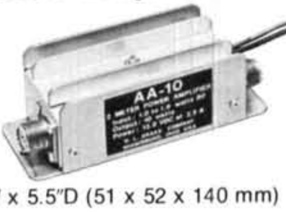
RECEIVER: • **Sensitivity:** less than .5 μV for 20 dB noise quieting. • **Selectivity:** + 30 kHz adjacent channel rejection greater than 75 dB. • **Modulation acceptance:** at least ± 7 kHz. • **Inter modulation Rejection:** 70 dB referenced to sensitity level. • **First i-f:** 10.7 MHz with monolithic crystal filter. • **Second i-f:** 455 kHz with ceramic filter. • **Audio Output:** nominal 1 watt at less than 10% distortion into 8 ohm built-in speaker or external speaker.

TRANSMITTER: • **Rf Output Power:** 1.5 watts minimum with 13.0 volts dc supply. • **Frequency Deviation:** Direct frequency modulation adjustable to at least ± 7 kHz deviation, factory set at ± 5 kHz • Separate microphone gain and deviation adjustments • Drake 1525EM Push Button Encoding Mike can be used direct with no modification.

DRAKE TR-33C ACCESSORIES

Drake AA-10 Power Amplifier

10 dB power increase greatly adds to the transmitting distance covered by any 2-meter fm transceiver running up to 1.8 watts output



Small size: 2"H x 2.1"W x 5.5"D (51 x 52 x 140 mm)

Drake AC-10 Power Supply

Powers the AA-10, TR-22C, TR-33C and TR-72. Simultaneously can charge the TR-22C/33C nicads. Supplies 13.8 volts up to 3 amps from 120 V-ac 60 Hz input. • **Accessory Crystals.** • **Model No. 1333 Drake MMK-33 Mobile Mount.**

- **Model AA-10 Power Amplifier .... $49.95 ea.**
- **Model AC-10 Power Supply .... 49.95 ea.**
- **Accessory Crystals .... 6.30 ea.**
- **Model MMK-33 Mobile Mount .... 12.95 ea.**
- **Model 7079 Vinyl Carrying Case .... 9.95 ea.**

Drake 1525EM Push Button Encoding Mike

- Microphone and auto-patch encoder in single convenient package with coil cord and connector. Fully wired and ready for use.
- High accuracy IC tone generator, no frequency adjustments.
- High reliability Digitran® keyboard.
- Power for tone encoder obtained from transceiver through microphone cable. No battery required. Low current drain.
- Low output impedance allows use with almost all transceivers.
- Four pin microphone plug: directly connects to Drake TR-33C without any modification in transceiver. Compatible with all previous Drake and other 2 meter units with minor modifications.

Drake 1525EM, microphone with tone encoder — **$49.95**
Drake 7073DM without tone encoder — **$19.00**

All prices (suggested amateur net) and specifications subject to change without notice.

To receive a FREE Drake Full Line Catalog, please send name and date of this publication to:

R. L. DRAKE COMPANY DRAKE®

540 Richard St., Miamisburg, Ohio 45342
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flea market

1977 DURHAMFEST May 28-29. South Square Shopping Center, Durham, North Carolina. Two day flea market under covered parking deck. Fantastic prizes, Seminars, Bingo and shopping for the family. Durham FM Assoc. Box 8651, Durham, N.C. 27707.

AUCTION AND FLEA MARKET: Candlewood Amateur Radio Association will hold their annual auction and flea market Sat. May 14 at St. Mary's School, downtown Ridgefield Conn. Doors open 10 a.m. Auction 1 p.m. Admission $1. Table space $1. Outdoor tail gate space available S.A.S.E. to K1QPP for info & map.

EASTERN SHORE OF MARYLAND HAMFEST, MAY 22, 1977. Rain or shine, 10 am — 4pm. Only hamfest held on the Eastern Shore of Maryland or the Del-Mar-Va. Peninsula. Location is 5 miles north of Easton, Maryland on US Rt. #50, at the Talbot County Agricultural Center. From the Baltimore or DC area, go across the Chesapeake Bay Bridge and follow Rt. 50 East for 21 miles from the bridge. Exact location is between mile markers 60 & 61. Hamfest signs will be on Rt. 50 both north and south, and talk-in on .52, and 146.445-147.045. Some tables available both inside and outside. Food and drinks. Lots of room. Donation $2.00. Additional $2.00 for tables and tailgaters. Info. from K3ONU, Robert L. Roberts, Jr., PO Box 781, Easton, Md. 21601. Phone 301-822-0943 after 6PM.

MISSISSIPPI IS BEAUTIFUL IN JUNE. The Tri-State Hamfest will be held at the National Guard Amory, Interstate 55, at Hernando, on Sat. & Sunday June 11th and 12th. Demonstrations, displays, forums, flea market, hospitality room, informal dinners with many outstanding prizes. Dealers welcome too. All indoor facilities with plenty of parking. Contact Royce Gates, WB5EGO % C.A.R.A. P.O. Box 2, Hernando, Miss. 38632.

WASHINGTON D.C. AREA— Manassas Hamfest: The "Ole Virginia Hams" A.R.C. Inc. Annual Hamfest June 5, 1977 at the Prince William County Fairgrounds, ½ mile south of Manassas, Virginia on Rt. 234. Gates open 7 am — Fantastic Prizes again this year 5 Band SSB Transceiver, Digital Frequency counter, Bird 43 Wattmeter and many others. Admission $3.00, children under 12 free. Tailgating $2.00 per vehicle. Refreshments, YL Program, Children's Entertainment, FM Clinic: Spectrum Analysis, Deviation, and Power Checks. Lecture on QSL Bureaus. Talk-in on 146.37/97 146.52 147.84/24. Campground adjacent — Motels in Area. Indoor exhibit space available for Dealers, for info Write: Frank Atkinson K4CB, Box 1255, Manassas, Virginia 22110.

THE SATELLITE AMATEUR RADIO CLUB is sponsoring its annual Santa Maria Amateur Radio Picnic and Swapfest, Sunday June 19, beginning at noon, Newlove-Union Oil Picnic Grounds on Orcutt Hill. (Watch for the sign at turn-off one mile south of Clark Ave. on U.S. 101). Swap tables $3 each. Santa Maria Style Barbecue 2:30 p.m. (all you can eat), soft drinks available, bring your own beer. Talk-in on 146.52 and 7280 KHZ. Many prizes including a Yaesu FT 221. Tickets $5. adults, $2.50 for under 12. Send checks to Santa Maria Swapfest, Box 1031, Nipomo, California 93444. Please order in advance so enough meat can be ordered.

THE HUMBOLDT AMATEUR RADIO CLUB'S annual hamfest will again be held this year on Sunday, May 22, at Shady Acres City Park in Trenton, Tenn. Flea market, prizes, ladies activities, etc. For further information contact Ed Holmes, W4IGW, 501 N. 18th Ave., Humboldt, TN 38343.

CHAMPAIGN/LOGAN A.R.C. annual Flea Market. Free admission. Door prizes. Time: 10:00 AM. Date: Sunday, May 15. Place: Lion's Park, West Liberty, OH Talk-in on 52 Simplex. Vendors $1.00.

Stolen Equipment

STOLEN: Swan Model 400 Transceiver, #100801, grey case, from my car on 2-10-77 at 17137 E. Gale Ave., City of Industry, CA 91745, Ira C. Bechtold. Refer any info to Sheriff's Dept. (213) 330-3322, Detective Bureau, File #577-02681-1424-696.

A CLEGG FM-DX 2 meter FM transceiver (serial #HM-298) and microphone were stolen from the van of WA3BGN on Feb. 5, 1977, in downtown Bridgeport, Conn. Please contact Jon P. Zaimes, WA3BGN, 681 Longhill Ave., Shelton, Conn. 06484 (phone 203-929-4659) or the Bridgeport police department, file #6856.

More Details? CHECK—OFF Page 150

More Details? CHECK—OFF Page 150

State of the art

by **K.V.G.**

CRYSTAL FILTERS and DISCRIMINATORS

9.0 MHz FILTERS

XF9-A	2.5 kHz	SSB TX	$33.55
XF9-B	2.4 kHz	SSB RX/TX	$47.75
XF9-C	3.75 kHz	AM	$51.40
XF9-D	5.0 kHz	AM	$51.40
XF9-E	12.0 kHz	NBFM	$51.40
XF9-M	0.5 kHz	CW (4 pole)	$35.95
XF9-NB	0.5 kHz	CW (8 pole)	$67.15

9.0 MHz CRYSTALS (Hc25/u)

XF900	9000.0 kHz	Carrier	$4.00
XF901	8998.5 kHz	USB	$4.00
XF902	9001.5 kHz	LSB	$4.00
XF903	8999.0 kHz	BFO	$4.00
F-05	Hc25/u Socket		.50

Export Inquiries Invited

Shipping $1.25 per filter

VHF CONVERTERS UHF

	MMc50	MMc144	MMc220	MMc432	MMc1296
RF Freq. (MHz) †	50-54	144-148	220-224	432-436	1296-1300
IF Freq. †	28-32	28-32	28-32	28-32	28-32
N.F. (typical)	2.5dB	2.8dB	3.4dB	3.8dB	9.0dB
Nom. Gain	30dB	30dB	26dB	28dB	20dB
	$44.95	$49.95	$54.95	$59.95	$69.95

†Other ranges, amateur, commercial & scientific to order. Power 12V DC Low N.F. units on special order. Size 1¼" x 2½" x 4½" plus connectors. L.O. output option — $5.00 extra. Shipping: Converters $2.50 each.

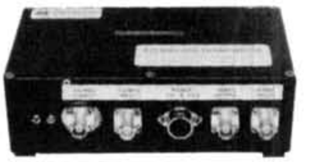
432 MHz SSB TRANSVERTER, MMt432

Use your HF Transceiver on the 432 MHz band with the addition of the MMt432 linear Transverter. The MMt432 operates on all modes; SSB, CW, AM, FM. It contains BOTH the linear transmit up-converter and the receive down-converter. An internal PIN diode T/R connects to your Transceiver T/R line. The MMt432 is FT101 and similar HF rig compatible. Add the 70/MBM48 MULTIBEAM and operate direct into OSCAR 7 mode B. Write for free application note.

Specifications:

Output Power	10 W peak
Drive, 10 meters	½ W max
Receiver N.F.	3.0dB max
Receiver gain	30 dB typ
Bandwidth	4 MHz
Prime Power	12 V D.C.

Price **$254.95**
Shipping: $3.50



Also Available:
144 MHz SSB Transverter, MMt 144 $214.95

146 MHz 440 MHz FM TRANSVERTER

Use your 2 meter Transceiver on the 440 MHz band with addition of the FMt440 TRANSVERTER. No changes needed to your 2 meter transceiver. Connect FMt440 in place of regular 2 meter antenna. Switch selected band changeover. Write for application note.

FMt440 Specifications:

2 meter Drive Power	30 W max
440 MHz Sensitivity	0.5μVolt
Frequency Ranges	144 - 150 MHz 430 - 450 MHz

Price: $174.95 Repeater Groups write for terms
Shipping $3.50 Application Note available free

Also Available
432 MHz Transverter, QMt 432 $174.95

LINEAR AMPLIFIERS and TRANSVERTERS

by POLAR ELECTRONIC DEVELOPMENTS

The linear amplifiers are designed to boost your transmitted power when using the new MMt144, MMt432 solid state transverters or similar low power transmitters on the 2 meter and 70 cm bands. All transmission modes are possible: CW, AM, SSB, FM, RTTY, etc.

Specifications: EDL144

Drive Power	20 W PEP max
Output Power	100 W PEP max
Rx Pre-Amp Gain	20 dB typ
N.F.	2.5 dB typ
Power Supply	115 V A.C.
Size:	10" x 6" x 7"

The EDL144 amplifier contains a high power transmit linear amplifier (5894 PA) and power supply (115v) together with a low noise receive pre-amplifier (2.5 dB NF). T/R switching is automatic by an internal VOX circuit; no changes are needed to your existing transceiver.

Specifications: EDL432P

Drive Power	10 W PEP max
Output Power	50 W PEP max
Power Supply	115 V A.C.
Size:	10" x 6" x 11"

The EDL432P amplifier contains a high power triode amplifier (2C39A) with matching power supply (115v). The cabinet also contains the cooling air blower, antenna relays and full metering. The RF section is also available as a complete sub-assembly, model EDL432, for use with an existing power supply etc.

Use your 10 meter transceiver with the EDT50-28 or EDT144-28 transverters to operate on the 6M or 2M bands. These transverters operate in all modes; they have the same style P.A. design as the EDL144 amplifier. Receiving is with a MMc50 or MMc144 style converter mounted inside the cabinet.

Specifications:

EDT50-28	50-52 MHz
EDT144-28	144-146 MHz
Drive Power, 10M	0.5 W max
Output Power	100 W PEP max
Rx Gain	30 dB typ
N.F.	2.5 dB typ
Size:	10" x 6" x 7"

An external power supply is required.

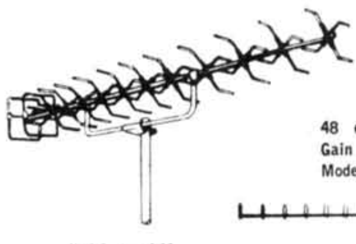
Write for full details and application notes. Visit our Dayton booth to see the full line demonstrated.

ANTENNAS

144-148 MHz

Model 8XY/2M	$39.95
Gain 9.5dB in each plane, 50Ω feed.	
For OSCAR communications add Circular polarization harness, PMH/2C	$9.70
Also available for 2 meters:	
8 over 8 J-Slot, Model D8/2M	$39.95
8 by 8 vertical pol. D8/2M-vert.	$48.70

for CW AM FM SSB OSCAR



420-450 MHz

48 element J-Beam MULTIBEAM
Gain +15.7 dBd. Feed 50Ω coaxial.
Model 70/MBM48 $52.45

1296 — LY
1296 MHz LOOP-YAGI
GAIN +20dBi
FEED 50Ω COAXIAL
$54.45

1250-1340 MHz

Shipping: Antennas FOB Concord, Mass. via UPS.
Write direct for Polar plots, Gain & VSWR curves.

si Spectrum International, Inc.
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Concord, Mass. 01742, USA

Send 26¢ (2 stamps) for full line catalogue of KVG crystal products and all your VHF & UHF equipment requirements.

Pre-Selector Filters	Pre-Amplifiers	SSB Transverters
Varactor Triplers	Crystal Filters	FM Transverters
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More Details? CHECK—OFF Page 150

AMCOMM S225 SYNTHESIZED TRANSCEIVER

730 WEST McNAB ROAD
FORT LAUDERDALE, FLORIDA 33309

SPECIFICATIONS

Frequency coverage:	144.000MHz to 147.995MHz
Number of semiconductor devices:	36 Transistors, 31 ICs, 8 LEDs
Modulation type:	16F3 emissions
Power requirement:	13.6 VDC.
Current drain:	Transmit — 6.5 Amps, Receive — 1.4 Amps, at maximum display brilliance.
Antenna input:	50 Ohms unbalanced
Dimensions:	7⅛" wide x 2⅝" high x 11½" deep (overall).
Weight:	4½ lbs.

TRANSMITTER

Frequency coverage:	144.000MHz to 147.995MHz in 5KHz steps (800 Channels).
Switching:	Solid-state type.
Audio distortion:	Less than 7% at 1KHz, 2/3 system deviation.
Frequency control:	Digitally synthesized
Modulation system:	Phase modulation
Microphone:	Low impedance professional grade.
RF power output:	25 Watts maximum, variable approximately from 2-25 Watts.
Frequency stability:	Within ±5PPM from —20°C to +60°C.
Audio frequency response:	+2dB to —8dB from the standard 6dB per octave de-emphasis, from 300Hz to 3000Hz
Frequency display:	6 digit, 7 segment LED
Hum and noise:	Better than —30dB 2/3 rated system deviation at 1KHz.
Spurious and harmonic:	At least 60dB below rated carrier power.

RECEIVER

Frequency coverage:	143.000MHz to 148.995MHz, Simplex — 800 Channels with 5KHz separation, Duplex — +600KHz, —600KHz, +1MHz, or —1MHz for each channel.
Frequency control system:	Digital synthesized
Intermediate frequency:	21.4MHz.
Sensitivity (usable):	.35uV, 12dB Sinad @ 50% Audio, 0.5uV minimum for 20dB.
Modulation acceptance bandwidth:	±7.5KHz minimum
Local oscillator frequency stability:	±5PPM
Audio output power:	4 Watts into an 8 Ohm load.
Quieting sensitivity:	(20dB) — 0.5uV minimum
Hum and noise:	—50dB squelched and —30dB unsquelched.
Squelch threshold sensitivity:	0.25uV minimum
Squelch limit sensitivity:	2.0uV or less
Spurious response attenuation:	70dB minimum
Optional accessory:	Plug in Touch-tone Encoder.

The AMCOMM S 2 25 Synthesized Tranceiver is designed and built for mobile amateur use on the 2-meter band. In view of technological improvements, specifications are subject to change without notice.

CONSIDER THESE UNIQUE ADVANTAGES:

1. Unequaled true "State of the Art" technology
2. Superb and unparalleled quality construction
3. Modular snap-in boards with exchange service
4. Variable RF output: 1 - 25 watts
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9. Compact and lightweight
10. Simple, artistic but aesthetic design and finish
11. List price - including touch tone pad $549.90
12. Our introductory price - competitive!

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ICOM IC 22S Frequency Encoder by Trans Com

Have the best of two worlds with your IC 22S. Up to 21 of your favorite frequencies AND full 146 to 148 MHz coverage.

- Tunes from 146.010 to 147.99 MHz in 15 kHz steps.
- Simple installation using either 9 pin ASSY plug or the optional 24 pin ASSY plug.
- Lever type switches for easy frequency selecting.
- Priced at $69.95 (wired and tested)

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Trans Com

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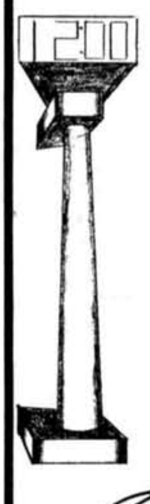
CLOCKS



6 digit AUTOMOTIVE CLOCK KIT complete with a CRYSTAL TIMEBASE accurate to .01 percent. 12 volts d.c. operation — built in noise suppression and voltage spike protection. Readouts blank when ignition is off — draws 25 mA in standby mode. Has .3 in. readouts. Use it in your car or for all applications where a battery-operated clock is needed. Approximate size 3" x 3.5" x 1.75"

WITH BLACK PLASTIC CASE	$34.95 ppd.
WITHOUT CASE	$29.95 ppd.
ASSEMBLED AND TESTED	$45.95 ppd.

CMOS CRYSTAL TIMEBASE KITS with .01 percent accuracy. 5-15 v.d.c. operation. Draws only 3 mA at 12 volts. Single I.C. — very small size — the P.C. board is 7/8" x 1-5/8". Choose a main output of 50 or 100 Hz., 60 Hz., 500 or 1000 Hz., or 1 Hz. Several related frequencies are also available on each board, in addition to the main ones listed above. Be sure to specify the Frequency you want. All kits are $10.95 ppd.

Flyer available —

NEXUS TRADING CO.

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7400N TTL

SN7400N	.16	SN7459A	.25		
SN7401N	.16	SN7460N	.22		
SN7402N	.21	SN7470N	.45	SN74154N	1.00
SN7403N	.16	SN7472N	.39	SN74155N	.99
SN7404N	.18	SN7473N	.37	SN74156N	.99
SN7405N	.24	SN7474N	.32	SN74157N	.99
SN7406N	.20	SN7475N	.50	SN74160N	1.25
SN7407N	.29	SN7476N	.32	SN74161N	.99
SN7408N	.25	SN7479N	5.00	SN74163N	.99
SN7409N	.25	SN7480N	.50	SN74164N	1.10
SN7410N	.18	SN7482N	.98	SN74165N	1.10
SN7411N	.30	SN7483N	.70	SN74166N	1.25
SN7412N	.33	SN7485N	.89	SN74167N	5.50
SN7413N	.45	SN7486N	.39	SN74170N	2.10
SN7414N	.70	SN7488N	3.50	SN74172N	8.95
SN7416N	.35	SN7489N	2.49	SN74173N	1.50
SN7417N	.35	SN7490N	.45	SN74174N	1.25
SN7420N	.21	SN7491N	.75	SN74175N	.99
SN7421N	.33	SN7492N	.49	SN74176N	.90
SN7422N	.49	SN7493N	.49	SN74177N	.90
SN7423N	.37	SN7494N	.79	SN74180N	.99
SN7425N	.29	SN7495N	.79	SN74181N	2.49
SN7426N	.29	SN7496N	.89	SN74182N	.95
SN7427N	.37	SN7497N	4.00	SN74184N	1.95
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SN7437N	.27	SN74122N	.39	SN74188N	3.95
SN7438N	.27	SN74123N	.50	SN74190N	1.19
SN7439N	.25	SN74125N	.60	SN74191N	1.25
SN7440N	.15	SN74126N	.60	SN74192N	.89
SN7441N	.89	SN74132N	1.09	SN74193N	.89
SN7442N	.59	SN74136N	.95	SN74194N	1.25
SN7443N	.75	SN74141N	1.15	SN74195N	.75
SN7444N	.75	SN74142N	4.00	SN74196N	1.25
SN7445N	.75	SN74143N	4.50	SN74197N	.75
SN7446N	.81	SN74144N	4.50	SN74198N	1.75
SN7447N	.69	SN74145N	1.15	SN74199N	1.75
SN7448N	.79	SN74147N	2.35	SN74200N	5.59
SN7450N	.26	SN74148N	2.00	SN74279N	.90
SN7451N	.27	SN74150N	1.00	SN74251N	1.79
SN7453N	.27	SN74151N	.79	SN74284N	6.00
SN7454N	.20	SN74153N	.89	SN74367N	.75

MANY OTHERS AVAILABLE ON REQUEST
20% Discount for 100 Combined 7400's

CMOS

CD4000	.25			74C04N	.75
CD4001	.25			74C10N	.65
CD4002	.25	CD4035	1.85	74C20N	.65
CD4006	2.50	CD4040	2.45	74C30N	.65
CD4007	.25	CD4042	1.90	74C42N	2.15
CD4009	.59	CD4044	1.50	74C73N	1.50
CD4010	.59	CD4046	2.51	74C74	1.15
CD4011	.25	CD4047	2.75	74C90N	3.00
CD4012	.25	CD4049	.79	74C95N	2.00
CD4013	.47	CD4050	.79	74C107N	1.25
CD4016	.56	CD4051	2.95	74C151	2.90
CD4017	1.35	CD4053	2.95	74C154	4.00
CD4019	.55	CD4060	3.25	74C157	2.15
CD4020	1.49	CD4066	1.75	74C160	3.25
CD4022	1.25	CD4069	.45	74C161	3.25
CD4023	.25	CD4071	.45	74C163	3.00
CD4024	1.50	CD4081	.45	74C164	3.25
CD4025	.25	CD4511	2.50	74C173	2.60
CD4027	.69	CD4518	2.50	74C193	2.75
CD4028	1.65	MC14566	3.00	74C195	2.75
CD4029	2.90	74C00N	.39	MC4044	4.50
CD4030	.65	74C02N	.55	MC14016	.56

LINEAR

LM300H	.80			LM1351N	1.65
LM301H	.35			LM1414N	1.75
LM301CN	.35			LM1458C	.65
LM302H	.75	LM370N	1.15	LM1496N	.95
LM304H	1.00	LM373N	3.25	LM1556V	1.85
LM305H	.95	LM377N	4.00	LM2111N	1.95
LM307CN	.35	LM380N	1.39	LM2901N	2.95
LM308H	1.00	LM380CN	1.05	LM3065N	.69
LM308CN	1.00	LM381N	1.79	LM3900N	.55
LM309H	1.10	LM382N	1.79	LM3905N	.60
LM309K	.99	NE501K	8.00	LM3909	1.25
LM310CN	1.15	NE510A	6.00	LM5556N	1.85
LM311H	.90	NE531H	3.00	MC5558V	1.00
LM311N	.90	NE536T	6.00	LM7525N	.90
LM318CN	1.50	NE540L	6.00	LM7535N	1.25
LM319N	1.30	NE550N	.79	8038B	4.95
LM320K-5	1.35	NE555V	.39	LM75450	.49
LM320K-5.2	1.35	NE560B	5.00	75451CN	.39
LM320K-12	1.35	NE561B	5.00	75452CN	.39
LM320K-15	1.35	NE562B	5.00	75453CN	.39
LM320T-5	1.75	NE565H	1.25	75454CN	.39
LM320T-5.2	1.75	NE565N	1.75	75491CN	.79
LM320T-8	1.75	NE566CN	1.25	75492CN	.89
LM320T-12	1.75	NE567H	1.95	75494CN	.89
LM320T-15	1.75	NE567V	1.50	**RCA LINEAR**	
LM320T-18	1.75	LM703CN	.45	CA3013	2.15
LM320T-24	1.75	LM709H	.29	CA3023	2.56
LM323K-5	9.95	LM709N	.29	CA3035	2.48
LM324N	1.80	LM710N	.79	CA3039	1.35
LM339N	1.70	LM711N	.39	CA3046	1.30
LM340K-5	1.95	LM723H	.55	CA3059	3.25
LM340K-6	1.95	LM723N	.55	CA3060	3.25
LM340K-8	1.95	LM733N	1.00	CA3080	.85
LM340K-12	1.95	LM739N	1.00	CA3081	2.00
LM340K-15	1.95	LM741CH	.35	CA3082	2.00
LM340K-18	1.95	LM741CN	.35	CA3083	1.60
LM340K-24	1.95	LM741-14N	.39	CA3086	.85
LM340T-5	1.75	LM747H	.79	CA3089	3.75
LM340T-6	1.75	LM747N	.79	CA3091	10.20
LM340T-8	1.75	LM748H	.39	CA3102	2.95
LM340T-12	1.75	LM748N	.39	CA3123	2.15
LM340T-15	1.75	LM1303N	.90	CA3130	1.39
LM340T-18	1.75	LM1304N	1.19	CA3140	1.25
LM340T-24	1.75	LM1305N	1.40	CA3600	1.75
LM350N	1.00	LM1307N	.85	RC4194	5.95
LM351CN	.65	LM1310N	2.95	RC4195	3.25

74LS00 TTL

74LS00	.29			74LS139	1.95
74LS02	.29			74LS151	1.55
74LS03	.29	74LS74	.49	74LS153	1.89
74LS04	.35	74LS75	.69	74LS157	1.55
74LS05	.35	74LS76	.49	74LS162	2.25
74LS08	.29	74LS83	1.75	74LS163	2.25
74LS10	.29	74LS85	2.49	74LS164	1.95
74LS13	.69	74LS86	.49	74LS175	1.95
74LS14	1.75	74LS90	1.25	74LS181	3.69
74LS20	.29	74LS92	1.25	74LS190	2.85
74LS26	.39	74LS93	1.25	74LS191	2.85
74LS27	.39	74LS95	1.95	74LS192	2.85
74LS28	.39	74LS96	1.89	74LS193	2.85
74LS30	.29	74LS107	.59	74LS194	1.89
74LS32	.39	74LS109	.59	74LS195	1.89
74LS40	.29	74LS112	.59	74LS257	1.75
74LS51	.29	74LS132	1.25	74LS260	.55
74LS55	.29	74LS136	.59	74LS279	.79
74LS73	.49	74LS138	1.89	74LS670	3.95

CLOCK CHIPS

MM5309	6 Digit, BCD Outputs, Reset PIN	$9.95
MM5311	6 Digit, BCD Outputs, 12 or 24 Hour	4.95
MM5312	4 Digit, BCD Outputs, 1 PPS Output	4.95
MM5314	6 Digit, 12 or 24 Hour, 50 or 60 Hz	4.95
MM5316	4 Digit, Alarm, 1 PPS Output	6.95
MM5318	Video Clock Chip, For Use With (MM5841 - $9.95)	9.95
CT7001	6 Digit, Calendar, Alarm, 12 or 24 Hour	5.95

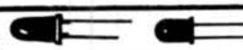
DATA HANDBOOKS

7400	Pin out & Description of 5400/7400 ICS	$2.95
CMOS	Pin out & Description of 4000 Series ICS	$2.95
Linear	Pin out & Functional Description	$2.95

ALL THREE HANDBOOKS $6.95

There is only *one* James ELECTRONICS

They can try and copy our ad, BUT They can't copy our service!



DISCRETE LEDS

.125" dia.			.190" dia.		
XC209	Red	10/$1	XC111	Red	10/$1
XC209	Green	4/$1	XC111	Green	4/$1
XC209	Orange	4/$1	XC111	Yellow	4/$1
XC209	Yellow	4/$1	XC111	Orange	4/$1

.200" dia.			.185" dia.			.200" dia.		
XC22	Red	10/$1	XC526	Red	10/$1	XC556	Red	10/$1
XC22	Green	4/$1	XC526	Green	4/$1	XC556	Green	4/$1
XC22	Yellow	4/$1	XC526	Yellow	4/$1	XC556	Yellow	4/$1
XC22	Orange	4/$1	XC526	Orange	4/$1	XC556	Orange	4/$1
SSL-22	RT	4/$1	XC526	Clear	4/$1	XC556	Clear	7/$1

.085" dia. MV50 - Red - 6/$1

INFRA-RED LED ¼" x ¼" x 1/16" Flat 5/$1.00

SPECIAL * — XC556 Red 100/$8.00 1000/$60.00 — SPECIAL *

DISPLAY LEDS

DL707 DL338

TYPE	POLARITY	HT		TYPE	POLARITY	HT	
MAN 1	Common Anode	.270	2.95	MAN 3640	Common Cathode-orange	.300	1.75
MAN 2	5 x 7 Dot Matrix	.300	4.95	MAN 4710	Common Anode-Red	.400	1.95
MAN 3	Common Cathode	.125	3/1.00	DL701	Common Anode-red ±	.300	.99
MAN 4	Common Cathode	.187	1.95	DL704	Common Cathode	.300	.99
MAN 7	Common Anode	.300	1.25	DL707	Common Anode	.300	.99
MAN 7G	Common Anode-green	.300	1.95	MAN 4740	Common Anode-Red	.400	.99
MAN 7Y	Common Anode-yellow	.300	1.95	DL741	Common Anode	.600	1.50
MAN 52	Common Anode-green	.300	.99	DL 747	Common Anode	.600	2.25
MAN 64	Common Anode-red	.400	.99	DL 750	Common Cathode	.600	2.49
MAN 74	Common Cathode	.300	1.50	DL 338	Common Cathode	.110	.50
MAN 82	Common Anode-yellow	.300	.99	FND70	Common Cathode	.250	.75
MAN 84	Common Cathode-yellow	.300	.99	FND503	Common Cathode	.500	1.00
MAN 3620	Common Anode-orange	.300	1.75	FND507	Common Anode	.500	1.00

FACTORY REJECTS ATARI GAME BOARDS

BOARD A — 8½" x 16" — **$6.95 ea.**
Over 60 each reusable IC's. Misc. Transistors, Resistors, Diodes, Caps, Crystals, Switch, etc. — ONLY 500 EA. AVAILABLE

DELUXE BOARD B — 11½" x 18" — **$9.95 ea.**
Over 100 each reusable IC's. Misc. Transistors, Resistors, Diodes, Caps, Crystals, Switches, LEDS, etc. — ONLY 500 EA. AVAILABLE

NEW AY-3-8500-1 TV GAME CHIP

28 Lead Dual In Line

- Score display
- Selectable angles, speed and bat size
- Auto or manual ball service
- Realism sounds
- 6 Games — tennis, hockey/soccer, squash, pelota/practice and two rifle games

The circuit is intended to be battery powered. Minimum number of external components required for complete system.

$24.95

IC SOLDERTAIL — LOW PROFILE (TIN) SOCKETS

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin	$.17	.16	.15	24 pin	$.38	.37	.36
14 pin	.20	.19	.18	28 pin	.45	.44	.43
16 pin	.22	.21	.20	36 pin	.60	.59	.58
18 pin	.29	.28	.27	40 pin	.63	.62	.61
22 pin	.37	.36	.35				

SOLDERTAIL STANDARD (TIN)

	1-24	25-49	50-100		1-24	25-49	50-100
14 pin	$.27	.25	.24	28 pin	$.99	.90	.81
16 pin	.30	.27	.25	36 pin	1.39	1.26	1.15
18 pin	.35	.32	.30	40 pin	1.59	1.45	1.30
24 pin	.49	.45	.42				

SOLDERTAIL STANDARD (GOLD)

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin	$.30	.27	.24	24 pin	$.70	.63	.57
14 pin	.35	.32	.29	28 pin	1.10	1.00	.90
16 pin	.38	.35	.32	36 pin	1.75	1.40	1.26
18 pin	.52	.47	.43	40 pin	1.75	1.59	1.45

WIRE WRAP SOCKETS (GOLD) LEVEL #3

	1-24	25-49	50-100		1-24	25-49	50-100
10 pin	$.45	.41	.37	24 pin	$1.05	.95	.85
14 pin	.39	.38	.37	28 pin	1.40	1.25	1.10
16 pin	.43	.42	.41	36 pin	1.59	1.45	1.30
18 pin	.75	.68	.62	40 pin	1.75	1.55	1.40

Plastic Push Button Switch

- 18 AWG Solid Wire - 5" Long
- .50 (wide) X .60 (high) ⅜-27 Thread
- 8 AMP @ 14 Volt - 1 AMP @ 110 Volt

		1-9	10-Up
J-188-1	Push On-Push Off	.59	.49
J-188-2	Normally Open	.59	.49
J-188-3	Normally Closed	.59	.49

MINATURE TOGGLE SWITCH

JMT-221	DPDT	on/off/on	$1.95
JMT-223	DPDT	on/none/on	$1.75
JMT-121	SPDT	on/off/on	$1.50
JMT-123	SPDT	on/none/on	$1.25

CLIPLITE 8/$1.49

LED MOUNTING SYSTEM use with XC556 LEDS

Specify Colors — Red - Green - Amber - Yellow

DIP SWITCHES

SPST Slide Action

- #206-4 (8 pin dip) 4 switch unit **$1.75 ea.**
- #206-7 (14 pin dip) 7 switch unit **$1.95 ea.**
- #206-8 (16 pin dip) 8 switch unit **$2.25 ea.**

50 PCS. RESISTOR ASSORTMENTS $1.75 PER ASST.

ASST. 1	5 ea.	10 OHM / 27 OHM	12 OHM / 33 OHM	15 OHM / 39 OHM	18 OHM / 47 OHM	22 OHM / 56 OHM	1/4 WATT 5% - 50 PCS.
ASST. 2	5 ea.	68 OHM / 180 OHM	82 OHM / 220 OHM	100 OHM / 270 OHM	120 OHM / 330 OHM	150 OHM / 390 OHM	1/4 WATT 5% - 50 PCS.
ASST. 3	5 ea.	470 OHM / 1.2K	560 OHM / 1.5K	680 OHM / 1.8K	820 OHM / 2.2K	1K / 2.7K	1/4 WATT 5% - 50 PCS.
ASST. 4	5 ea.	3.3K / 8.2K	3.9K / 10K	4.7K / 12K	5.6K / 15K	6.8K / 18K	1/4 WATT 5% - 50 PCS.
ASST. 5	5 ea.	22K / 56K	27K / 68K	33K / 82K	39K / 100K	47K / 120K	1/4 WATT 5% - 50 PCS.
ASST. 6	5 ea.	150K / 390K	180K / 470K	220K / 560K	270K / 680K	330K / 820K	1/4 WATT 5% - 50 PCS.
ASST. 7	5 ea.	1M / 2.7M	1.2M / 3.3M	1.5M / 3.9M	1.8M / 4.7M	2.2M / 5.6M	1/4 WATT 5% - 50 PCS.

ASST. 8R Includes Resistor Assortments 1-7 (350 PCS.) **$10.95 ea.**

$5.00 Minimum Order — U.S. Funds Only
California Residents — Add 6% Sales Tax
Spec Sheets - 25¢ — Send 35¢ Stamp for 1977A Catalog
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WIRE WRAP CENTER

HOBBY-WRAP TOOL-BW-630

- Battery Operated (Size C)
- Weighs ONLY 11 Ounces
- Wraps 30 AWG Wire onto Standard DIP Sockets (.025 inch)
- Complete with built-in bit and sleeve

$34.95 (batteries not included)

WIRE-WRAP KIT — WK-2-W

WRAP • STRIP • UNWRAP

- Tool for 30 AWG Wire
- Roll of 50 Ft. White or Blue 30 AWG Wire
- 50 pcs. each 1", 2", 3" & 4" lengths — pre-stripped wire.

$11.95

WIRE WRAP TOOL WSU-30

WRAP • STRIP • UNWRAP - $5.95

WIRE WRAP WIRE — 30 AWG

25 ft. min. $1.25 50 ft. $1.95 100 ft. $2.95 1000 ft. $15.00
SPECIFY COLOR — White - Yellow - Red - Green - Blue - Black

CUTTER CRIMPER TOOL (CS-8)

- Plier Nose (serrated-jaw)
- Scissors Action Cutting
- 6 Bolt Cutters (4-40, 5-40, 6-32, 8-32, 10-32, 10-24)
- Crimp Stations (7mm Auto — 22-20 to 12-X0 elect.)
- "Up-Front" Wire Cutting
- Scissors Action Stripping (No. 22-20 to No. 10)
- Crimp Stations — insulated (2w-20 to 12-10 elect.)

Actual Size - 8¼" length **$8.50**

Permacel Electrical Tape

- ¾" (wide) X 66 ft. (long) • All weather • Not import

$1.25 per roll — $9.95 per 10 roll package

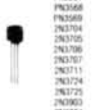
ZENERS — DIODES — RECTIFIERS

TYPE	VOLTS	W	PRICE	TYPE	VOLTS	W	PRICE
1N746	3.3	400mm	4/1.00	1N4005	600 PIV	1 AMP	10/1.00
1N751A	5.1	400m	4/1.00	1N4006	800 PIV	1 AMP	10/1.00
1N752	5.6	400m	4/1.00	1N4007	1000 PIV	1 AMP	10/1.00
1N753	6.2	400m	4/1.00	1N3600	50	200m	6/1.00
1N754	6.8	400m	4/1.00	1N4148	75	10m	15/1.00
1N959	8.2	400m	8/1.00	1N4154	35	10m	12/1.00
1N965B	15	400m	4/1.00	1N4305	75	25m	20/1.00
1N5232	5.6	500m	.28	1N4734	5.6	1w	.28
1N5234	6.2	500m	.28	1N4735	6.2	1w	.28
1N5235	6.8	500m	.28	1N4736	6.8	1w	.28
1N5236	7.5	500m	.28	1N4738	8.2	1w	.28
1N456	25	40m	6/1.00	1N4742	12	1w	.28
1N458	150	7m	6/1.00	1N4744	15	1w	.28
1N485A	180	10m	6/1.00	1N1183	50 PIV	35 AMP	1.60
1N4001	50 PIV	1 AMP	12/1.00	1N1184	100 PIV	35 AMP	1.70
1N4002	100 PIV	1 AMP	12/1.00	1N1185	150 PIV	35 AMP	1.50
1N4003	200 PIV	1 AMP	12/1.00	1N1186	200 PIV	35 AMP	1.80
1N4004	400 PIV	1 AMP	12/1.00	1N1188	400 PIV	35 AMP	3.00

SCR AND FW BRIDGE RECTIFIERS

C36D	15A @ 400V	SCR	$1.95
C38M	35A @ 200V	SCR	1.95
2N2328	1.6A @ 200V	SCR	.50
MDA 980-1	12A @ 50V	FW BRIDGE REC.	1.95
MDA 980-3	12A @ 200V	FW BRIDGE REC.	1.95

TRANSISTORS



MPS A05	5/$1.00			PN4249	4/$1.00
MPS A06	5/$1.00			PN4250	4/$1.00
2N2219A	3/$1.00	PN3567	3/$1.00	2N4400	4/$1.00
2N2221	4/$1.00	PN3568	4/$1.00	2N4401	4/$1.00
2N2222A	5/$1.00	PN3569	4/$1.00	2N4402	4/$1.00
2N2369	5/$1.00	2N3704	5/$1.00	2N4403	4/$1.00
2N2369A	4/$1.00	2N3705	5/$1.00	2N4409	5/$1.00
2N2484	4/$1.00	2N3706	5/$1.00	2N5086	4/$1.00
2N2906A	4/$1.00	2N3707	5/$1.00	2N5087	4/$1.00
2N2907A	5/$1.00	2N3711	5/$1.00	2N5088	4/$1.00
2N2925	5/$1.00	2N3724	$.65	2N5089	4/$1.00
2N3053	2/$1.00	2N3725	$1.00	2N5129	5/$1.00
2N3055	$.89	2N3903	5/$1.00	2N5138	5/$1.00
MJE3055	$1.00	2N3904	4/$1.00	2N5139	5/$1.00
MJE2955	$1.25	2N3905	4/$1.00	2N5209	5/$1.00
2N3392	5/$1.00	2N3906	4/$1.00	2N5951	5/$1.00
2N3398	5/$1.00	2N4013	3/$1.00	C106B1SCR	2/$1.00
		2N4014	3/$1.00	2N5432	$7.00
		2N4123	10/$1.00		

CAPACITOR CORNER

50 VOLT CERAMIC DISC CAPACITORS

	1-9	10-49	50-100		1-9	10-49	50-100
10 pf	.05	.04	.03	.001µF	.05	.04	.035
22 pf	.05	.04	.03	.0047µF	.05	.04	.035
47 pf	.05	.04	.03	.01µF	.05	.04	.035
100 pf	.05	.04	.03	.022µF	.06	.05	.04
220 pf	.05	.04	.03	.047µF	.06	.05	.04
470 pf	.05	.04	.035	.1µF	.12	.09	.075

100 VOLT MYLAR FILM CAPACITORS

	1-9	10-49	50-100		1-9	10-49	50-100
.001mf	.12	.10	.07	.022mf	.13	.11	.08
.0022	.12	.10	.07	.047mf	.21	.17	.13
.0047mf	.12	.10	.07	.1mf	.27	.23	.17
.01mf	.12	.10	.07	.22mf	.33	.27	.22

+20% DIPPED TANTALUMS (SOLID) CAPACITORS

	1-9	10-49	50-100		1-9	10-49	50-100
.1/35V	.28	.23	.17	1.5/35V	.30	.26	.21
.15/35V	.28	.23	.17	2.2/25V	.31	.27	.22
.22/35V	.28	.23	.17	3.3/25V	.31	.27	.22
.33/35V	.28	.23	.17	4.7/25V	.32	.28	.23
.47/35V	.28	.23	.17	6.8/25V	.36	.31	.25
.68/35V	.28	.23	.17	10/25V	.40	.35	.29
1.0/35V	.28	.23	.17	15/25V	.63	.50	.40

MINIATURE ALUMINUM ELECTROLYTIC CAPACITORS

Axial Lead				Radial Lead			
.47/50V	.15	.13	.10	.47/25V	.15	.13	.10
1.0/50V	.16	.14	.11	.47/50V	.16	.14	.11
3.3/50V	.15	.13	.10	1.0/16V	.15	.13	.10
4.7/25V	.16	.14	.12	1.0/25V	.16	.14	.11
10/25V	.15	.13	.10	1.0/50V	.16	.14	.11
10/50V	.16	.14	.12	4.7/16V	.15	.13	.10
22/25V	.17	.15	.12	4.7/25V	.15	.13	.10
22/50V	.24	.20	.18	4.7/50V	.16	.14	.11
47/25V	.19	.17	.15	10/16V	.14	.12	.09
47/50V	.25	.21	.19	10/25V	.15	.13	.10
100/25V	.24	.20	.18	10/50V	.16	.14	.12
100/50V	.35	.30	.28	47/50V	.24	.21	.19
220/25V	.32	.28	.25	100/16V	.19	.15	.14
220/50V	.45	.41	.38	100/25V	.24	.20	.18
470/25V	.33	.29	.27	100/50V	.35	.30	.28
1000/16V	.55	.50	.45	220/16V	.23	.17	.16
2200/16V	.70	.62	.55	470/25V	.31	.28	.26

More Details? CHECK—OFF Page 150

The world's first digitally tuned 80M-10M SSB transceiver

with over 40,000 frequency synthesized channels.

• Ultra-stable frequency synthesizer • Large LED readout • 200 Watts PEP input • *All* solid state including electronic tuning • Front end filtering • Built-in TVI filtering • Modular construction • WWV Receiver, Squelch, Noise blanker, VOX, Speech processing are standard • Full metering.

Discover a whole new world of communications with the CIR ASTRO 200 . . . the Ham SSB Transceiver that has established a new plateau of sophistication for the serious enthusiast.

The built-in digital synthesizer with LED readout gives you over 40,000 crystal controlled channels in the 80 through 10 meter bands with 100Hz resolution. Just press a momentary switch and tune your frequency with no moving parts.

Calibrate it with WWV at the turn of a switch for absolute accuracy. No more crystal calibration.

And, as for frequency drift, the ASTRO 200 is ten times better than VFO types. Total filtering sets the ASTRO 200 above all others for TVI and harmonic suppression. Selectable USB or LSB allows you complete flexibility.

CW operation features include semi break-in CW with adjustable delay and side tone . . . no key click or CW chirp.

CIR offers a complete range of accessories including fixed station console and external frequency synthesizer for crossband DX work.

This extremely compact transceiver is only 2.8" high by 9.5" wide by 12.3" deep including heat sink. With all of these features incorporating rugged militarized type construction, it has no equal for SSB and CW operation.

Be the first to learn more about the exciting new CIR ASTRO 200 . . . ham radio's next generation transceiver. List price, $995. Write or phone for complete details.

CIR
TRANSCEIVERS

CIR Industries, Inc., 1648 N. Magnolia Avenue, El Cajon, California 92020 U.S.A., Phone (714) 449-7633, Telex 69-7989

More Details? CHECK—OFF Page 150

NOW FROM Wilson:

AMATEUR: ANTENNAS • ROTORS • TOWERS

3 CRANK-UP TOWER MODELS AVAILABLE

TT-45 FREESTANDING CRANK-UP TOWER, 45 Ft.

The TT-45 will support 9 sq. ft. at a height of 39 ft. freestanding when properly bracketed to a house or wall at the 8 ft. level. The loads decrease as the tower extension Mast is lengthened. (Loads are based at 78 mph and load permitted on the tower decreases with increases in wind speed over 78 mph). The tower can be completely freestanding with our new concrete or tower rotating bases, which allow the use of our raising fixture. Using these accessories, the towers can be installed by one man easily.

List . . . **$345.00**

FOR THE TOWERING SIGNAL - WILSON'S SST-64 GUYED CRANK-UP TOWER, 64 Ft.

All steel tubing is galvanized plated and conforms to ASTM specifications for years of maintenance free service. The SST-64 is made of 4 sections, being 4.5", 3.5", 2.5" and 2". These large diameters give unexcelled strength and virtually makes the thin push-up poles a thing of the past. The large loads of today's antennas make the Wilson SST-64 the best value on the market today.

List **$421.00**

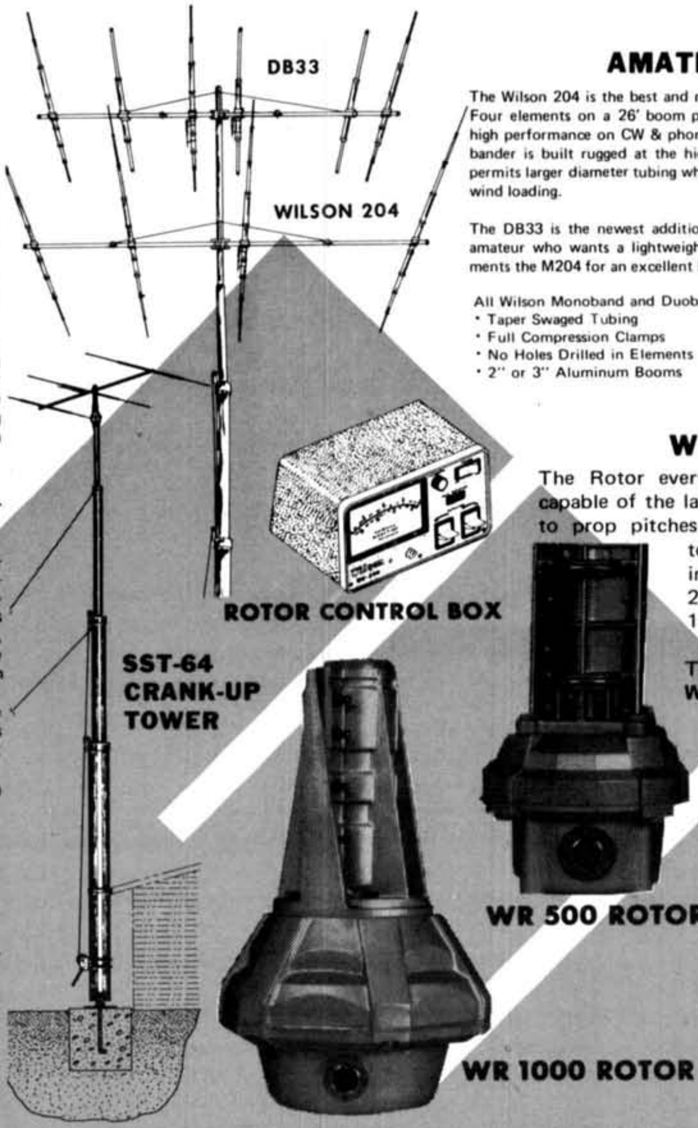
THE WILSON GT-46 GUYED CRANK-UP TOWER, 46 Ft.

The GT-46 features quality construction and materials, with the stability of the Guyed System.

FEATURES OF THE GT-46:

• Low cost • High capacity • all steel. Conforms to ASTM (American Standard of Testing Materials) • Fully galvanized • 800 lb. winch standard • Guy kits available for factory recommended installations • 2000 lb. raising cable standard (Aircraft Quality) • Can be roof mounted for extra height • Great looking, slim flag pole design, for the ecology minded.

List . . . **$249.00**



AMATEUR ANTENNAS

The Wilson 204 is the best and most economical antenna of its type on the market. Four elements on a 26' boom plus a Gamma Match (no balun required) make for high performance on CW & phone across the entire 20 meter band. The 204 Monobander is built rugged at the high stress points. Using taper swaged slotted tubing permits larger diameter tubing where it counts, for maximum strength with minimum wind loading.

The DB33 is the newest addition to the Wilson line of antennas. Designed for the amateur who wants a lightweight economical antenna package, the DB33 compliments the M204 for an excellent DXers combination.

All Wilson Monoband and Duoband beams have the following common features:

- Taper Swaged Tubing
- Full Compression Clamps
- No Holes Drilled in Elements
- 2" or 3" Aluminum Booms
- Adjustable 52 Ω Gamma Match
- Quality Aluminum
- Handle 4kw
- Heavy Extruded Element to Boom Mounts

WR 1000 ROTOR

The Rotor everyone has been waiting years for – capable of the largest arrays up to 40 sq. ft. –Superior to prop pitches – Full 4,000 inch lbs. of turning torque. Braking system requires 12,000 inch lbs. before over-riding – accepts 2" - 3" masts – Weighs 60 lbs. – Size: 11" diameter, 19" high.

The Finest Rotor in the Market Today
WR 1000 . . . . $459.00 List

WR 500 ROTOR

The Wilson WR500 Rotor has 860 inch lbs. of turning torque before stalling.

In addition, a Special Braking System requires 1300 inch lbs. of torque before windmilling– This is more than twice the braking ability of the other comparable rotor being marketed.

Full 96 Steel Ball Bearing raceway assures elimination of side torque jamming when Rotor is mounted in line with the mast.

Recommended for antennas of 6.5 sq. ft. or less . . . weighs 20 lbs.

The
WR500 Rotor . . $139.95 List

Coming Soon:
The New Wilson
WR750 Rotor!!!

WILSON AMATEUR ANTENNA SPECIFICATIONS

Model No.	Frequency	Forward Gain (dB)	Front-to Back Ratio (dB)	Front-to Side Ratio (dB)	Boom Length (ft.)	Number Elements	Longest Elements (ft.)	Turning Radius (ft.)	Surface Area (sq. ft.)	Wind Loading at 80 MPH (lbs.)	Assembled Weight (lbs.)	Shipping Weight (lbs.)	Price
M340	40	8.5	20	30	40	3	70'0"	39'0"	15	300	180	220	$749.00
M620	20	13.0	28	35	58	6	36'0"	32'0"	10.5	210	98	123	420.00
M520	20	12.0	26	30	40	5	36'4"	27'0"	8.75	175	74	96	299.00
M204	20	10.0	25	30	26	4	36'4"	22'6"	6.8	136	42	48	169.00
M203	20	8.5	20	30	19	3	36'0"	20'5"	5.25	105	35	40	129.00
M155	15	12.0	26	30	26	5	24'3"	18'0"	5.0	100	41	44	159.00
M154	15	10.0	25	30	19	4	24'3"	15'9"	4.0	80	30	33	109.00
M153	15	8.5	20	30	17	3	24'3"	14'0"	3.0	60	21	24	89.00
M108	10	13.5	26	30	40	8	18'0"	22'0"	5.5	110	49	77	219.00
M106	10	13.0	26	30	31	6	19'0"	16'1"	4.0	80	34	36	119.00
M105	10	12.0	26	30	26	5	18'0"	15'8"	3.0	60	29	32	109.00
M103	10	8.5	20	30	11½	3	18'0"	10'0"	2.0	40	10	12	39.00
DB54	20	12.0	26	30	40	5	36'4"	27'0"	12.75	255	94	119	349.00
	15	10.0	25	30		4	24'3"						
DB43	15	8.5	20	30	19	4	24'3"	15'8"	6.0	120	38	43	149.00
	10	10.0	25	30		3	18'0"						
DB33	15	8.5	20	30	17	3	24'3"	12'2"	4.5	90	30	33	109.00
	10	8.5	20	30		3	18'0"						

AVAILABLE THRU YOUR LOCAL DEALER

FOR THE NAME OF YOUR NEAREST AMATEUR DEALER *OR FOR A FREE CATALOG OF THE ABOVE PRODUCTS, CONTACT:*

Wilson Electronics Corp.

4288 SO. POLARIS AVENUE • P.O. BOX 19000 • LAS VEGAS, NEVADA 89119 • (702)739-1931 • TELEX 684-522

Prices Effective May 1, 1977

More Details? CHECK—OFF Page 150

More Details? CHECK—OFF Page 150

More Details? CHECK—OFF Page 150

MODERN RADIO COMMUNICATION

A SEMINAR IN HIGH FREQUENCY RADIO ENGINEERING
MAY 16-20, 1977

This 4-day course is designed to bridge the gap between available literature and the latest in Radio Communication Development. It will provide current information and explain the most recent Radio Design Techniques by summarizing the state of the art to date and indicating future trends.

Detailed information will be given on designs of special interest such as new wide band amplifiers, mixers, and frequency synthesizers.

Speakers: Ulrich L. Rohde
Prof. Dept. of Electrical Engineering (Coordinator)

Donald G. Childers
Prof. Dept. of Electrical Engineering

Jack R. Smith
Prof. Dept. of Electrical Engineering

Tuition is $300.00

For application and information call or write:

Dr. S. H. Schafer
Div. of Continuous Education
2012 W. University Ave.
University of Florida
Gainesville, FL 32611

Tel.: (904) 392-1701

DON & BOB'S

SUPER BUYS

WIRE, ETC. Premax heavy-duty 4 ft. ground rod + clamp **$4.00** Consolidated antenna wire: #14 stranded **$5.00/100 ft.** #12 stranded **$8.00/100 ft.** #22 GA phosbronze longwire antenna wire **$3.50/1000 ft.** Belden #14 stranded copper covered steel wire **$5.00/100 ft.**

KLM KR400 Rotor + 100 ft. rotor cable **$100.00**
CDE Big Talk + 100 ft. rotor cable **$100.00**

Hy Gain handi talkie **$189.95 - call for quote**
Midland 13-510 2m FM synthesized **$399.00 - call for quote**

CABLE 5/32", 6-strand, soft-drawn guy cable. For mast or light tower, 3¢ foot.

RAYTHEON 811A $16.00/pr. **572B/T160L ea. $21.95**

BELDEN COAX RG8U 8237 **19¢ ft.** 8214 RG8 foam **23¢ ft.** 8235 300 ohm kw twinlead **$12.00/C.** 8210 72 ohm kw twinlead **$19.00/C.** Silver Plate Amphenol PL259 **59¢** UG175 **19¢.** **Saxton** uninsulated open wire line: 300 ohm, 450 ohm **$10/per 100 ft.** Belden 100 ft. RG8 foam with installed plugs **$25.00.**

CDE Ham-2 $129.00. CD44 $104.00. Belden 8 wire rotor cable **14¢ ft.**

EXTRAS Reed switch **3/$1.00.** Buss AGC3 fuse **5¢ CDE.** .001/10KV doorknob cap **$1.95.** Mallory 2.5A/1000PIV epoxy diode **19¢ ea.**

1⅝" x 12 ft. solid aluminum mast **$25.00** (freight collect)

CALL US FOR QUOTES ON: ATLAS 350XL, KENWOOD TS520, TS700A, TR7400A, FT101E. ALL IN SEALED CARTONS.

CALL US FOR QUOTES & ITEMS NOT LISTED

MADISON
ELECTRONICS SUPPLY, INC.

1508 McKINNEY **HOUSTON, TEXAS 77002**
713/658-0268 **Nites 713/497-5683**

TERMS: All prices FOB Houston. Quotes Good 30 Days. All Items Guaranteed. Some items subject to prior sale. Send letterhead for Amateur dealers price list.

HAM-MODEL MAKER

WANT TO WORK ON ANTENNA R & D?

If you are a Ham who currently has a job as a machinist and/or model maker, we have a position for you.

You should have at least 3 years experience in model making or prototype work and have a good knowledge of antennas and electronics.

Our large, new facility, located in Addison, Illinois, a small community outside of Chicago, offers a choice of urban, suburban, or rural living. We offer excellent salary, benefits and working conditions.

Send your resume in confidence-stating education, work and salary history to:

Mr. H. Turner
AVANTI
Research & Development, Inc.
340 Stewart Avenue, Addison, Illinois 60101

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Research & Development, Inc.
An Equal Opportunity Employer M/F

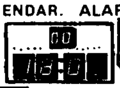
More Details? CHECK—OFF Page 150

6-DIGIT LED CLOCK CALENDAR KIT

DATE-TIME-SNOOZE ALARM & MORE... KIT 7001

FOR THE BUILDER THAT WANTS THE BEST. FEATURING 12 OR 24 HOUR TIME — 29-30-31 DAY CALENDAR. ALARM, SNOOZE AND AUX. TIMER CIRCUITS

Will alternate time (8 seconds) and date (2 seconds) or may be wired for time or date display only, with other functions on demand. Has built-in oscillator for battery back-up. A loud 24 hour alarm with a repeatable 10 minute snooze alarm, alarm set & timer set indicators. Includes 110 VAC/60Hz power pack with cord and top quality components through-out.

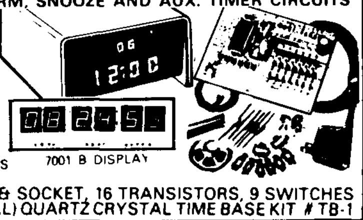


7001C DISPLAY

7001 X DISPLAY

7001 B DISPLAY

CHOICE OF DIGITAL DISPLAYS



PRINTED CIRCUIT BOARDS for CT-7001 Kits sold separately with assembly info. PC Boards are drilled Fiberglass, solder plated and screened with component layout. Specify for 7001 **B, C or X - $7.95**

KIT-7001B WITH 6-.5" DIGITS $39.95
KIT - 7001C WITH 4 - .6" DIGITS & 2-.3" DIGITS FOR SECONDS $42.95
KIT-7001X WITH 6-.6" DIGITS $45.95

KITS ARE COMPLETE (**LESS CABINET**) WITH PC BOARDS, POWER SUPPLY, IC & SOCKET, 16 TRANSISTORS, 9 SWITCHES AND ALL REQUIRED PARTS. ALL 7001 KITS FIT CABINET I AND ACCEPT (OPTIONAL) QUARTZ CRYSTAL TIME BASE KIT # TB-1

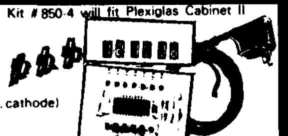
6 DIGIT LED CLOCK KIT #850-4

12/24 HR. OPERATION BIG .4" DIGITS - 50/60 HZ OPERATION.

KIT INCLUDES
- INSTRUCTIONS
- QUALITY COMPONENTS
- 50 or 60 Hz OPERATION
- 12 or 24 HR OPERATION

6-LED Readouts (FND-359 Red, com. cathode)
1-MM5314 Clock Chip (24 pin)
13-Transistors
3-Switches
6-Capacitors
5-Diodes
9-Resistors
24-Molex pins

Kit # 850-4 will fit Plexiglas Cabinet II



$11.95 ea. QTY. 1-5
$10.95 ea. QTY. 6-11
$9.95 ea QTY. 12 OR MORE

"Kit #850-4 will furnish a complete set of clock components as listed. The only additional items required are a 7-12 VAC transformer, a circuit board and a cabinet, if desired."

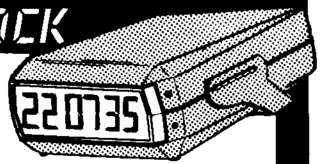
PRINTED CIRCUIT BOARD FOR KIT #850-4, SCREEN PRINTED DRILLED AND SOLDER PLATED FIBERGLASS $2.95
MINI-BRITE RED LED'S (FOR COLON IN CLOCK DISPLAY) ... Pkg. of 5-$1.00
MOLDED PLUG TRANSFORMER 115/10 VAC (WITH CORD) $2.50

NOTE: Entire Clock may be assembled on one PC Board or Board may be cut to remote display.

MOBILE LED CLOCK

12/24 HR **.4" DIGITS!**

MODEL #2001 12 VOLT AC or DC POWERED



- 6 JUMBO .4" RED LED'S BEHIND RED FILTER LENS WITH CHROME RIM
- SET TIME FROM FRONT VIA HIDDEN SWITCHES • 12/24-Hr. TIME FORMAT
- STYLISH CHARCOAL GRAY CASE OF MOLDED HIGH TEMP. PLASTIC
- BRIDGE POWER INPUT CIRCUITRY — TWO WIRE NO POLARITY HOOK-UP
- OPTIONAL CONNECTION TO BLANK DISPLAY (Use When Key Off In Car, Etc.)
- TOP QUALITY PC BOARDS & COMPONENTS - EXCELLENT INSTRUCTIONS
- MOUNTING BRACKET INCLUDED

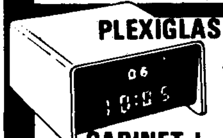
KIT #2001 COMPLETE KIT (Less 9V. Battery) **$29.95 EA.** 3 OR MORE **$27.95 EA.** 115 VAC Power Pack #AC-1 **$2.50 EA.**

ASSEMBLED UNITS WIRED & TESTED ORDER #2001 WT (LESS 9V. BATTERY) **$39.95 EA.** 3 OR MORE **$37.95 EA.**
WIRED FOR 12 HR. OP. IF NOT SPECIFIED OTHERWISE

60 HZ. XTAL TIME BASE

Will enable Digital Clock Kits or Clock-Calendar Kits to operate from 12V DC. 1"x2" PC Board Power Req: 5-15V (2.5 MA. TYP.) Easy 3 wire hookup Accuracy: ± 2PPM **#TB-1** (Adjustable) Complete Kit **$4.95 ea** **Wir & Cal $9.95**

PLEXIGLAS CABINETS



Great for Clocks or any LED Digital project. Clear-Red Chassis serves as Bezel to increase contrast of digital displays.

CABINET I 3"H, 6¼"W, 5½"D
CABINET II 2½"H, 5"W, 4"D
Black, White or Clear Cover **$6.50 ea.**

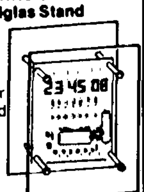
RED OR GREY PLEXIGLAS FOR DIGITAL BEZELS 3"x6"x1/8" **95¢ ea. 4/$3**

SEE THE WORKS Clock Kit Clear Plexiglas Stand

- 6 Big .4" digits
- 12 or 24 hr. time
- 3 set switches
- Plug transformer
- all parts included

Plexiglas is Pre-cut & drilled

Kit #850-4CP



Size: 6"H, 4½"W, 3"D

$23.50 ea. 2/$45. A SUPER CLOCK!

JUMBO DIGIT CLOCK

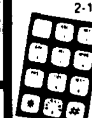
A complete Kit (less Cabinet) featuring: six .5" digits, MM5314 IC, 12/24 Hr. time, 50/60 HZ., Plug-Transformer, Line Cord, Switches, and all Parts. (Ideal Fit in Cabinet II) Kit # 5314-5 ... **$19.95 2/$38.**
WITH PC Boards

JUMBO DIGIT CONVERSION KIT $9.95 ea.
Convert small digit LED clock to large .5" displays. Kit includes 6 - LED's, Multiplex PC Board & easy hook-up info.
Kit # JD-1CC For common Cathode
Kit # JD-1CA for common Anode

TELEPHONE FORMAT KEYBOARD

BY Chomerics # EF-21360

2-1/4"x3"



5/32" thick

$4.95 6/$28.

25 AMP BRIDGE

$1.95 ea. 3/$5.00

NEW LSI TECHNOLOGY

FREQUENCY COUNTER KIT

8 LARGE .4" RED LED DIGITS

• ONLY 8 IC's! • XTAL TIME BASE

A truly "State of the Art" counter using quality components throughout.

KIT INCLUDES: DETAILED INSTRUCTIONS, XTAL, TOP QUALITY FIBERGLASS DOUBLE SIDED PC BOARD, IC'S WITH SOCKETS AND ALL PARTS LESS POWER SUPPLY AND CABINET.

50 MHZ COUNTER KIT	#FC-50	$69.95
5 VOLT REGULATED 1 AMP POWER SUPPLY KIT	#PS-02	$9.95
350 MHZ PRESCALER KIT	#PSL-350	23.95
650 MHZ PRESCALER KIT	#PSL-650	$29.95
CABINET (& MTG HARDWARE)	#CAB III	$19.95

[CABINET WILL HOUSE #FC-50, #PS-02, AND A PRESCALER]

DELIVERIES TO START IN MAY, 1977

Fairchild Super Digit FND-359

.4" Char. Ht. 7 segment LED RED Com. Cath. Direct pin replacement for popular FND-70.

95¢ ea, 10/$8.50 100/$79.00

SET OF 6 FND-359 WITH MULTIPLEX PC BOARD $6.95

NYLON WIRE TIES

8" TIE-WRAP 100/$1.95
4" TIE-WRAP 100/$1.75

PLUG TRANSFORMERS

12 VAC at 150 MA	$ 2.50
12 VAC at 500 MA	3.50
7VAC at 1.75 VA	$3.50

SCHOTTKY TTL

74S00	$ .35
74S01	.40
74S04	.55
74S05	.60
74S09	.55
74S10	.40
74S20	.50
74S22	.45
74S40	.45
74S50	.45
74S51	.55
74S60	.85
74S64	.55
74S74	.85
74S75	1.75
74S78	1.50
74S86	.95
74S107	.95
74S112	.95
74S113	1.40
74S114	.95
74S133	.75
74S134	.75
74S138	1.75
74S139	1.50
74S151	1.95
74S153	1.95
74S155	1.95
74S156	1.95
74S157	1.80
74S158	2.50
74S174	2.50
74S175	2.50
74S181	2.95
74S182	1.95
74S251	2.75

DIGITAL CLOCK IC's

MM 5312	$ 4.95
MM 5314	3.95
MM 5375 AB	3.95
CT-7001	7.95
CT-7002	13.95
MM 5369	2.50

LED DRIVERS

7447	$ .95
7448	.95
75491	.65
75492	.65

PRESCALE

11C90DC	$15.95
95H90	9.95

VOLTAGE REGULATORS

LM 309 H	TO-5	$ .95
LM 309 K	TO-3	1.25
7805	TAB	.95
7812	TAB	1.25
7812	TO-3	1.50
7815	TO-3	1.25
7815	TAB	1.25
78L 15	TO-5	.75
7824	TO-3	1.25
723	DIP	.75
723	TO-5	.75

PROM

1702 E Prom $8.95
5203 E Prom $8.95

SWITCHES

ROCKER SPDT		6/$1.
MINI-SLIDE SPDT		5/$1.
REG. SLIDE DPDT		6/$1.
PUSH BUTTON N.O.		3/$1
MINI	SPDT	$1.30
TOGGLE	DPDT	1.50

IC SOCKETS

PINS	1-24	25	100
8	$ .25	$ .22	$ .20
14	.25	.22	.20
16	.28	.25	.23
18	.31	.28	.26
24	.50	.45	.40
28	.60	.55	.50
40	.75	.70	.65

XTAL

3.579545 MHZ. $1.95

21L02

PRIME - 450 NS LOW POWER FAIRCHILD OR SIGNETICS

1-24	$1.95
25-99	1.75
100-199	1.60
200-499	1.45
Over 500	1.40

TRANSISTORS

2N2222 A	TO-18	3/$1.00
2N2712	TO-98	5/$1.00
2N3415	TO-9	5/$1.00
2N3704	TO-92	5/$1.00
2N4400	TO-92	5/$1.00
2N4125	TO-92	5/$1.00
2N4249	TO-92	5/$1.00
2N4437	TO-92	5/$1.00
2N6027	PUT	2/$1.00
2N5457	N J-Fet	2/$1.00

DIODES

IN 4002	1A, 100 PIV	12/$1.00
IN 4005	1A, 600 PIV	11/$1.00
IN 4007	1A, 1000 PIV	10/$1.00
RECTIFIER	2.5A, 1000 PIV	4/$1.00
IN 914	SIL. SIGNAL	20/$1.00
IN 4148	SIL. SIGNAL	20/$1.00
DYAC	28V.	4/$1.00

LINEAR

555 TIMER	2/$1.00
556 DUAL TIMER	.95
565 PLL	.95
566 FUNCTION GEN.	1.75
567 TONE DECODER	1.75

TRANSISTOR SOCKET TO-5/18 GOLD PINS

5/$1.00

7-SEG LED

COMMON CATHODE

	COLOR	HT	DEC PT	PR EA
FND-359	RED	.4"	RHDP	$ .95
FND 503	RED	.5"	RHDP	$1.35
DL-750	RED	.6"	LHDP	$2.95
XAN-654	GREEN	.6"	NDP	$1.95
XAN-664	RED	.6"	NDP	$1.95

COMMON ANODE

DL 747	RED	.6"	LHDP	$1.95
XAN-72	RED	.3"	LHDP	$1.25
MAN 72	RED	.3"	LHDP	$1.25
XAN-81	YELLOW	.3"	RHDP	$1.75
XAN-351	GREEN	.3"	RHDP	$1.50
XAN-361	RED	.3"	RHDP	$1.50
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XAN-692	RED	.6"	NDP	$1.95

OP AMPS

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709 DIP
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AN EASY TO ASSEMBLE AND EASY TO INSTALL ALARM PROVIDING MANY FEATURES NOT NORMALLY FOUND. KEYLESS ALARM HAS PROVISION FOR POS. & GROUNDING SWITCHES OR SENSORS. WILL PULSE HORN RELAY AT 1HZ RATE OR DRIVE SIREN. KIT PROVIDES PROGRAMMABLE TIME DELAYS FOR EXIT, ENTRY & ALARM PERIOD. UNIT MOUNTS UNDER DASH - REMOTE SWITCH CAN BE MOUNTED WHERE DESIRED. CMOS RELIABILITY RESISTS FALSE ALARMS & PROVIDES FOR ULTRA DEPENDABLE ALARM. DO NOT BE FOOLED BY LOW PRICES! THIS IS A TOP QUALITY COMPLETE KIT WITH ALL PARTS INCLUDING DETAILED DRAWINGS AND INSTRUCTIONS OR AVAILABLE WIRED AND TESTED.

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- VARIABLE FROM 4 to 14V
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- 723 IC REGULATOR
- 2N3055 PASS TRANSISTOR
- CURRENT LIMITING AT 1 Amp

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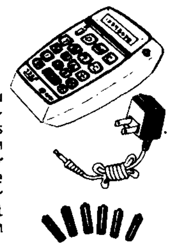
More Details? CHECK—OFF Page 150

SEMICONDUCTORS & MORE!

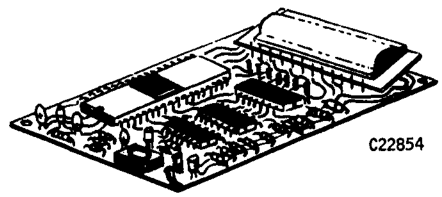
COMPLETE CALCULATOR OFFER

SPECIAL C22857 $11^95



Your best buy is this special combination semi-kit containing everything you need to make a quality rechargeable calculator. Contains our C22853 calculator, C22856 AC adapter, and 6 C22855 nicad rechargeable batteries. It's called a semi-kit because you have to wire up the 6 nicads and install them in the battery compartment (a simple job which requires about an hour or less to complete). You can also use your calculator immediately using the AC adapter without even installing the batteries (as we have installed for you the miniature jack that is normally sent with the AC adapter). Just plug in the adapter and you are ready to use a nice desk calculator then when you have time install the rechargeable nicads for portable operation.

CALCULATOR BOARD WITH 8 DIGIT READOUT



C22854

2 FOR $1^50

Miniature calculator boards by Bowmar. Each is loaded with quality components including the calculator chip, 2 to 4 IC's, magnifying type red 8 digit readout, DIP tantalum capacitors, transistors, resistors, capacitors, toroid transformer and diodes. The keyboards have been removed from board but all other components as listed are on each board. Styles may vary but approx. size is 4½" L. x 2¾" W. Unbelievable value — the readout alone is worth more than this low price. Sold as is.

BURROUGHS PANAPLEX II 9 DIGIT DISPLAY

C22736

3 for $1

Type BR 12259 gas discharge 7 segment display. Requires 160VDC. Right hand decimal on right of each digit. Bright and easy to read, has ⅛" thick glass over ceramic substrate. The displays we have are used, excellent condition. Compare elsewhere up to $3.50 each. No sockets available.

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TRW RF TRANSISTORS PT3551C 15W output 12.6V @ 175 MHz. Same as 2N6081 but has no Stud
$3.50 or 10/$20.00

ITT RF TRANSISTORS 2N5214 50W output @ 40V, @ 175MHz or 30W output, @ 24V @ 175MHz. $15.95

G. E. Miniature Lamps
TYPE 1738D 2.7V @ .06A
TYPE 2114D 6.0V @ .06A
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MDA952A-4	8 Amps	400V	$3.00
MDA962-4	10 Amps	400V	$5.00
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100 PIECES OF SEMICONDUCTOR HARDWARE...... **$1**

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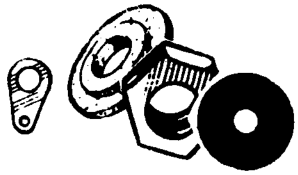
Prepackaged mtg. kits for most stud mounting rectifiers and zener diodes

C22540

3 for 49¢



TUBES							
2C39	$2.00	4X150G	10.00	6080WB	3.00	7289	2.50
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3B28	4.00	578	3.00	6336A	7.00	4600A	150.00
3D21WB	3.50	811	6.95	6360	5.00	4-125A	15.00
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		5894	25.00	6939	7.00		

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		AMS6003	3.00	MC2360G	2.00		

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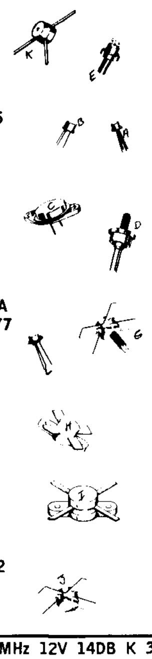
		1N1202	.40	1N4999	.65	1N5892B	5/1.00
1N250B	$0.65	1N754A	5/1.00	1N5271B	5/1.00	1N5894B	5/1.00
1N914	30/1.00	1N3050	1.00	1N5276B	5/1.00	1N5895B	5/1.00
1N1602	.65	1N4719	.60	1N5278B	5/1.00	1N4148	30/1.00
1N1828	.65	1N4749A	5/1.00	1N5862B	5/1.00	1N823	5/1.00
1N2804B	1.00	1N4754A	5/1.00	1N5890B	5/1.00		

R.F. POWER TRANSISTORS



Type #	MHz	Vcc	Power	Case	Price
2N2857	1000	10	30mw	A	$ .95
2N2857 JAN	1000	10	30mw	A	$ 1.10
2N2947	50	25	15W	C	$ 8.00
2N2950	50	25	3.5W	D	$ 4.50
2N3291	250	10	16DB	A	$ .85
2N3375/MM3375	100	28	11.6W	E	$ 3.50
2N3818	150	28	20W	E	$ 4.50
2N3866	400	28	1W	B	$ .65
2N3866 JAN	400	28	1W	B	$ 2.00
2N3866 JAN TX	400	28	1W	B	$ 3.00
2N3925	175	13.6	5W	D	$ 2.50
2N3948	200	20	1W	B	$ 1.25
2N3950	50	28	50W	E	$10.00
2N4072	175	13.6	.25W	A	$ 1.00
2N4957	1200	10	17DB	A	$ 5.00
2N5109/PT3571A	1200	15	11DB	B	$ 1.10
2N5177/MRF5177	400	28	30W	F	$10.00
2N5179	900	6	15DB	A	$ .50
2N5589	175	13.6	3W	G	$ 4.60
2N5590	175	13.6	10W	G	$ 6.30
2N5591	175	13.6	25W	G	$10.35
2N5637	400	28	20W	G	$10.00
2N5862	150	27	75W	H	$49.00
2N5942	30	28	80PEP	I	$44.00
2N6081	175	12.5	15W	G	$ 8.50
2N6083	175	12.5	30W	G	$11.25
2N6084	175	12.5	40W	G	$14.95
2N6097	175	12.5	40W	H	$15.00
MM1500	1500	20	250mw	L	$15.00
MM1607/2N5842	1700	4		A	$ 6.00
MM4049	4000	5		A	$ 7.00
MM8006	1000	6	14DB	A	$ 1.25
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7289	$ 2.50
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2N4170	$1.00
2N4441	$ .75
2N4444	$1.00
2N5060	$ .30
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MAC21-2 50V 25A	$1.50
MAC21-3 100V 25A	$2.00
MAC21-5 300V 25A	$3.00
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2N3567	5/$1.00	2N619	4/$1.00
2N3638	5/$1.00	2N718 JAN	3/$1.00
2N3640	5/$1.00	2N742	3/$1.00
2N3644	5/$1.00	2N961	3/$1.00
2N3702	5/$1.00	2N964	3/$1.00
2N3703	5/$1.00	2N1048	$3.00
2N4001	$1.00	2N1142 JAN	2/$1.00
2N4291	4/$1.00	2N1312	4/$1.00
2N5192	2/$1.00	2N1381	4/$1.00
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MM3002	$ .75	2N914	10/$1.00
MM4000	$ .75	2N2494	2/$1.00
MM4003	$ .75	2N2904	4/$1.00
2SC458	5/$1.00		
2SD235	2/$1.00		
MJE800	$ .65		
MJE1093	$1.00		
MJE3055	$ .75		
MPSA-13	4/$1.00		
2N2369A	10/$1.00		
2N3013	10/$1.00		

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1N4148	30/$1.00
1N2061	10/$1.00
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More Details? CHECK—OFF Page 150

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A compact, well regulated triple output power supply. Gives +5VDC @ 1.5A and +15 @ 150ma and –15 @ 150ma. Complete with PC Board, components, heatsinks & quality transformer. **PS–01B** same as above but with +/–12 output instead of +/– 15; **Please specify model number when ordering.**

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A complete transmitter/receiver kit that will flood an average sized room with 23KHZ sound and detect any movement in the area. The output is a DC level that can be used to trigger a relay, bell or alarm. Uses 2 quality transducers. All components & PC Board included. **(Requires 9-15 VDC @ 60ma [not supplied]).**

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PS–12 POWER SUPPLY KIT

We Guarantee your Satisfaction!

Not only is the PS–12 able to supply a continuous 10 AMPS (15 AMPS intermittent) of low ripple, regulated DC voltage, but it is also variable from 3 to 30 volts! Use it as a building block for a fantastic bench supply. *We leave the chassis work up to you!*

FEATURES:
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- Adjust. Current limiting to 15 amps.
- Special Pre-regulator circuit eliminates need for massive heat sinks.
- Better than 1% Load & Line Regulation from 0 to 15 amps
- Low Ripple output
- Heavy duty 10 lb. Transformer

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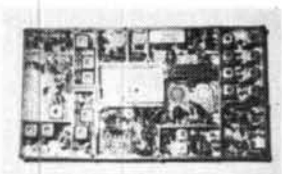

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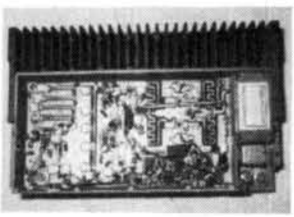

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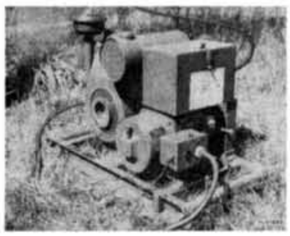

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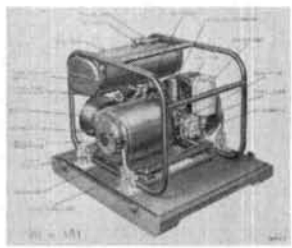

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