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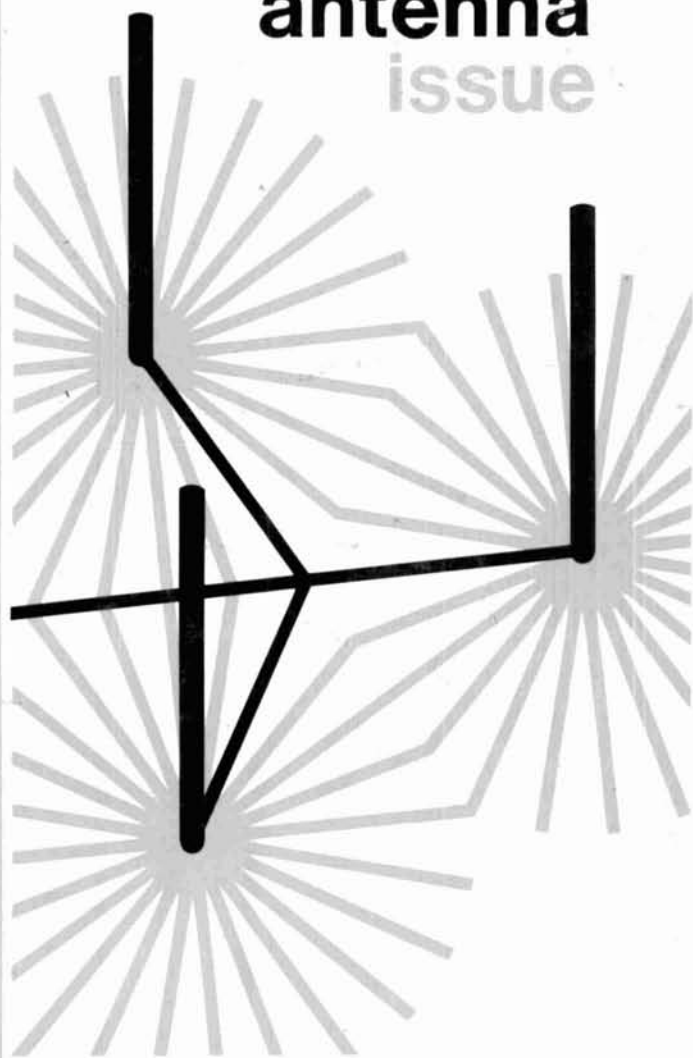
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MAY 1977

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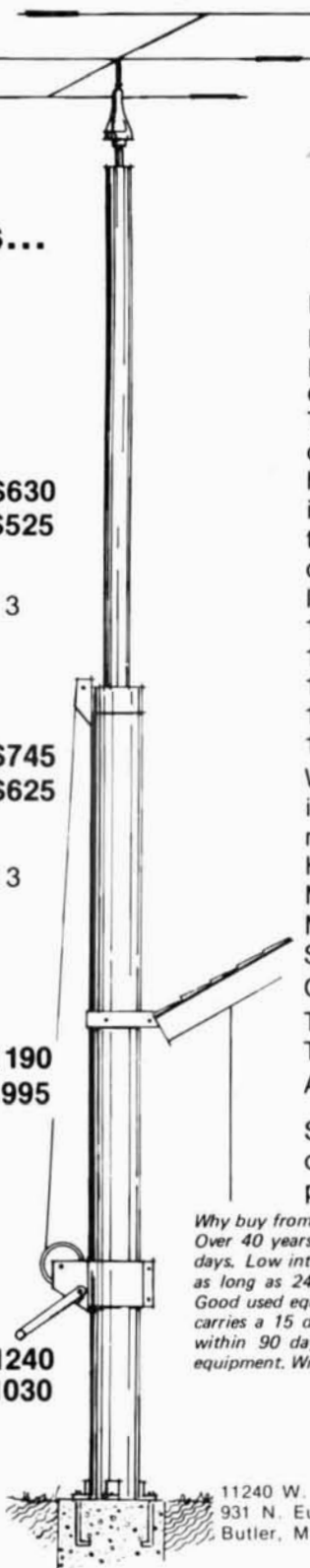
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publisher

James R. Fisk, W1HR
editor-in-chief

editorial staff

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Alfred Wilson, W6NIF
assistant editors

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Patricia A. Hawes, WA1WPM
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Ontario, Canada, N7A 3Y5

Ham Radio Europe
Box 444
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20 bis, Avenue des Clarions
89000 Auxerre, France

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Postbus 3051
Delft 2200, Holland

Ham Radio Italy
S.E. Via Maniago 15
I 20134 Milano, Italy

Ham Radio UK
Post Office Box 63, Harrow
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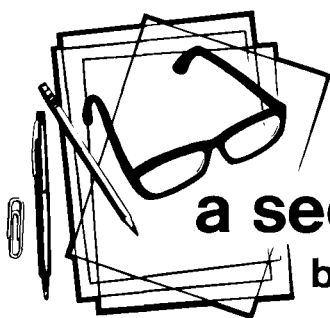
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a second look

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
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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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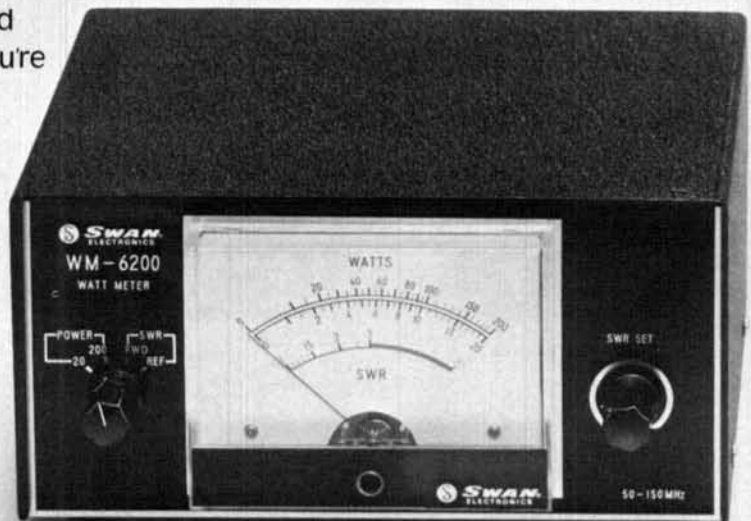


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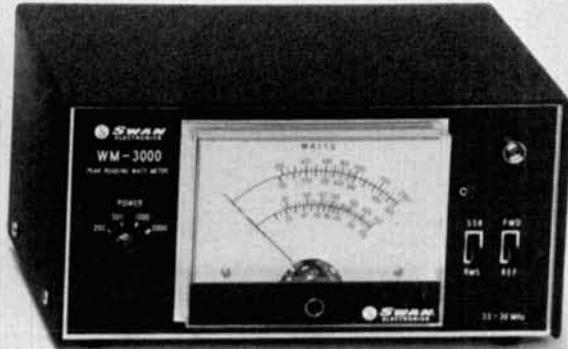
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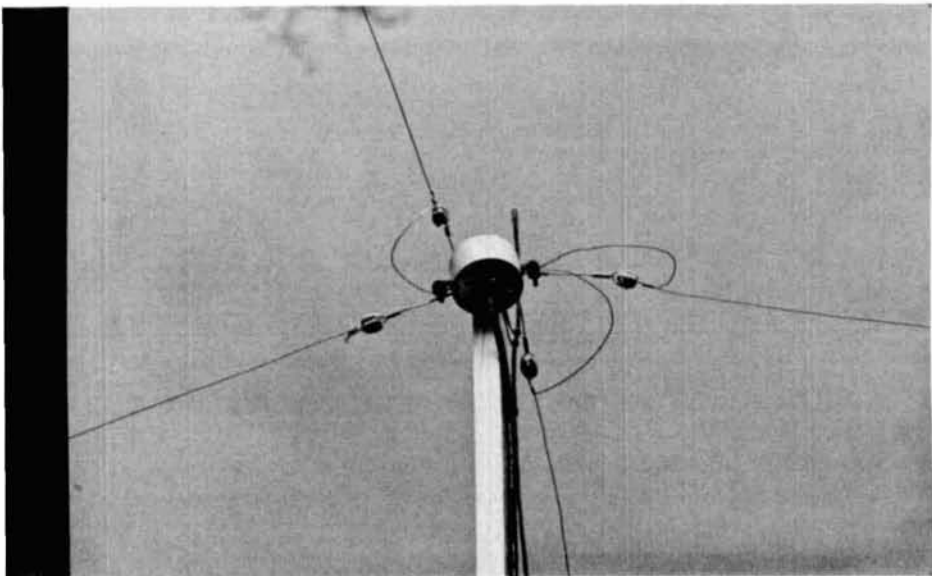


Photo by Douglas Fowley, WA4RPY

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 contacts 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 long-wires. 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

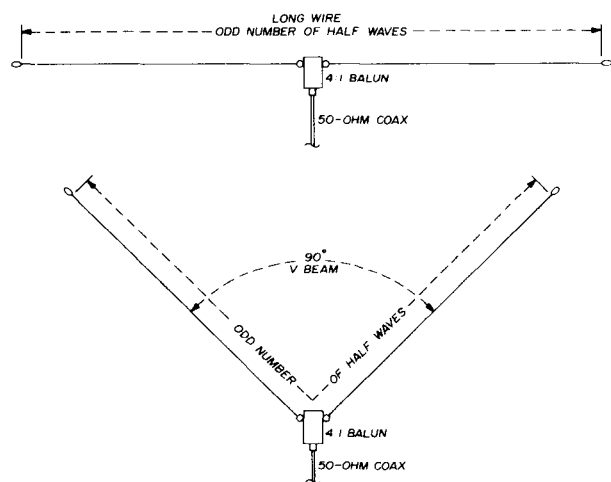


fig. 1. Basic elements author used to form 23 different antenna configurations for comparative signal-strength tests under skip conditions. Measured impedance at the feedpoint of both antennas was 200 ohms, which gave an excellent impedance match using the feed method shown.

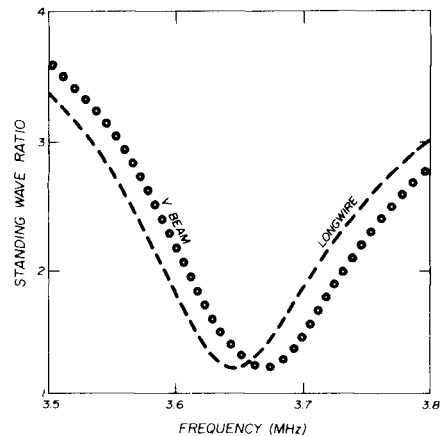


fig. 2. Swr measured on the two basic elements shown in fig. 1. At resonance the swr was 1.2:1; bandwidth at the 2:1-point was 120 kHz, or about 3% of the resonant frequency for both longwire and V beam.

\$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.

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

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.

Terman³ 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

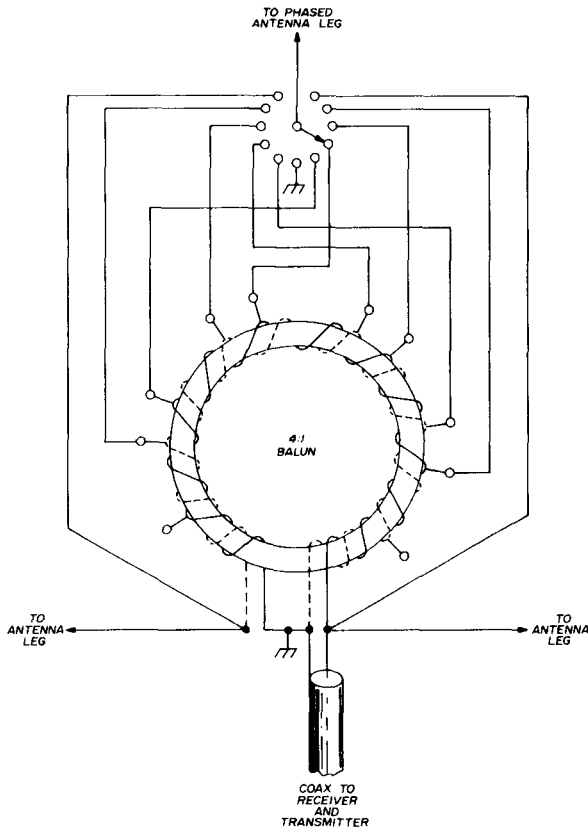


fig. 3. Special tapped balun using Amidon Associates KW balun kit to test steerable phased arrays.

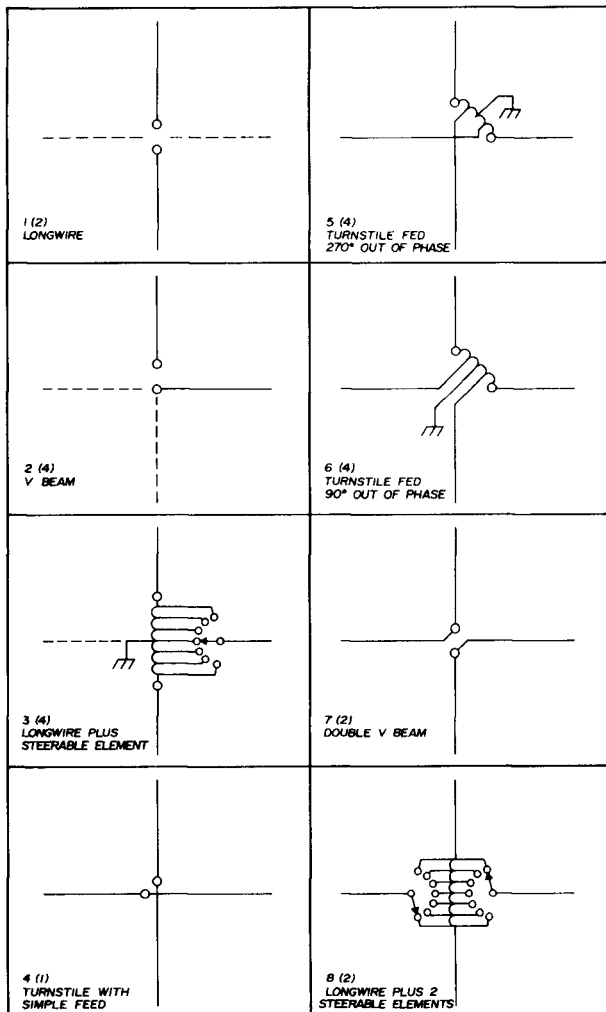


fig. 4. Eight basic antenna designs tested under skip conditions. Numbers in parentheses signify use of additional legs for variations.

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 antenna 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

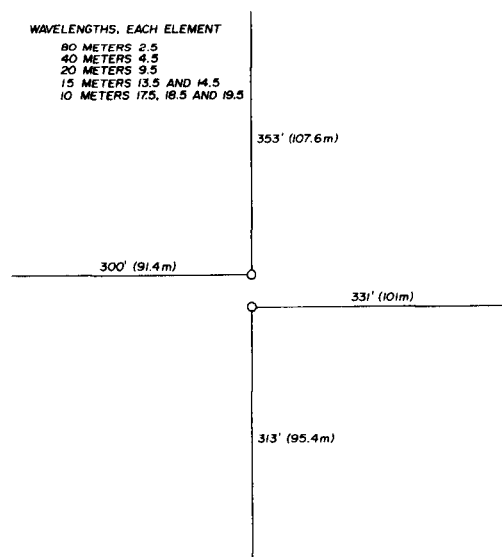


fig. 5. Author's final design, the "double V."

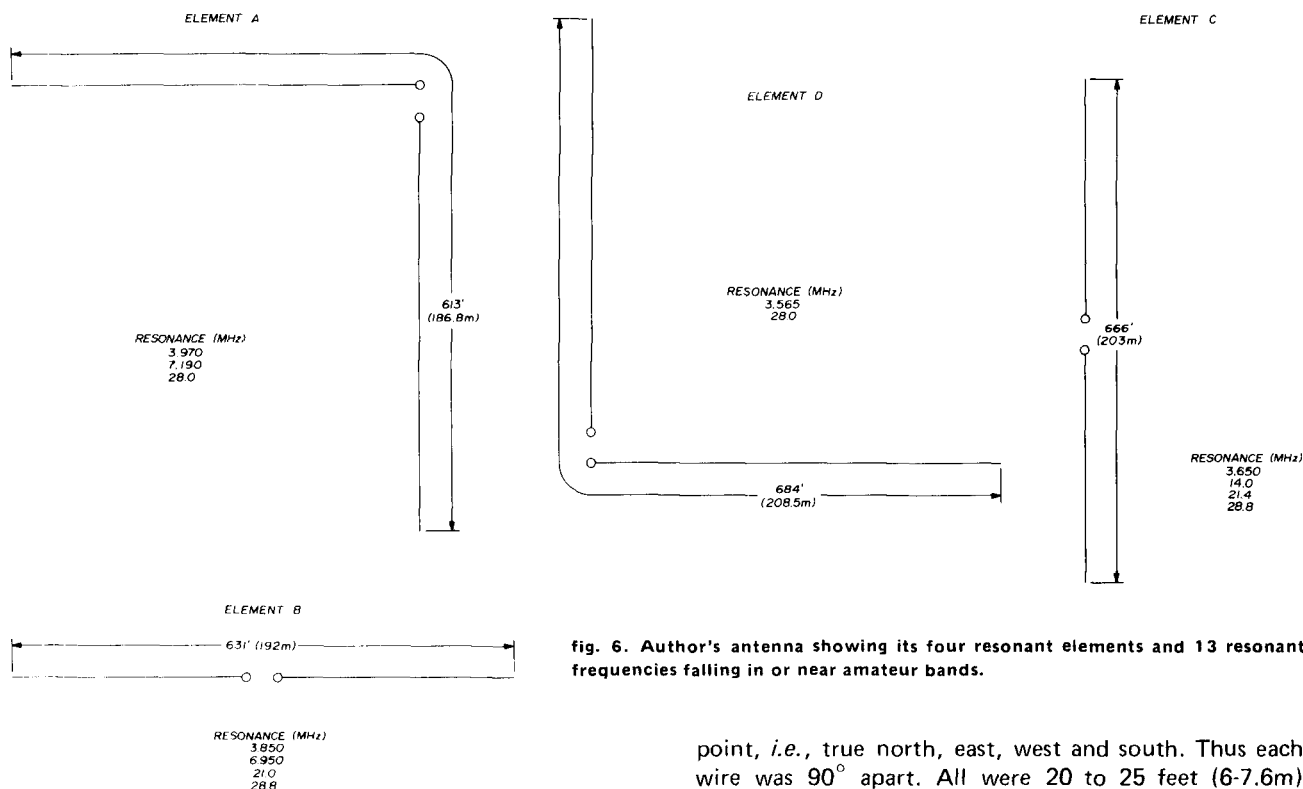


fig. 6. Author's antenna showing its four resonant elements and 13 resonant frequencies falling in or near amateur bands.

checks on 20. Note that a 625-foot (191m) wire is $2\frac{1}{2}$ wavelengths long at 3.9 MHz and $4\frac{1}{2}$ 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 $2\frac{1}{2}$ wavelengths at 3.7 MHz and $9\frac{1}{2}$ 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 $1\frac{1}{4}$ 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 configuration 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

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.

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

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

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:

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

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.

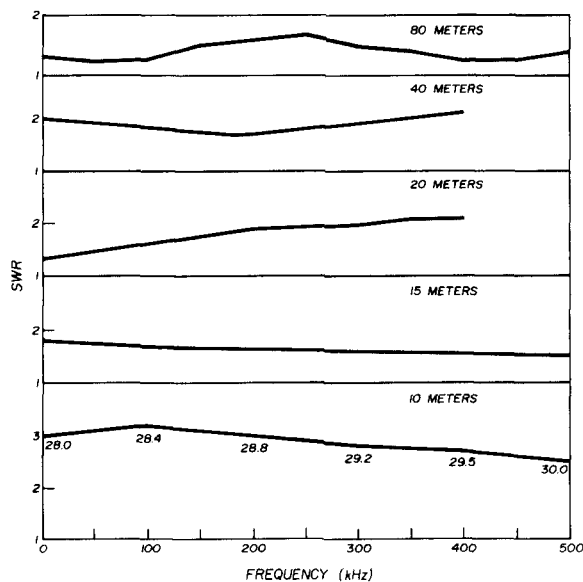


fig. 7. Measured swr of author's antenna on all bands, 80-10 meters. The curve for 10 meters covers 28 to 30 MHz. The curves for the other bands start with the lower band edge on the left side of the chart.

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

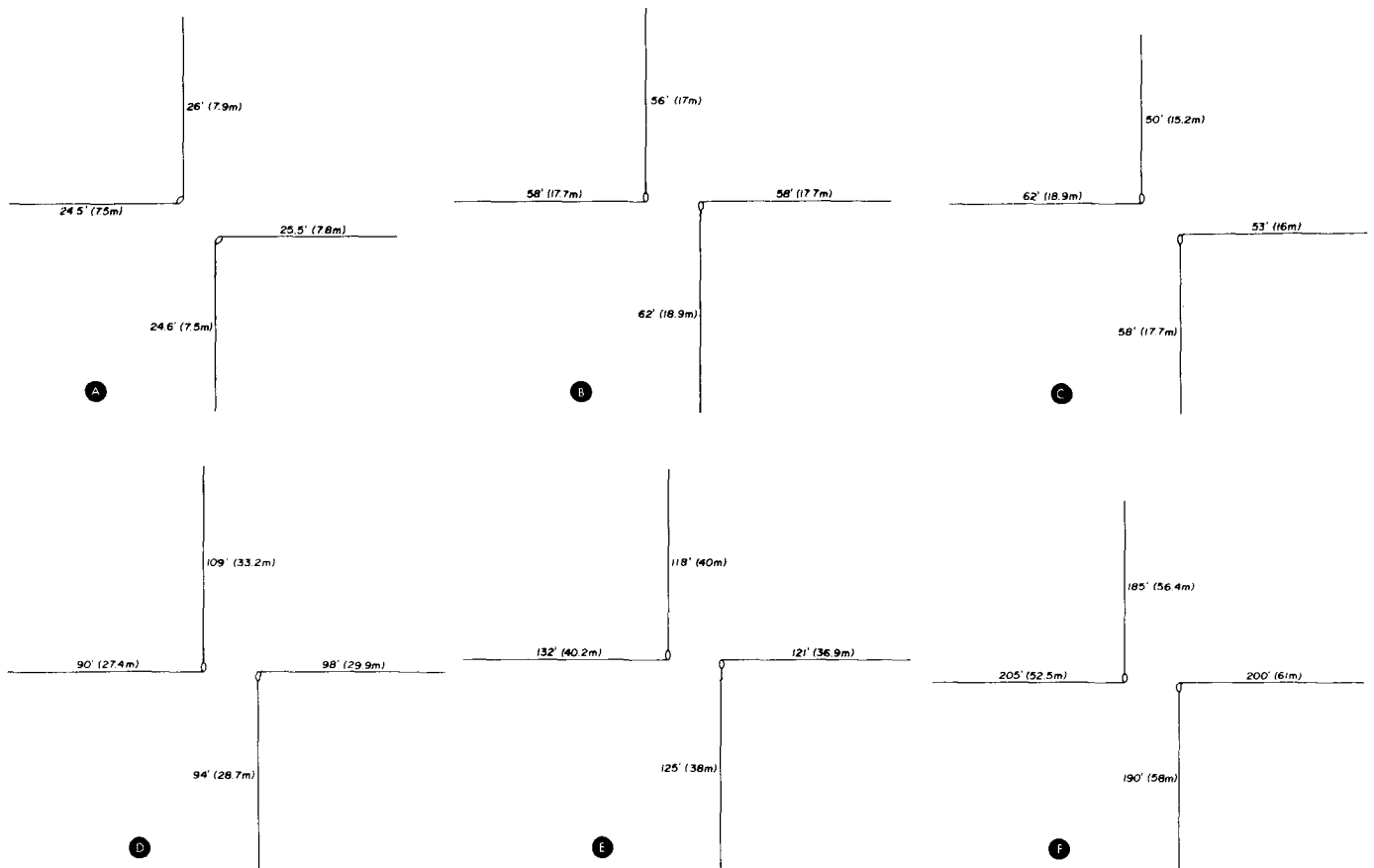
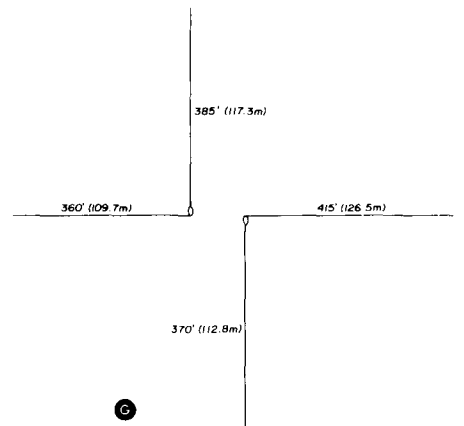


fig. 8. (A) 10-meter broadband design. This is an extension of the simple 10-meter antenna referred to previously. Its four staggered leg lengths will provide a low swr across the entire 10-meter band. It should make a good OSCAR antenna for the high end of 10 meters as well as a good communications 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 (40470m²), 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:		feet		(meters)		feet		(meters)	
	full	half								
waves	waves									
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:		feet		(meters)		feet		(meters)	
	full	half								
waves	waves									
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:		feet		(meters)		
	full	half					
waves	waves						
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:		feet		(meters)		
	full	half					
waves	waves						
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	half						
waves	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	half								
waves	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.

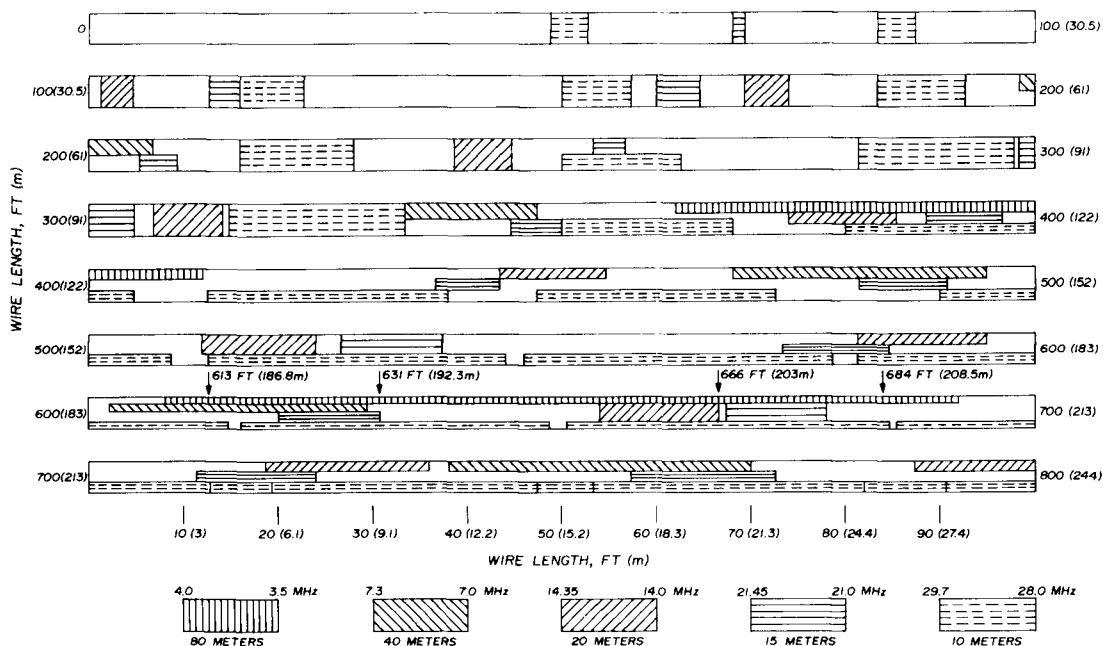


fig. 9. Design aid showing wire lengths from zero to 800 feet (0-244m) in 100-foot (30.5m) increments with amateur bands identified for odd number of half-wave resonances. Wire length of author's antenna is identified by arrows.

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.

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.

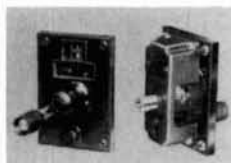
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2. F. E. Terman, *The Radio Engineer's Handbook*, 1st edition, 1943, McGraw-Hill, page 822.

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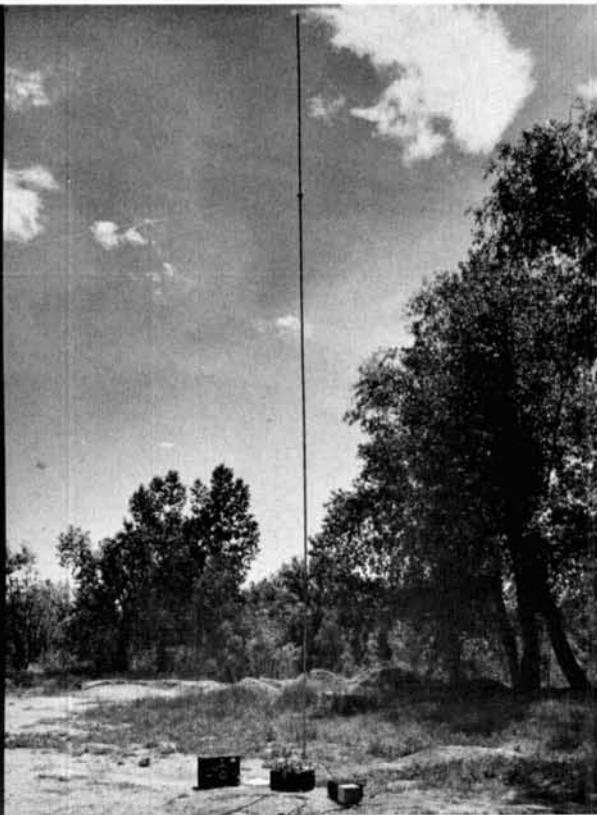
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ground screen — an alternative to a buried radial system

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 W0SPM'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 (20m²) 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 (5.6m²) 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 ($R_r + R_g$) occurred 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

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 **case 7** cross. **Case 9** yielded the lowest total R on all three bands.

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)



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.

yielded the lowest ground loss. A single 30 by 3-foot ($9.1 \times 0.9\text{m}$) 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.

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	$100^\circ = 48$ ohms
3.6 MHz	0.139 wavelength	$50^\circ = 9$ ohms
1.8 MHz	0.069 wavelength	$25^\circ = 2$ 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 Epstein² 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 ($2.7 \times 2.7\text{m}$) 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

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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

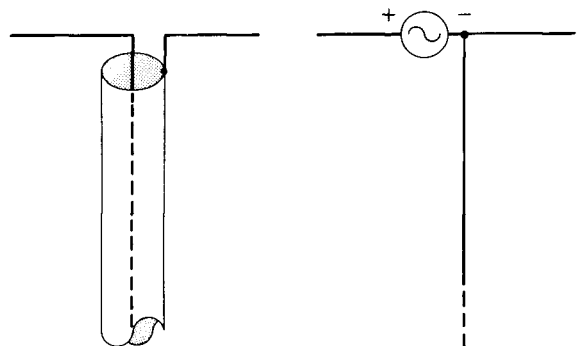


fig. 1. A dipole antenna fed directly with coaxial cable, left, and its electrical equivalent, right.

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 $Z_1 = Z_0 = 50 \text{ ohms}$ and $Z_L = 200$

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

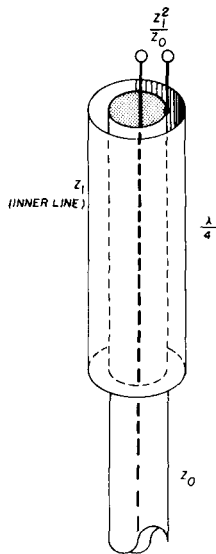


fig. 3. The sleeve or bazooka balun has a fixed transformation ratio of 1:1. Its construction can be complicated by the lack of readily available materials for different impedance ratios.

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.

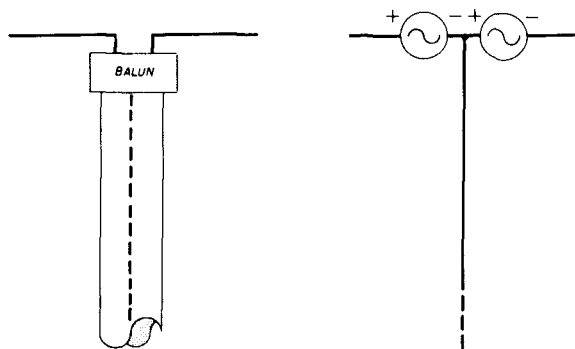


fig. 2. A dipole fed through a balancing device will appear as two balanced generators. In this case there is no radiation from the feedline.

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

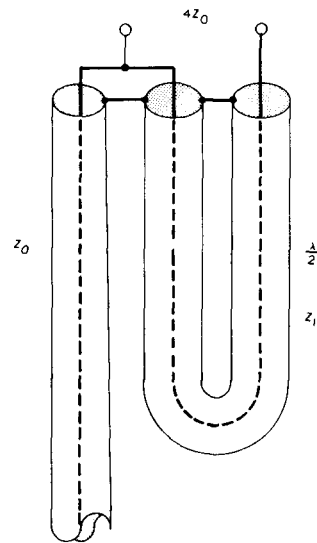


fig. 4. The halfwave-loop balun has a normal transformation ratio of 4:1. The characteristic impedance of the matching section has no effect on the transformation ratio.

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

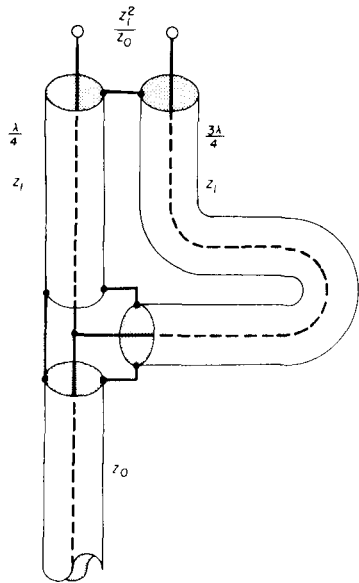


fig. 5. The variable transformer balun as described by the author. By selecting the correct value of characteristic impedance for the matching section, the transformation ratio can be changed.

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

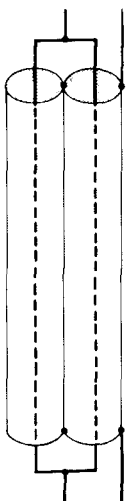


fig. 6. A two-element coaxial section. The characteristic impedance of the composite line is the parallel combination of the individual sections.

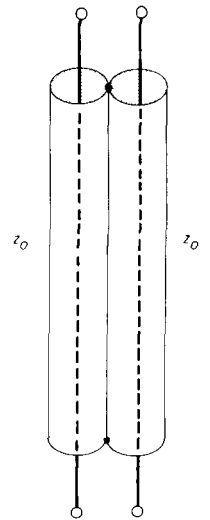


fig. 8. Low impedance, balanced transmission line can be built by using two sections of coaxial cable. This line will retain the shielded characteristics of coaxial cable.

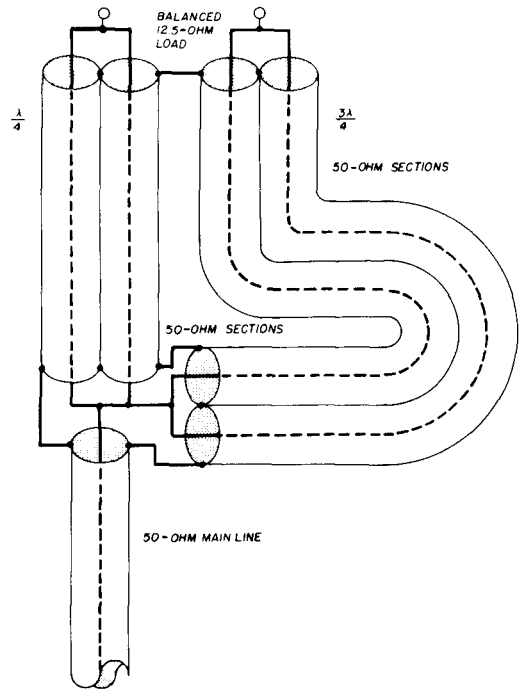


fig. 7. A balun can be built by combining the techniques of composite lines with the variable transformer. This balun will match a 4:1 unbalanced-to-balanced, impedance ratio using only 50-ohm cable.

low values of characteristic impedance may be obtained. A low impedance may be the simplest solution to a particular matching problem.

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 shrieking 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, $2h_i^\circ$, of a doublet antenna is less than 180 degrees ($\lambda/2$), or the electrical length, h_i° , 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 $+jX_L + (-jX_C) = j\omega \text{ ohms}$ 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

table 1. Mean characteristic impedance of cylindrical antennas.

Doublet	$K_A = 120 \left[\log_e \frac{2(h_t^\circ)}{a} - 1 \right] \text{ ohms}$	1
Grounded monopole	$K_m = 60 \left[\log_e \frac{2(h_t^\circ)}{a} - 1 \right] \text{ ohms}$	2

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

End open circuited
 $(Z_s = \infty) \quad Z_{in} = -jK_{A,M} \cotan h_n^\circ$ 3

End short circuited
 $(Z_s = 0) \quad Z_{in} = +jK_{A,M} \tan h_n^\circ$ 4

End terminated in complex impedance
 $(Z_s = R \pm jX)$
 $Z_{in} = K_{A,M} \frac{(Z_s) \cos h_n^\circ \pm jK_{A,M} \sin h_n^\circ}{K_{A,M} \cos h_n^\circ \pm j(Z_s) \sin h_n^\circ}$ 5

Note: when $j(Z_s) = j(R \pm jX) = jR + j^2X = jR - j^2X$, where: $+j^2 = -1$
 $-j^2 = +1$

Useful Relationships

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

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

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

terminals, and at a minimum at the end (or ends) of the antenna.

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

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

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.

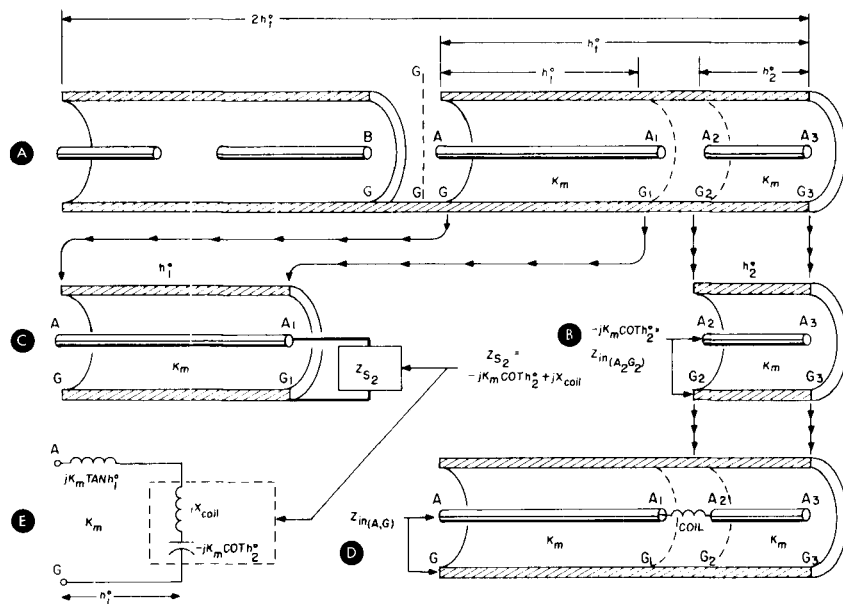
Fig. 1A shows a doublet antenna of total length, $2h_t^\circ$, in the form of an analog coaxial transmission line. This is a model of the actual antenna, so think of the inner conductor of the analog line as the equivalent antenna conductor and the coaxial shield as the surrounding ground plane surface 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, $2h_t^\circ$, 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-

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 $h_1^\circ + h_2^\circ = h_t^\circ$. 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 .

fig. 1. (A) Analog transmission line representation of a doublet antenna of length $2h_t^\circ$ 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_{n1}° , 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.

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

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 $h_1^\circ = \text{zero degrees}$, because no break or gap would exist along the inner conductor for this case. With $h_1^\circ = \text{zero}$, 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:

$$\begin{aligned} K_{m(1)} &= 60[(\log_e \frac{2(h_t')}{a_1}) - 1] = 60[(\log_e \frac{245.8}{0.004}) - 1] \\ &= 60[(\log_e 22900) - 1] = 60(10.04 - 1) \\ &= 542.32 \text{ ohms} \end{aligned}$$

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

$$\begin{aligned} K_{m(2)} &= 404.18 \text{ ohms} \\ K_{m(3)} &= 335.80 \text{ ohms} \end{aligned}$$

Case 1. Base-loaded monopole. Coil in series with base terminal A at monopole input ($h_1^\circ = \text{zero degrees}$). Enter the normalized Smith chart (**fig. 2**) at its "output" end terminals A_3G_3 located at 0.250λ 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 0.250λ 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:

$$\begin{aligned} +jX_{coil(1)} &= +j 835.10 \text{ ohms} & (K_m = 542.32 \text{ ohms}) \\ +jX_{coil(2)} &= +j 622.22 \text{ ohms} & (K_m = 404.18 \text{ ohms}) \\ +jX_{coil(3)} &= +j 517.13 \text{ ohms} & (K_m = 335.80 \text{ ohms}) \end{aligned}$$

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.

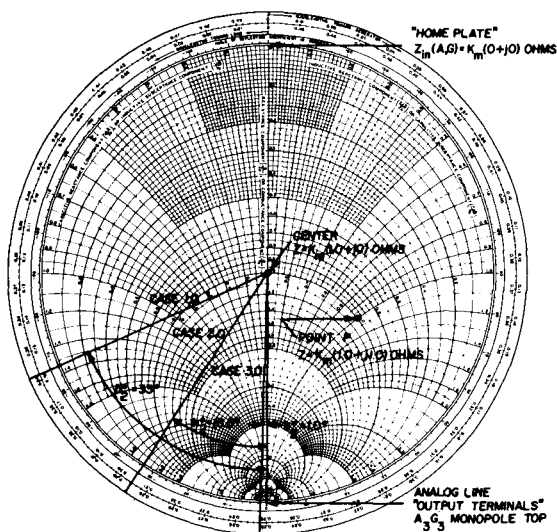


fig. 2. Normalized Smith chart which gives solution for loading coil reactance necessary to resonate a grounded monopole ($h_t^\circ = 33^\circ$) of any K_m and three locations, h_1° , for the loading coil: Case 1, base loading; Case 2, center loading; Case 3, loading 1° from top of monopole.

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

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

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,

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

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 $16.5^\circ - 0.30$

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

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

$$\begin{aligned} jX_{coil(1)} &= +j 1670.35 \text{ ohms} & (K_m = 542.32 \text{ ohms}) \\ jX_{coil(2)} &= +j 1244.87 \text{ ohms} & (K_m = 404.18 \text{ ohms}) \\ jX_{coil(3)} &= +j 1034.26 \text{ ohms} & (K_m = 335.80 \text{ ohms}) \end{aligned}$$

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 $h_1^\circ = 32^\circ$ and $h_2^\circ = 1.0^\circ$. Having to go only $1.0^\circ/360^\circ$ 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 $-jK_m(X_{in})A_2G_2$ — 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 $-jK_m(X_{in})A_2G_2$:

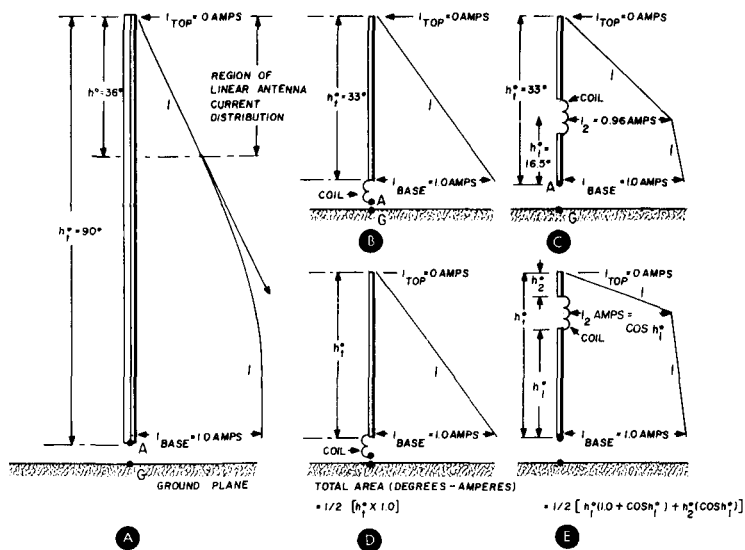
$$\begin{aligned} -jK_m(X_{in})A_2G_2 &= -jK_m(\cot 1.0^\circ) \\ &= -jK_m(57.29) \text{ ohms} \end{aligned}$$

Flipping the sign of the answer above to plus (and

coupling chokes in the power supply leads in your transmitter! Incidentally, 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_1° 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

fig. 3. (A) Sinusoidal current distribution along naturally resonant quarter-wavelength monopole antenna. (B) Linear current distribution for base-coil loaded monopole, $h_1^\circ = 33$ degrees. (C) Same height monopole with center-coil loading. (D) Total current area for base coil loaded monopole, h_1° 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.



knowing that $\tan h_1^\circ = \tan 32^\circ = 0.625$) we plug these values into eq. 1-1:

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

Our final table of coil reactances follows

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

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

$$\begin{aligned} \text{Coil (1)} &= 2.48 \times 10^{-3} \text{ henry} = 2.48 \text{ mH} \\ \text{Coil (2)} &= 1.85 \times 10^{-3} \text{ henry} = 1.85 \text{ mH} \\ \text{Coil (3)} &= 1.53 \times 10^{-3} \text{ henry} = 1.53 \text{ mH} \end{aligned}$$

Coils of this size are large enough to serve as de-

short monopoles?" To answer these critical questions we must turn to the problem of antenna radiation resistance in electrically short antennas.

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_1° . 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, $\sin h_t^\circ$, 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

$$R_r = 0.01215 A^2 \quad (1-2)$$

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 ampli-

tudes 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 $I_2 = \cosine h_1^\circ$.

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

$$\begin{aligned} A &= \frac{1}{2} (33^\circ \times 1.0 \text{ ampere}) \\ &= 16.5 \text{ degree-amperes} \end{aligned}$$

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, $I_2 \cos 16.5^\circ = 0.96$ amperes relative, giving us the area from fig. 3E as,

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

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

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

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

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

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

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

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

$$I_{in} = \sqrt{\frac{P_i}{R_r + R_o}} \text{ amperes} \quad (1-5)$$

where P_i 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

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

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 micro-wave 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 $K_m = 335.8 \text{ ohms}$ would resonate the 45.8 foot tall monopole to a frequency below 1.97 MHz in the 160 meter band; the coil for $K_m = 542.3 \text{ ohms}$ 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.

Forward 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 $Z_{in(A,G)} = 36 + j0 \text{ ohms}$. 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

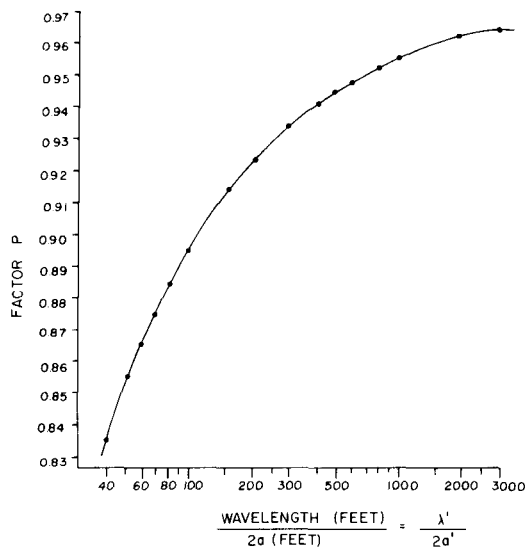


fig. 4. Correction to obtain height, h_t (feet) equal to 90 electrical degrees at resonant frequency. To use this chart use the following procedure:

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

$$\lambda = 984/3.6 = 273.33 \text{ feet}$$

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

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

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 $Z_o = 36 \text{ ohms}$ (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, $Z_{in} = 50.91 \angle \pm 45^\circ \text{ ohms}$.

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

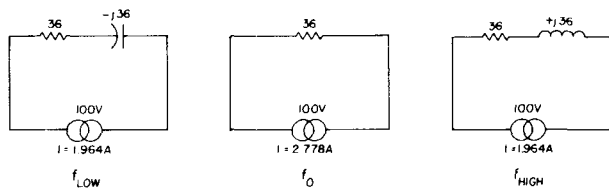
$$Q = \frac{f_o}{f_{high} - f_{low}} \quad (1-7)$$

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,

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

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

*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:

$$\begin{aligned} \text{Power at } f_{low} &= 138.86 \text{ watts} \\ \text{Power at } f_o &= 277.72 \text{ watts} \\ \text{Power at } f_{high} &= 138.66 \text{ watts} \end{aligned}$$

Note that the power difference is exactly 3 dB.

antenna conductor length-to-radius ratio to give you this value of K_m .

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

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

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

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

$$K_m = (46.5 \times 16.97) + 3 = 792 \text{ ohms} \quad (\text{from eq. 1-8})$$

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

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

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

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 $h_t' = 0.250 \times 34.11' = 8.53 \text{ feet}$; $2(h_t') = 17.05 \text{ feet}$.

Therefore,

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

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

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

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. Its 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 non-symmetrical 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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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

*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*).

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

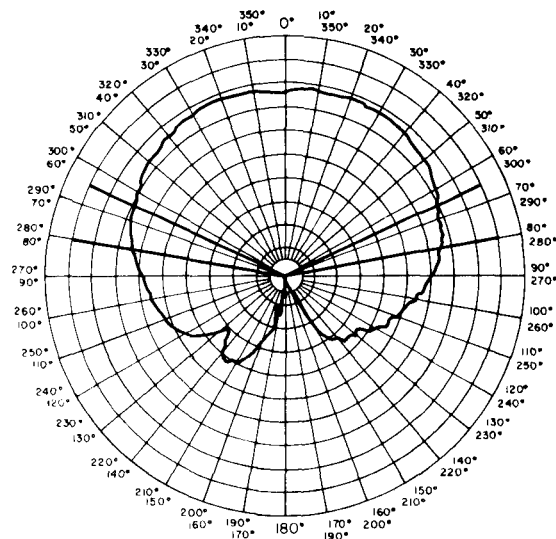


fig. 1. Vertical radiation pattern for the Hewlett-Packard X281 coax-to-waveguide adapter measured at 10.25 GHz. The 3-dB half-angle beamwidth is 65 degrees; 10-dB half-angle beamwidth is 80 degrees.

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

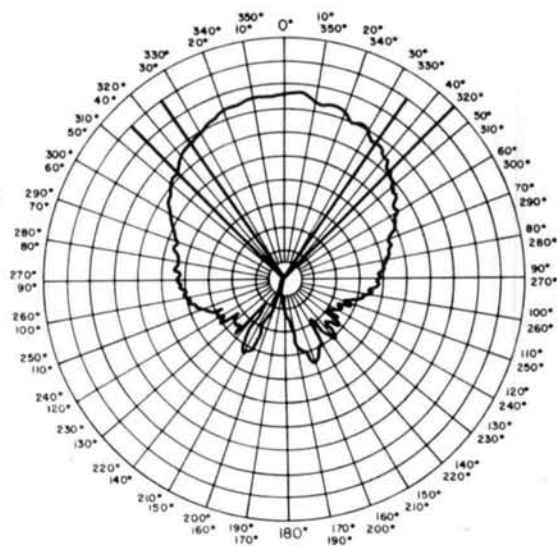


fig. 2. Horizontal radiation pattern of the Hewlett-Packard X281 coax-to-waveguide adapter measured at 10.25 MHz. The 3-dB half-angle beamwidth is 35 degrees; 10-dB half-angle beamwidth is 45 degrees.

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.

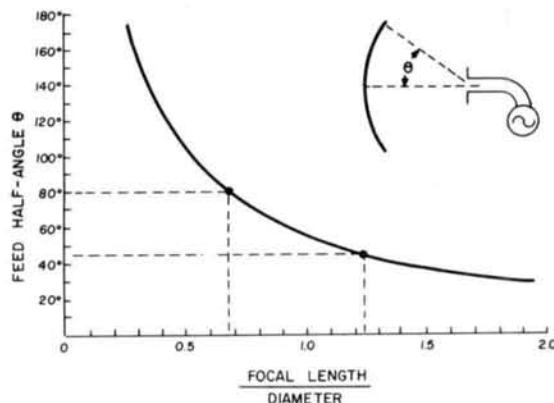


fig. 3. Optimum feed half-angle beamwidth vs focal length to diameter ratio (f number) of a parabolic reflector. The simple antenna described here should be used with reflectors with f numbers between 0.68 and 1.25 as shown by the dashed lines.

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.

ham radio

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Frequency Range	10 Hz to 500 MHz
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Sensitivity	10 Hz to 25 MHz 10 mv 25 MHz to 50 MHz 30 mv 50 MHz to 500 MHz 150 mv
Time Base Stability	STD ± 2 ppm 15° to 55°C ($\pm 0.0002\%$) Optional ± 5 ppm 0° to 60°C ($\pm 0.00005\%$)
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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 $\overline{\text{LEFT}}$ and $\overline{\text{RIGHT}}$ 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

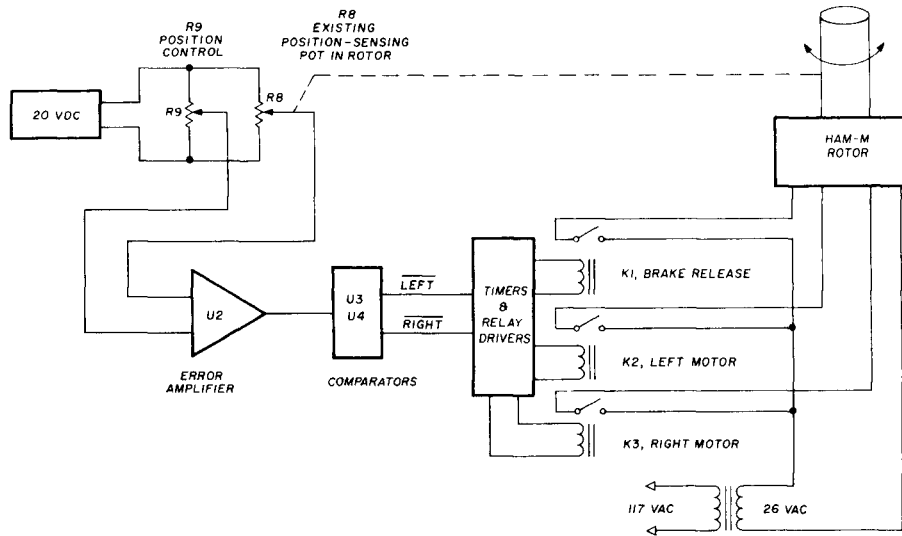


fig. 1. Simplified block diagram of the automatic position control system for HAM-M antenna rotor.

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-

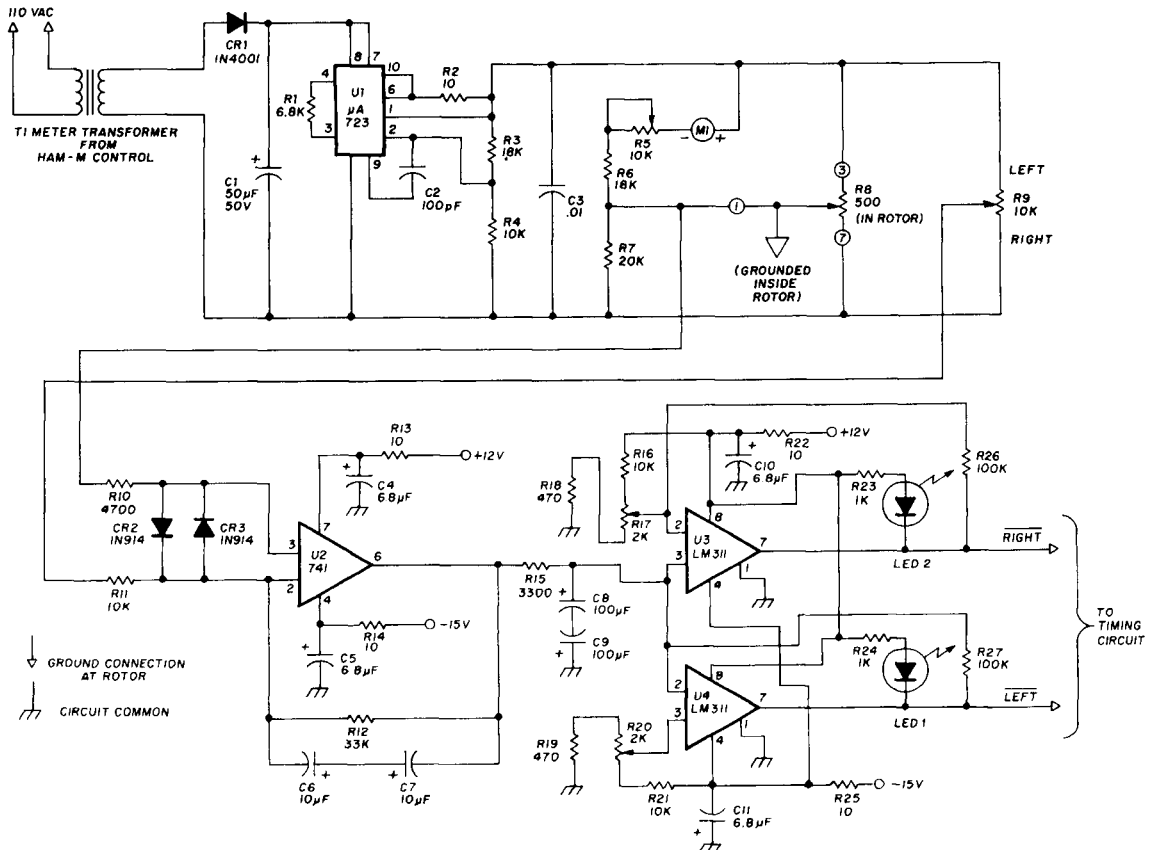


fig. 2. Error amplifier and comparator schematic.

ments of $3^\circ 45'$, 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 μ A723 regulator. It would probably be easier and less expensive to use the newer

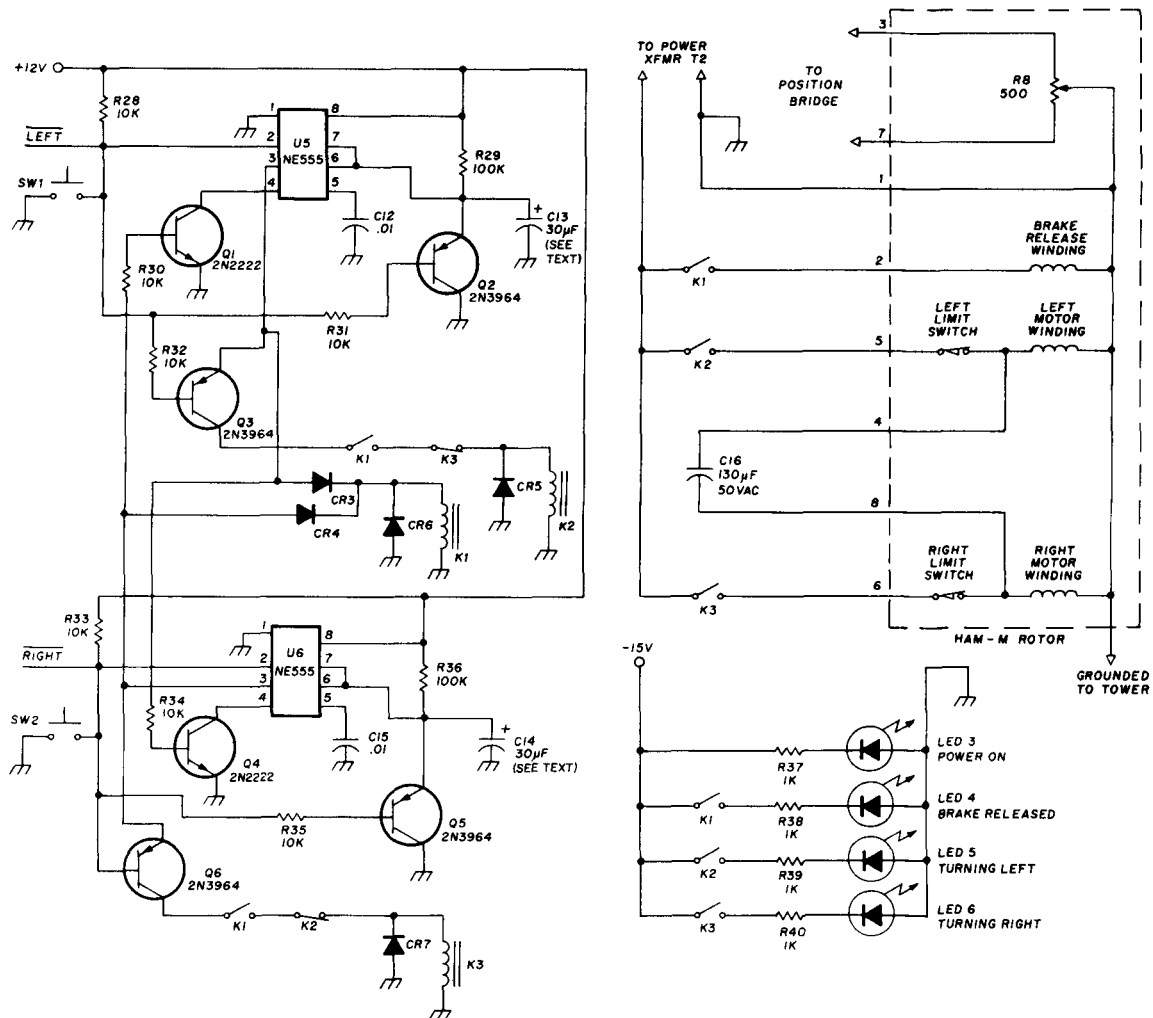


fig. 3. Timing-circuit schematic. C13, C14 see text. CR3-CR7 1N645A or similar. K1-K3 12 Vdc 185-ohm coil, 29 V 5A contacts (Potter & Brumfield R10-E1-X4-V185 or Allied TF154-CCCC-12V). LEDs are HP 4403.

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

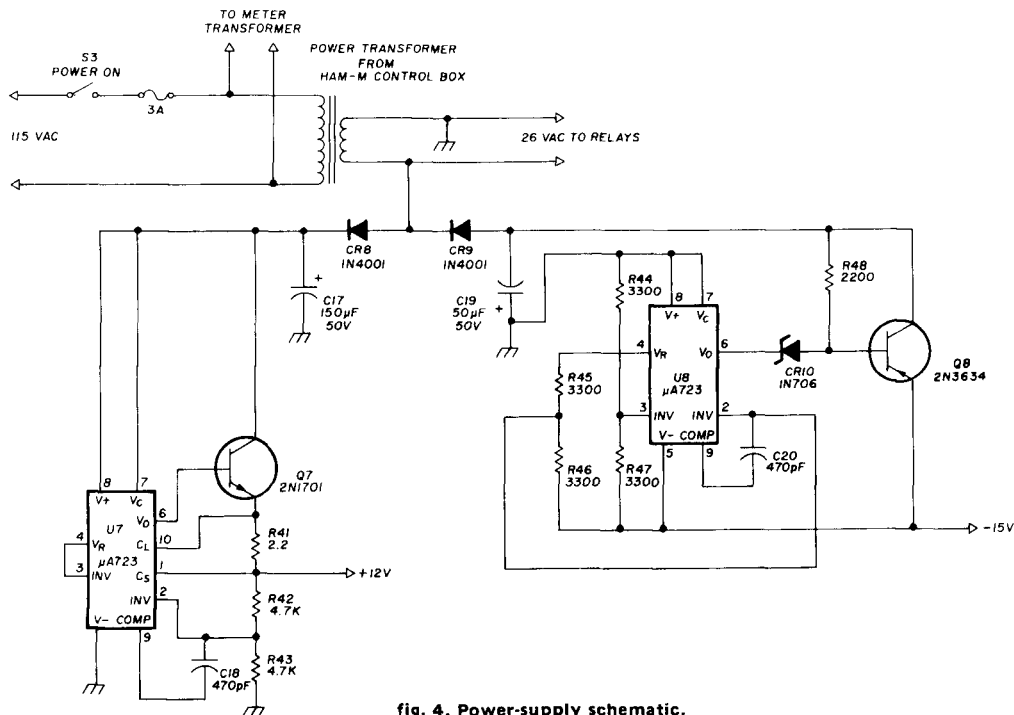


fig. 4. Power-supply schematic.

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

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

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

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 Brown² 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 chart² 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 divider⁵, the jeep-coil type, and the ohms-law type⁶ 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

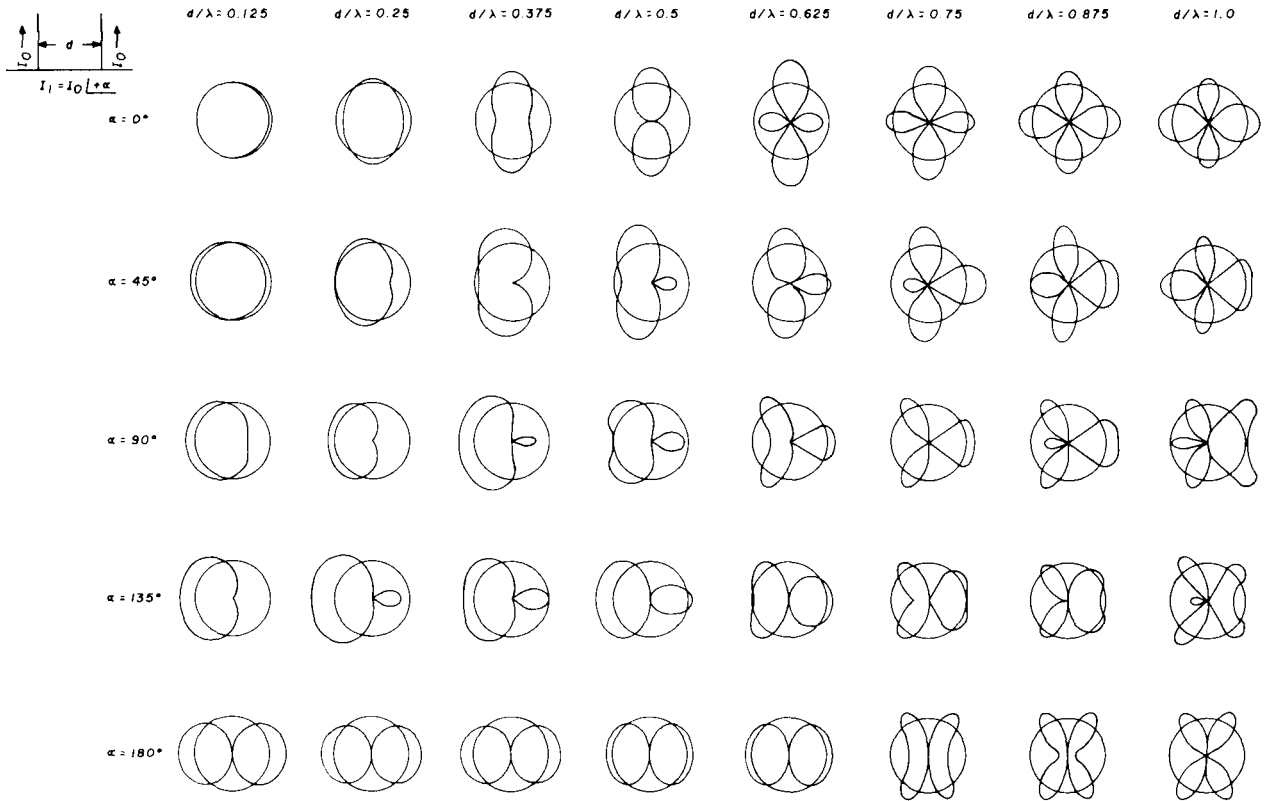


fig. 1. Horizontal patterns for two vertical radiators fed with currents of equal magnitude (after Brown, reference 1). Circles indicate the relative field from one radiator alone with the same power input.

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

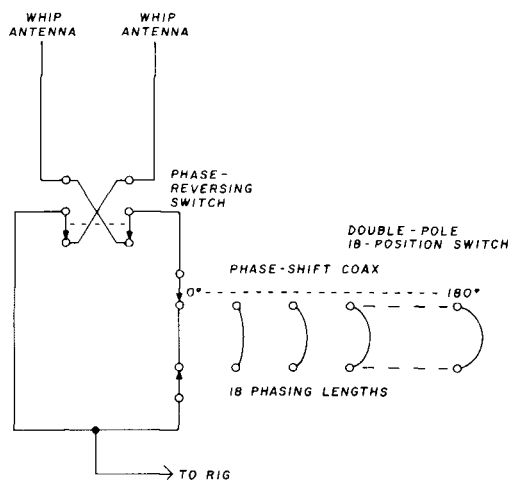


fig. 2. A method for shifting phase in 10-degree steps. Eighteen separate pieces of coax cable would be required — not a very practical scheme.

the pattern from the norm created by a wide assortment of phase shifts.

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 angle⁷ 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

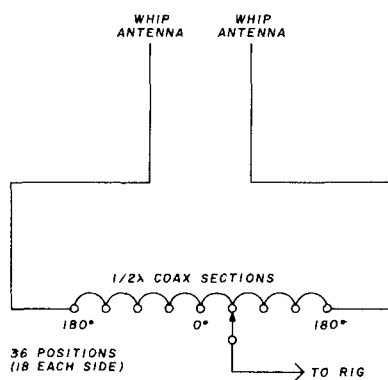


fig. 3. Simple and practical method for an antenna phasing system using a half-wavelength of coax cable with as many taps as desired.

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.

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

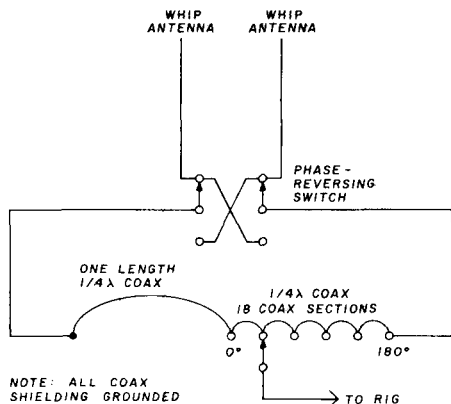


fig. 4. System as shown in fig. 3 but with only one side of cable tapped and a dpdt switch used for phase reversal.

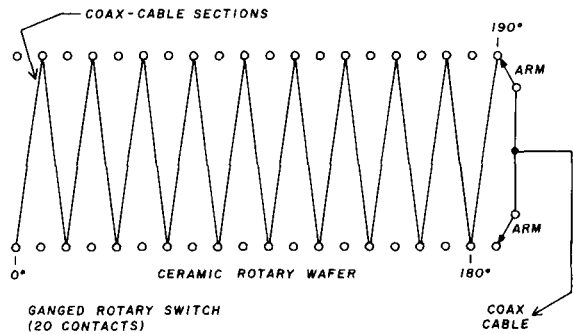


fig. 5. Method for connecting small-length coax sections to a 20-position rotary switch. The switch was modified so that the wafers were far enough apart to accommodate each coax-cable segment. The switch should be able to carry the rf current.

tuning" needed. I could have provided additional switching and shifted phase every 10 degrees, but I would have ended up with 18 separate rolled-up coils of coax, an unwieldy arrangement to say the least (fig. 2).

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

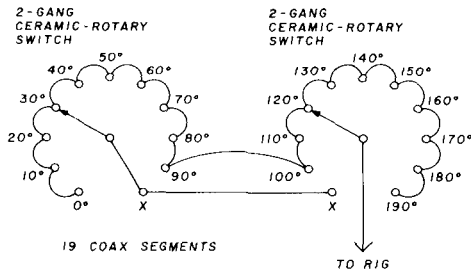


fig. 6. Switch arrangement using two ganged sections. One phasing coax-cable segment is used as a link between each ganged section. Whichever switch is not in use should be set at contact marked with an X.

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

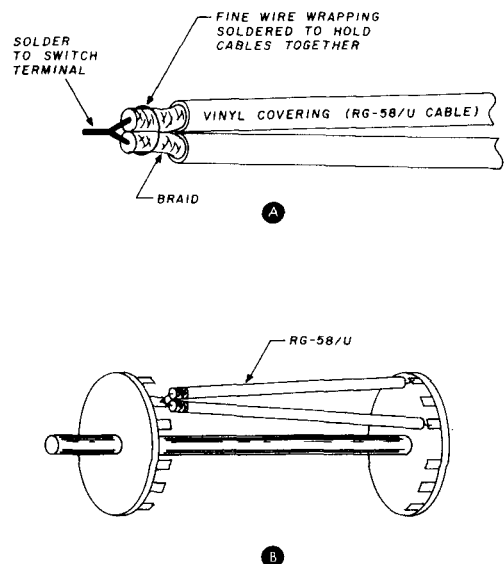


fig. 7. Method for mounting coax cable to rotary-switch segments. Sketch A shows how to secure the cable ends. Sketch B is an example of the coax-cable segment in (A) mounted to a two-gang ceramic rotary switch.

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.

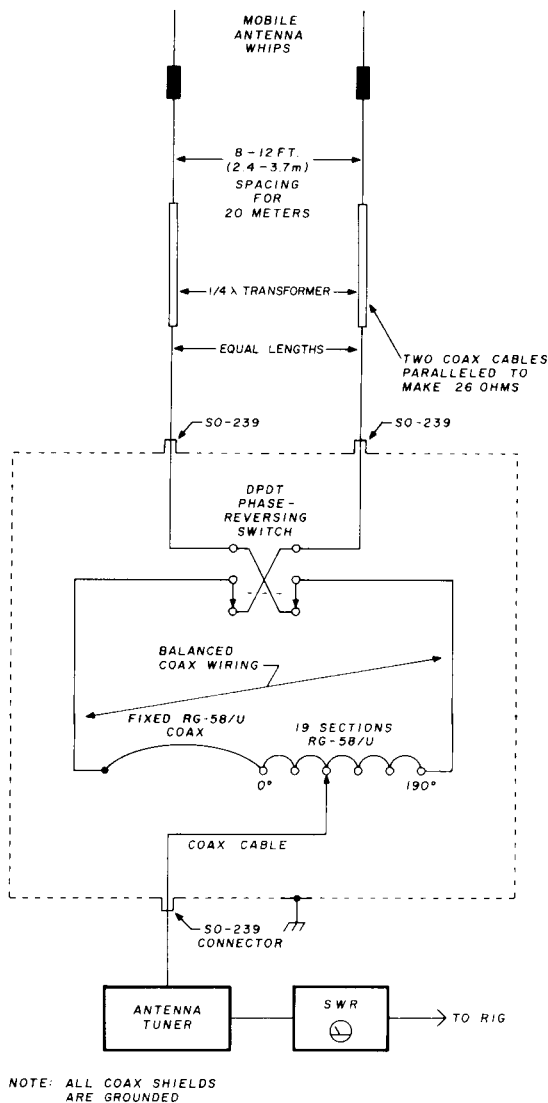


fig. 8. Final schematic diagram of phasing unit shown connected to antennas, tuner and swr indicator.

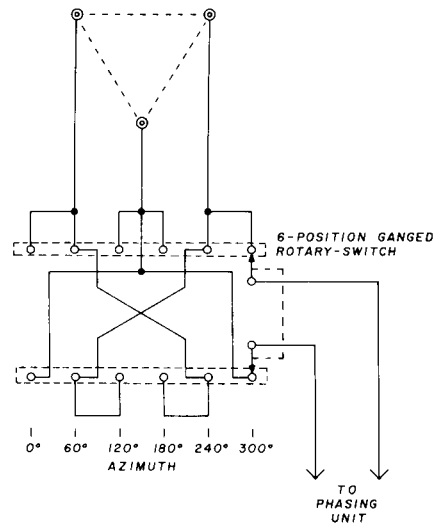


fig. 9. Arrangement of three vertical antennas in a triangle for full directional coverage.

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 flexibility 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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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-eighth 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 (160km/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, W4MNV, 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

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

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 Specialists¹ 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)

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

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.

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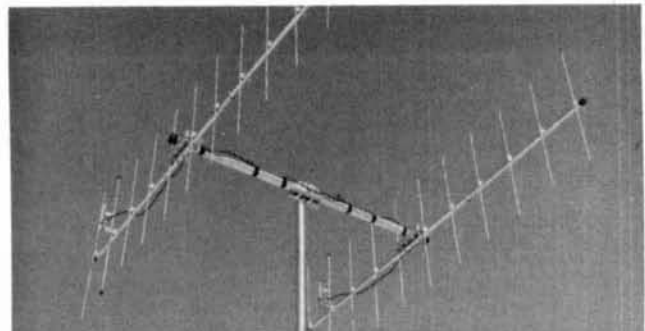
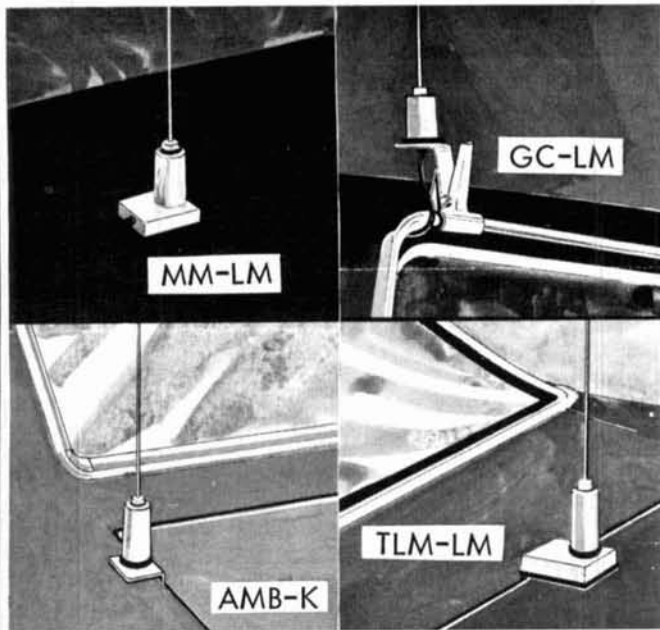
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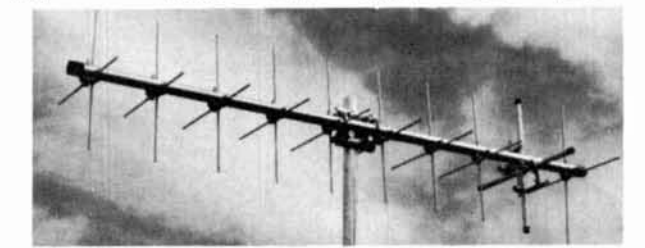
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Gain/F/B ratio dB	13.2/28	9/20	13.2/28	11/25	13.2/28
1/2 Power beam	48°	66°	48°	60°	48°
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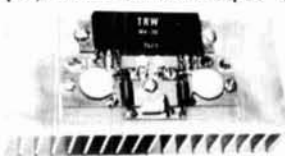
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While tuning around the different amateur bands, you can find that the antennas in use fall into a familiar pattern. On 10, 15, and 20 meters, most people are using a Yagi or quad; on 40 meters, the majority are using a vertical or dipole. However, 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, discons, 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

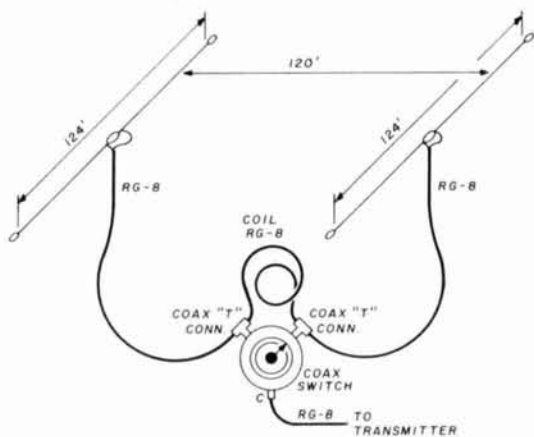


fig. 1. The antennas are fed through identical lengths of coax. By tuning each antenna individually to the same frequency, it is possible to switch directions without retuning the amplifier. The coax switch cannot be self-grounding.

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 75-meter phone band.

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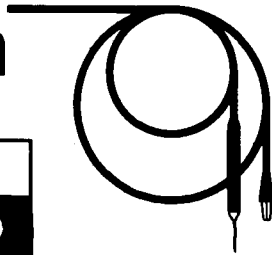
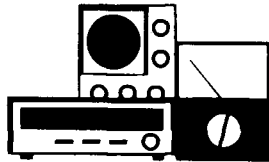
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Bob Stein, W6NBI

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,

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

which appears to have been designed originally as military equipment.

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_0 , 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_0 , 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,

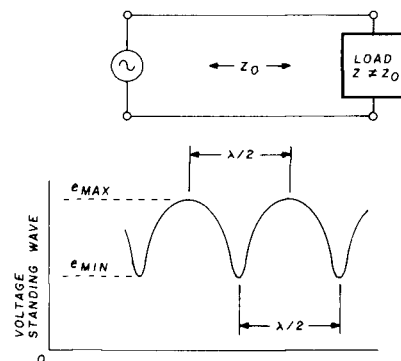


fig. 1. Standing wave on a transmission line terminated by a load impedance which is not equal to its characteristic impedance.

e_{min} , enabling us to determine the voltage standing-wave ratio from the following equations:

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

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

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.

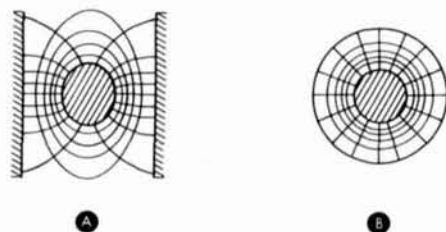


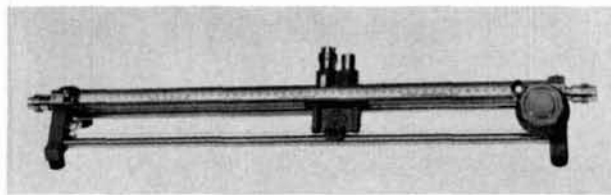
fig. 2. Cross-sections of the slab-type (A) and coaxial (B) slotted lines. The radial lines represent the electric field, the concentric lines the magnetic field. Courtesy Hewlett-Packard Company.

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

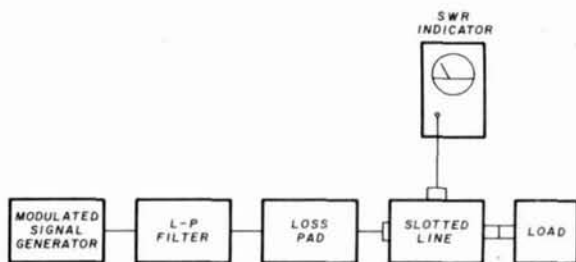


fig. 3. Equipment set-up for measuring swr, using an swr indicator for direct measurement readings.

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

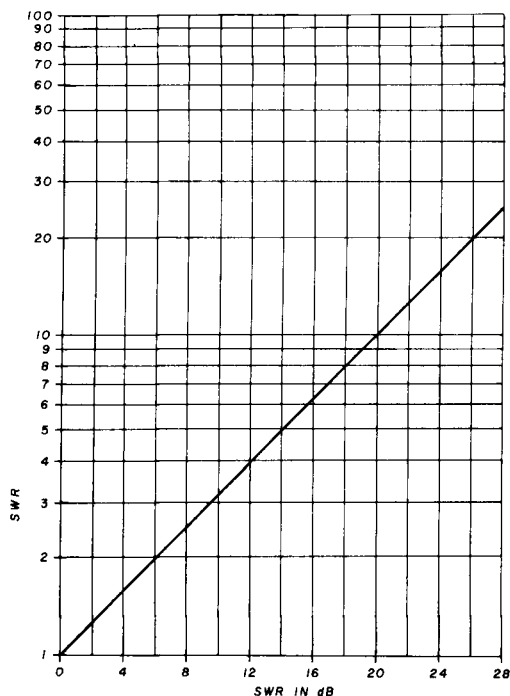


fig. 4. Swr vs swr in dB.

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:

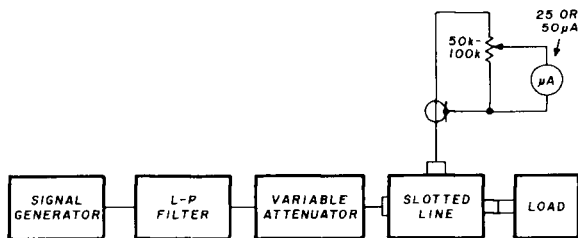


fig. 5. Equipment set-up for measuring *swr*, using a microammeter for an indicator. The signal generator does not have to be modulated in this arrangement.

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**.

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

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.

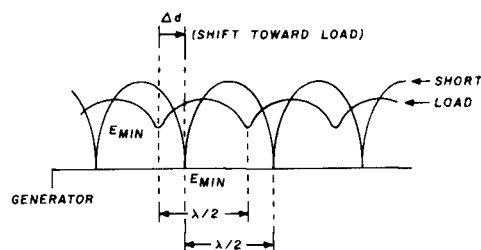


fig. 6. Standing-wave patterns on a slotted line with a capacitive load and with a shorting termination. Courtesy Hewlett-Packard Company.

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 $\lambda/2$, 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,

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

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:

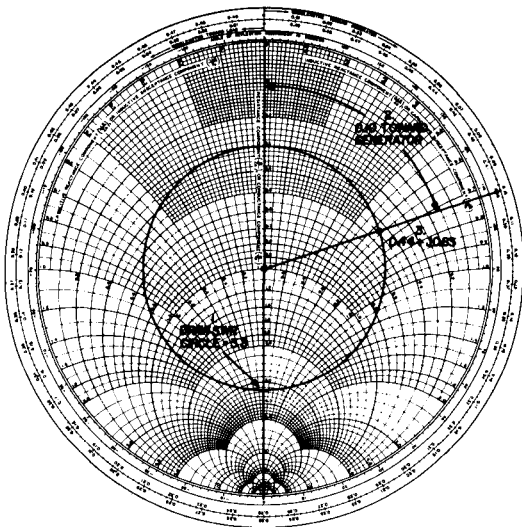


fig. 7. Example of determining impedance by use of a Smith chart. Courtesy Hewlett-Packard Company.

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

*Reprinted from reference 3 by permission of Hewlett-Packard Company.

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.

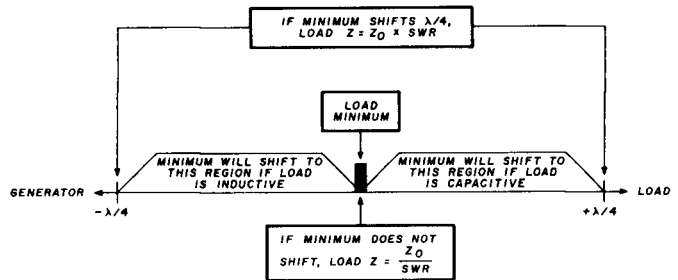


fig. 8. Summary of rules for impedance measurements. Courtesy Hewlett-Packard Company.

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:

$$\text{swr} = 3.3$$

$$\lambda/2 = 150 \text{ mm, with one minimum at 220 mm}$$

$$\Delta d = 30 \text{ mm, toward generator}$$

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 \pm 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.

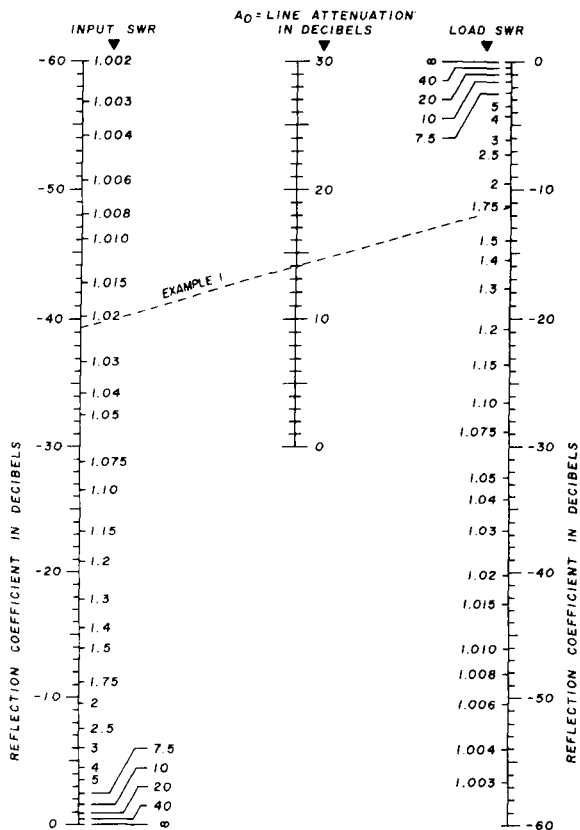


fig. 9. Line attenuation for low input standing-wave ratios. Reprinted from reference 4 by permission of Howard W. Sams & Co., Inc.

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. Obviously 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

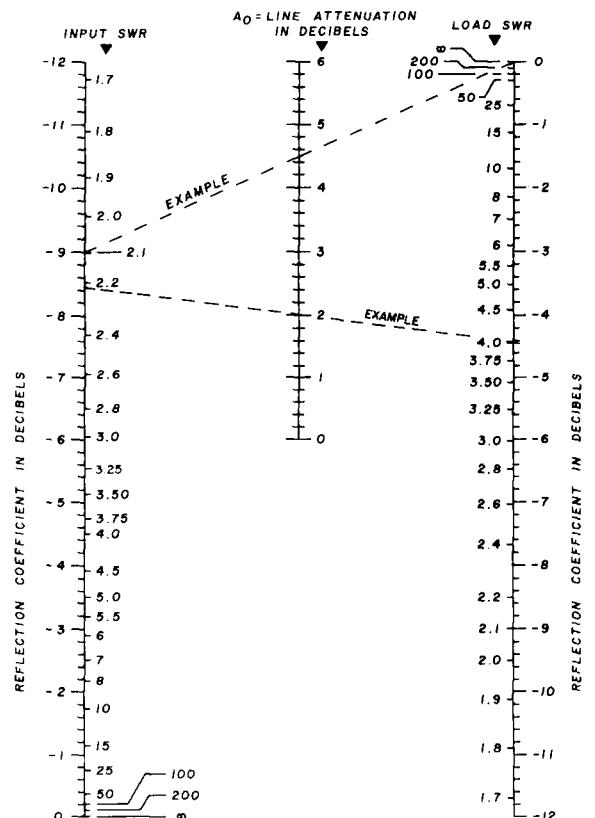
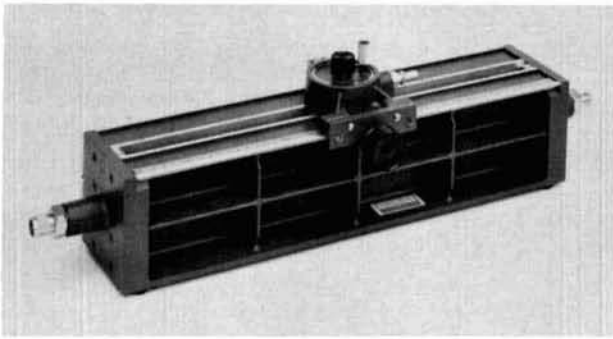


fig. 10. Line attenuation for high input standing-wave ratios. Reprinted from reference 4 by permission of Howard W. Sams & Co., Inc.



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.

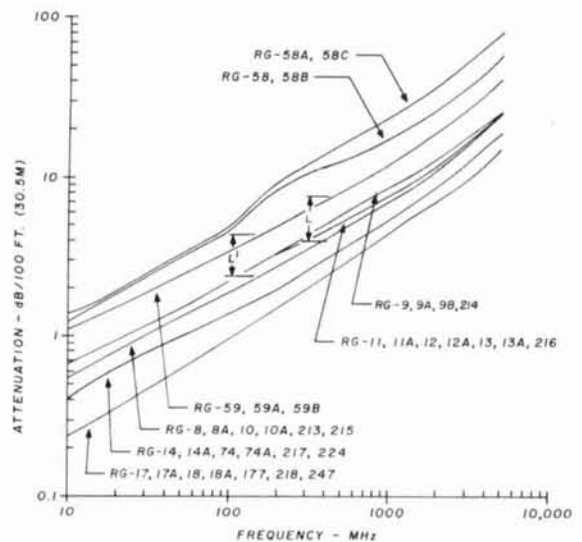


fig. 11. Attenuation vs frequency for commonly used coaxial cables. Dimension L and L' are used in the example in the text of translating line loss to a lower frequency.


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.

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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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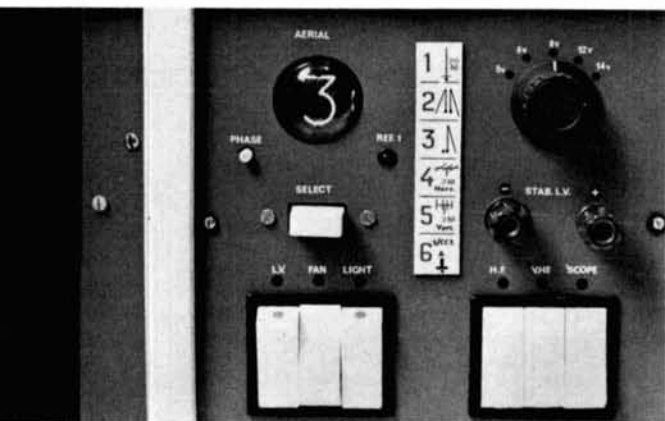
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remote switching

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 $\frac{1}{2}$ -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 $\frac{1}{2}$ -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 posi-

tion. 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

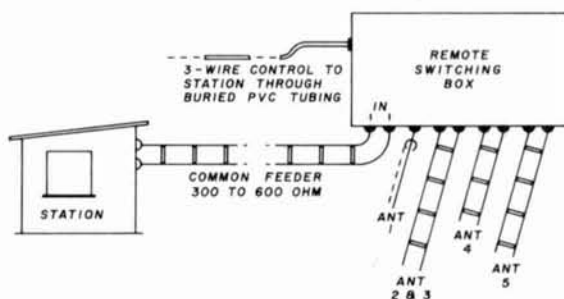


fig. 1. Arrangement of common transmission line and remote switching terminal between amateur station and antennas.

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

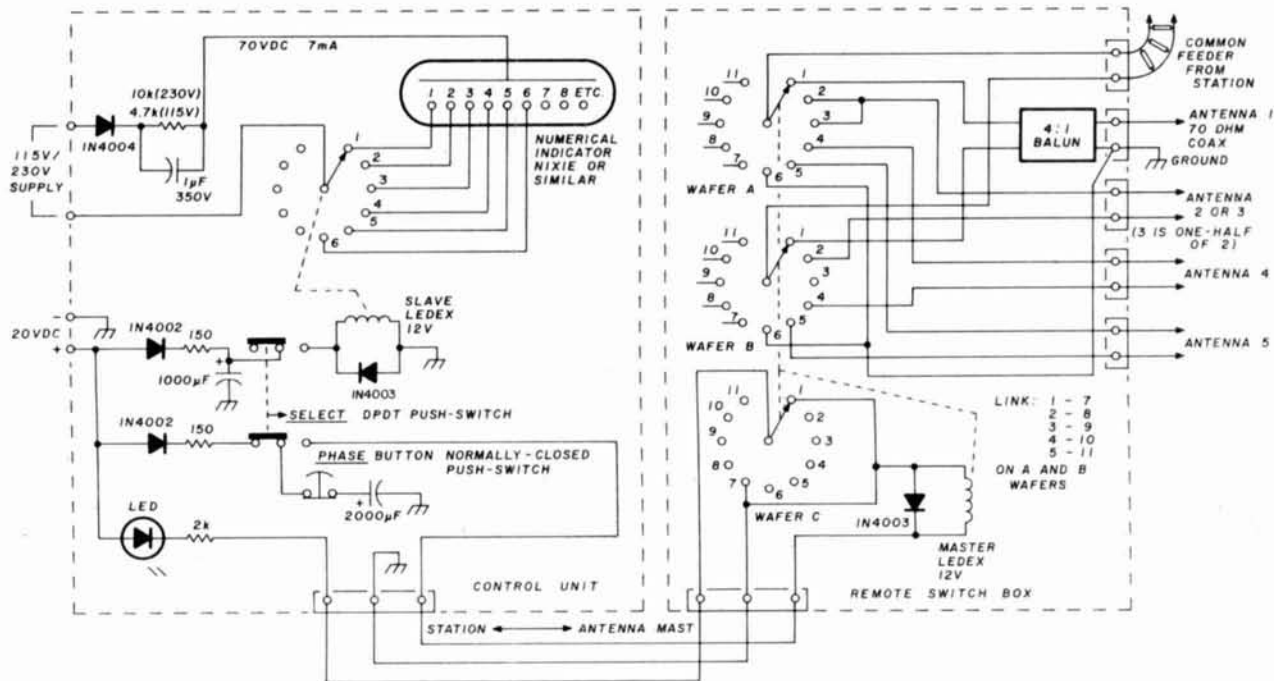


fig. 2. Schematic of the remote antenna switching system. Master and slave Ledex solenoids are used between amateur station and antenna-mast base to minimize number of control wires. NIXIE feature shows selected antenna.

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

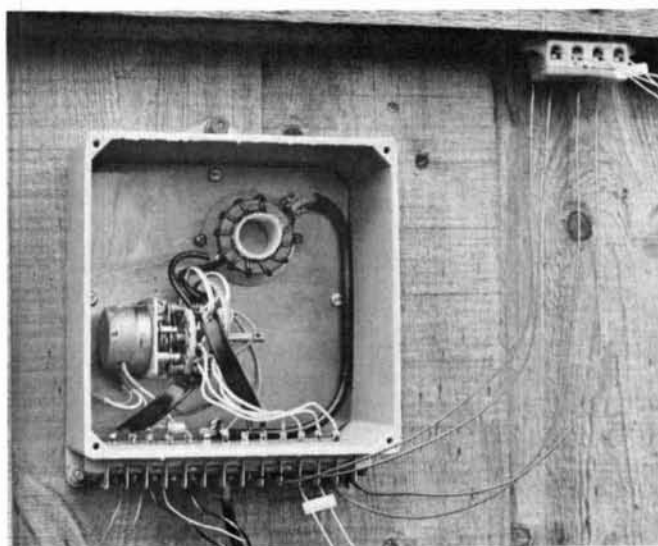


fig. 3. Remote switch box with cover removed. Ledex stepping solenoid is shown at lower left, balun transformer at upper right. Main terminal block is shown at bottom left.

balun converts the open-wire line impedance (about 300 ohms) to about 70 ohms to feed the half-wave vertical antenna for 20 meters.

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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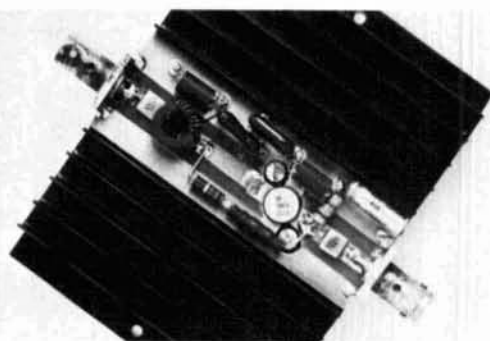
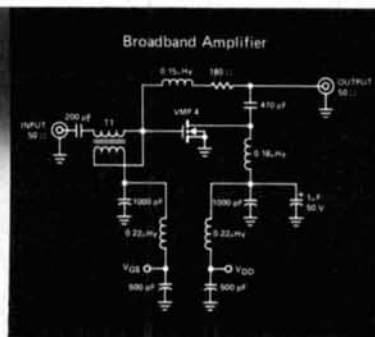
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the gin pole: a simple lever for raising masts

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

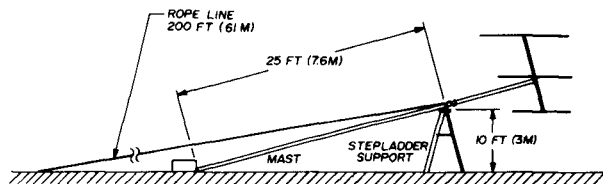


fig. 1. A typical problem — a mast is to be erected at point X. The mast is temporarily propped with a stepladder or other support. Rope is secured to the mast as shown and extended in the direction to which the mast is to rise. Forces involved can be tremendous and the mast may buckle.

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 reference² 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

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

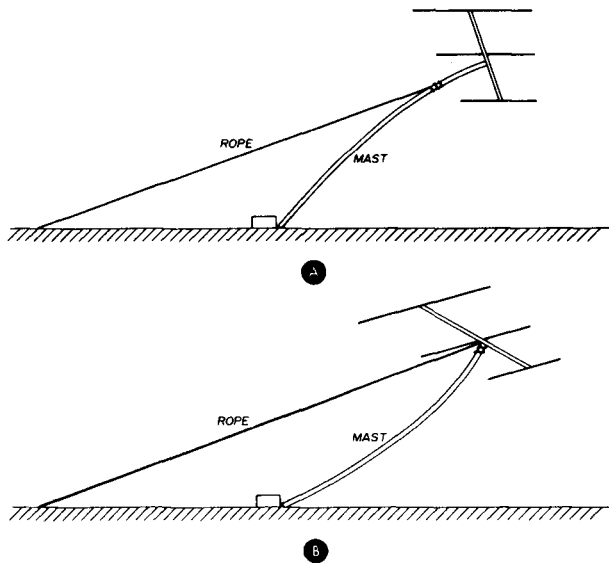


fig. 2. The buckling problem. In sketch (A) a single rope is secured above the mast balance point, which allows the mast to sag, as does a single rope secured to the top of the mast (B). In either case the mast may buckle.

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.

Rossnagel² 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 rope² 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

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)

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.

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

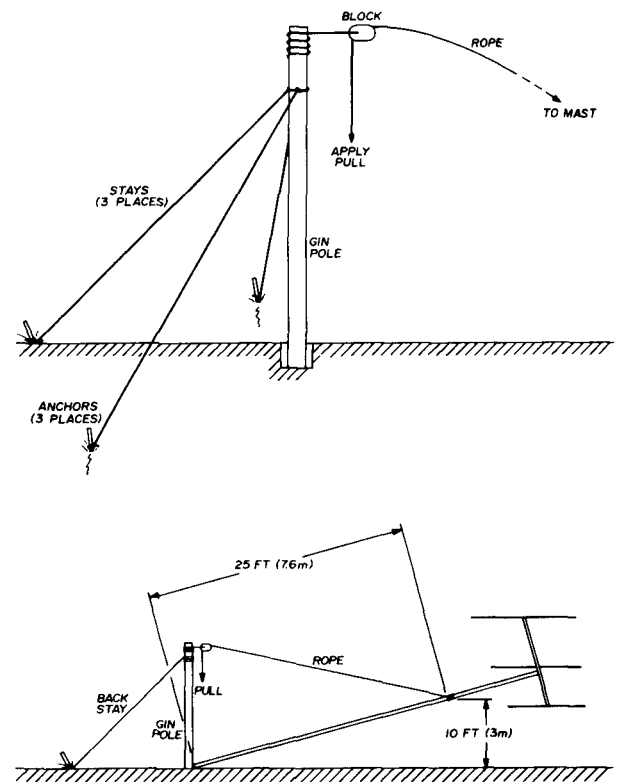


fig. 3. Gin pole no. 1: a fully guyed gin pole whose butt is located at the butt of the mast to be raised.

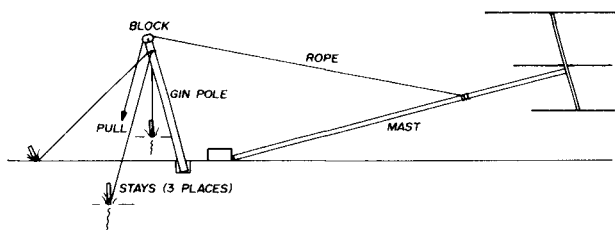


fig. 4. Gin pole no. 2: a fully guyed gin pole located some distance from the mast.

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

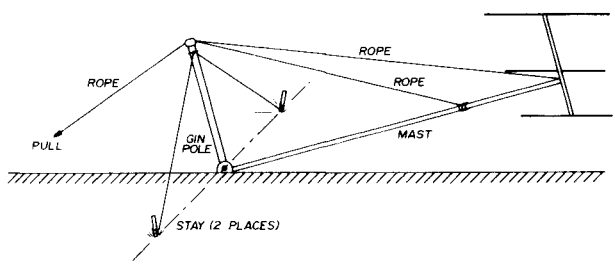


fig. 5. Gin pole no. 3: a swinging gin pole with mast and pull ropes secured at the gin-pole top. Gin pole swings vertically. Side sway is prevented with guys or stays.

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.

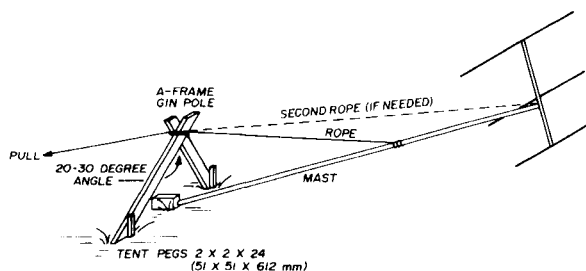


fig. 6. Gin pole no. 4: A-frame swinging gin pole. The spread legs provide help against side sway and allow mast and gin-pole butts to line up. Tent pegs are used to butt mast and gin-pole assembly.

Remember this as in the other procedures: helpers prevent mast sideways 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 raising the

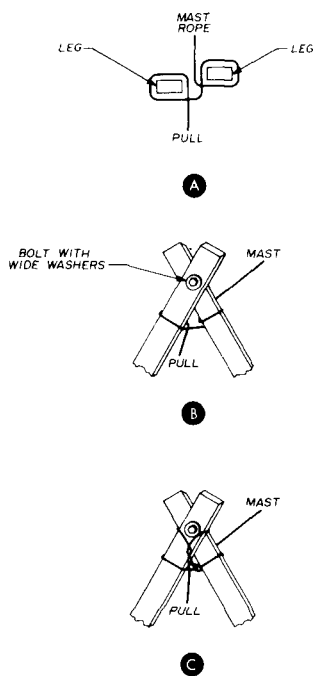


fig. 7. Rope ties at A-frame cross. Basic method is shown in (A) and (B). Rig at (C) is preferred to minimize slipping and bind the joint.

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.

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

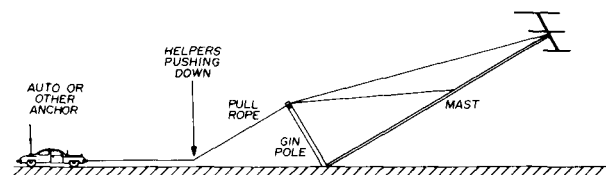


fig. 8. The "walking-up" procedure. With pull rope tight and anchored, the pulling crew walks toward the gin pole, pushing down on the pull rope. As the mast rises, crew pulls rope during the last few feet of rise (see text).

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.

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? Kraus¹ and Jasik² 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.

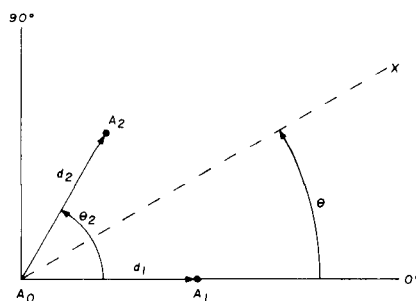


fig. 1. Element positions for an antenna array, showing the terms used in the formula for calculating the radiation pattern. A_0 is the reference element.

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 Page _____
 Programmer _____

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

LINE	DISPLAY	KEY ENTRY	X	Y	Z	T	COMMENTS	REGISTERS
00	41						FIX 3 display	
01	2308	STO 6						R ₀ α ₁ ·K ₁
02	2401	RCL 1						
03	41							
04	1405	f CoB						R ₁ θ ₁ ·βd ₁
05	2401	RCL 1						
06	1501	gFRAC						
07	2407	RCL 7						R ₂ α ₂ ·K ₂
08	61	x						
09	61	x						
10	2400	RCL 0						R ₃ θ ₂ ·βd ₂
11	41							
12	2400	RCL 0						
13	1501	gFRAC						
14	1409	f=R						R ₄ Used (cleared)
15	5104	STO+4						
16	21	ks y						
17	5105	STO+5						R ₅ Used (cleared)
18	2406	RCL 6						
19	2403	RCL 3						R ₆ θ
20	41							
21	1405	f CoB						
22	2403	RCL 3						R ₇ 1000
23	1501	gFRAC						
24	2407	RCL 7						
25	61	x						
26	61	x						
27	2402	RCL 2						
28	2402	RCL 2						
29	1501	gFRAC						
30	1409	f=R						
31	5104	STO+4						
32	21	ks y						
33	5105	STO+5						
34	74	R/S					Stop	
35	2406	RCL 6						
36	1302	GTO 02						
37	2408	RCL 5						
38	2404	RCL 4						
39	1508	g=P						
40	2407	RCL 7						
41	61	x						
42	1409	f=R						
43	01	1						
44	51	+						
45	1509	g=P	P(θ)	Phase				
46	00	0	0	P(θ)				
47	2304	STO 4	0	P(θ)			R4 Cleared	
48	2305	STO 5	0	P(θ)			R5 Cleared	

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load Program			
2	Switch to RUN and store element information	α ₁ ·K ₁ STO 0 θ ₁ ·βd ₁ STO 1 α ₂ ·K ₂ STO 2 θ ₂ ·βd 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 (If N>3 go to step 7)	N≤ GTO 3 R R/S		0
6	Roll Down*	R↓		P(θ)
7a	If N>3 store element information on next 2 elements	α ₃ ·K ₃ STO 0 θ ₃ ·βd ₃ STO 1 α ₄ ·K ₄ STO 2 θ ₄ ·βd ₄ STO 3		
7b	Repeat	R/S		Partial Sum
8	Continue	GTO 3 R 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

$$P(\theta) = |1 + \sum_{n=1}^{N-1} K'_n e^{j\psi_n}| \quad (1)$$

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 leading phase)

βd_n = the electrical distance (in degrees) from the driven element to the n^{th} element

θ_n = the spatial angle between A_0A_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

$$P(\theta) = |1 + 1000 \sum_{n=1}^{N-1} K_n e^{j\psi_n}| \quad (2)$$

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

*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

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 $5I_0$ 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 $\theta_1 = 0^\circ$, and it's spaced out $\lambda/3$ so that $\beta d_1 = (2\pi/\lambda)(\lambda/3) = 120^\circ$. 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 $2I_0 \angle -90^\circ$ 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

*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° [$P(0^\circ) = 5.984$]. 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:

$$\alpha_1 \cdot K_1 = 0.004 \text{ (Register 0)}$$

$$\theta_1 \cdot \beta d_1 = 0.180 \text{ (Register 1)}$$

$$\alpha_2 \cdot K_2 = 0.006 \text{ (Register 2)}$$

$$\theta_2 \cdot \beta d_2 = 0.360 \text{ (Register 3)}$$

(We're using the same normalizing constant.) Plug in $\theta = 0^\circ$ 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

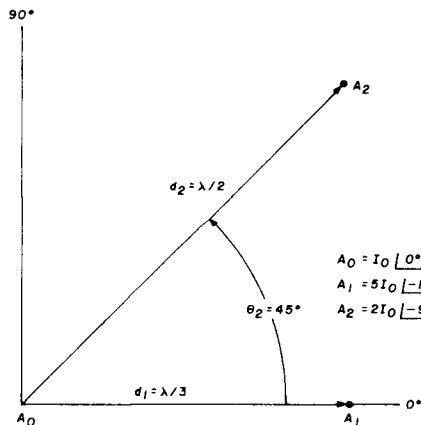


fig. 2. Three-element antenna array used as an example in the text. Radiation pattern of this array is plotted in **fig. 3**.

partial sum on all five elements. Now press G TO 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, $P(0^\circ) = 0.00008727 \approx 0$. Repeat the process in 5° increments and you should get the pattern of **fig. 4**. This

* The new HP-67 and HP-97 programmable calculators have sufficient storage for up to 12 elements. **Editor**

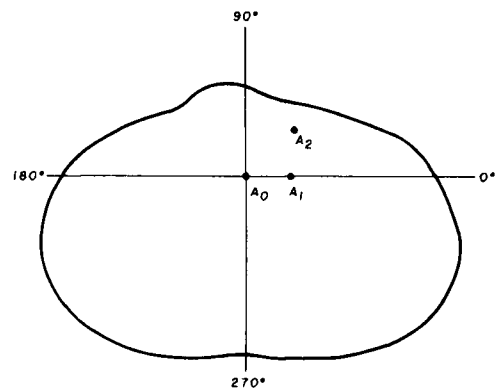


fig. 3. Radiation pattern for a 3-element array shown in **fig. 2**.

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.

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 $R_7 =$

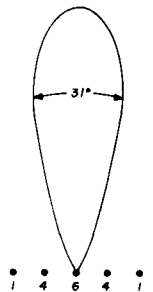


fig. 4. Radiation pattern for a 5-element binomial array calculated with an HP-25 programmable calculator. Only the upper half of the pattern is shown.

$1,000,000$; $K_n = K'_n \times 10^{-6}$; and $R_1 = \theta_1 \cdot (\beta d_1 \times 10^{-6})$.

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.

references

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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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ham radio

all-band bobtail curtain array

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

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

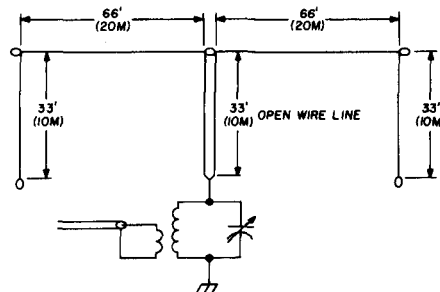


fig. 1. Layout of the all-band bobtail curtain array. The center leg has been split into an open-wire line providing a feed system for 80, 20, 15, and 10 meters. A normal bobtail curtain is one wavelength long on the top portion, with the vertical legs being one-quarter wavelength. The normal feed is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

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

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.

On 80 meters the tuner was wired as in **fig. 2**, with the antenna current distribution 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

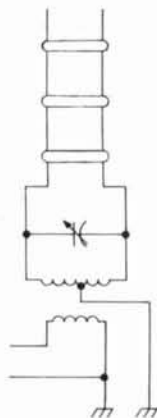


fig. 2. A single-band bobtail curtain can be fed across a parallel-tuned circuit, since the input is a high impedance. To provide a balanced feed, for bands other than 40 meters, a split secondary was used on the inductor.

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

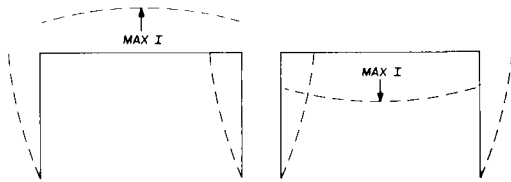


fig. 3. Current distribution when the modified bobtail curtain is used on 80 meters.

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

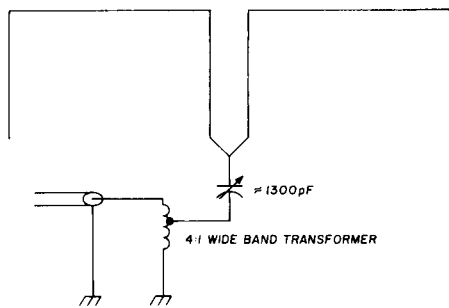


fig. 4. Method of feeding the bobtail curtain on 160 meters. Instead of using the balanced feeders, the antenna can be fed against a system of ground radials.

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:

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

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

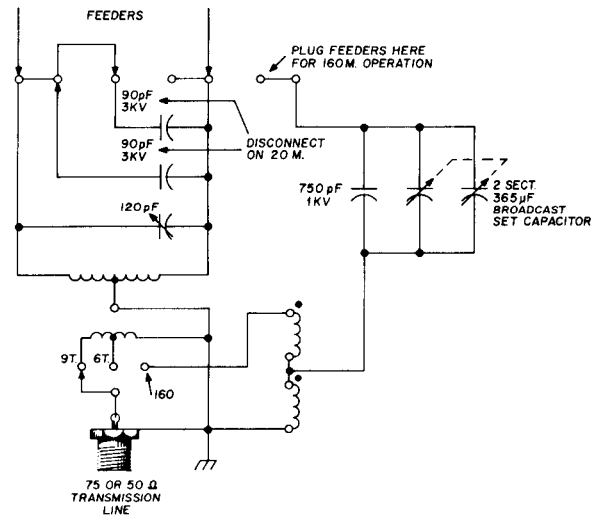


fig. 5. Schematic diagram of the complete tuner that will permit a 40-meter bobtail curtain to be used on all bands. The feedline is plugged into the appropriate jacks for each band. The coil is 2 inches (5cm) in diameter with 17 turns (center tapped) wound to be 3 inches (7.6cm) long. The link for the 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.

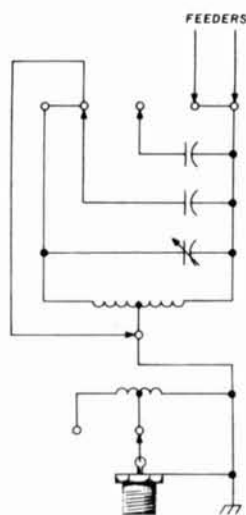
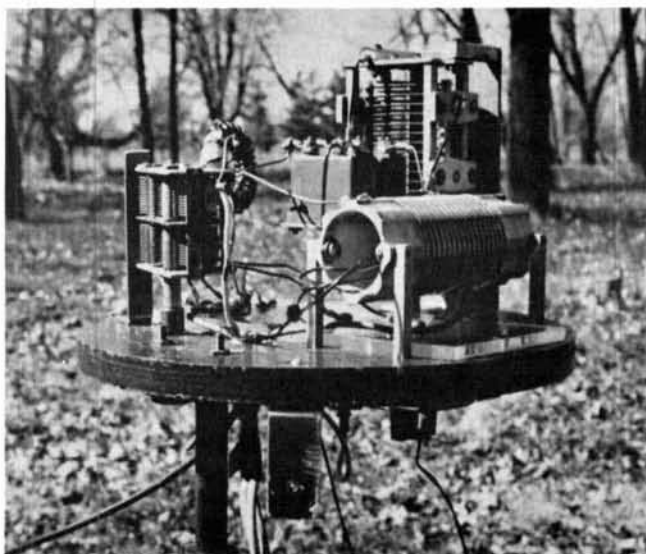


fig. 6. Patching the tuner for 40-meter operation.

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

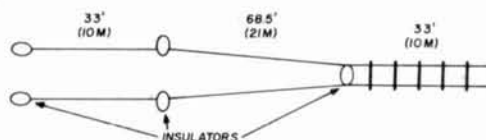


fig. 7. The entire antenna can be fabricated by installing the insulators and spreaders with the wires suspended a short distance above the ground. This will allow the feeders to hang straight.

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.

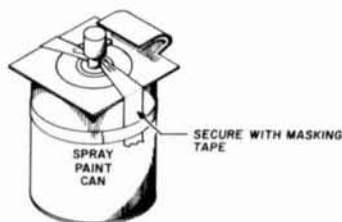


fig. 8. The guard for the spray can is fabricated from light metal stock. By using the guard, the spray will cover the wire and not dissipate in the air.

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

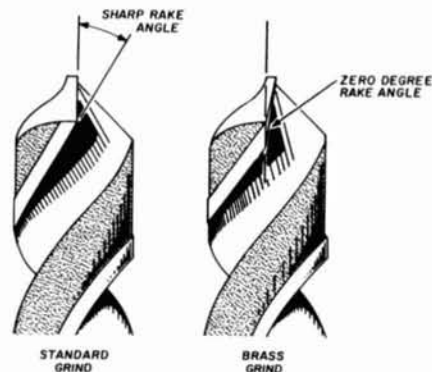


fig. 9. Normal drills can be converted to a brass grind by changing the rake angle at the tip. This alleviates problems with cracking and chipping when drilling plastics.

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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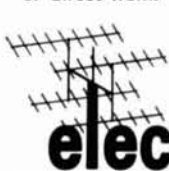
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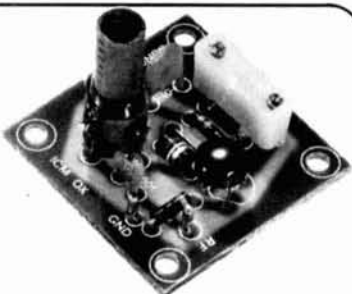
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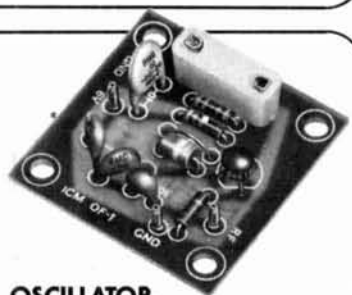
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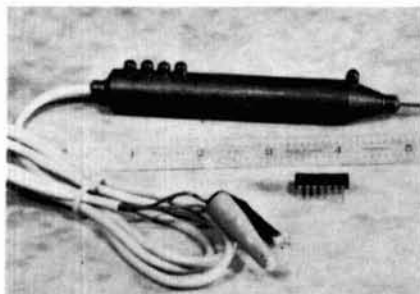
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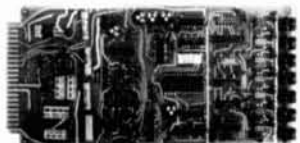
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146.61	147.63
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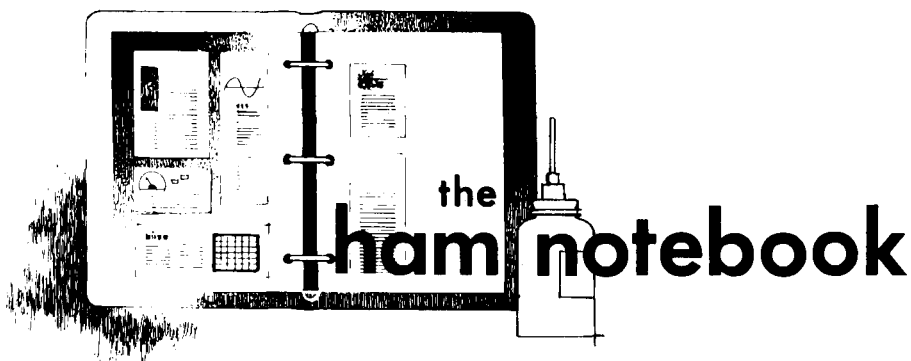
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converting a low-band mobile antenna for two-meters

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

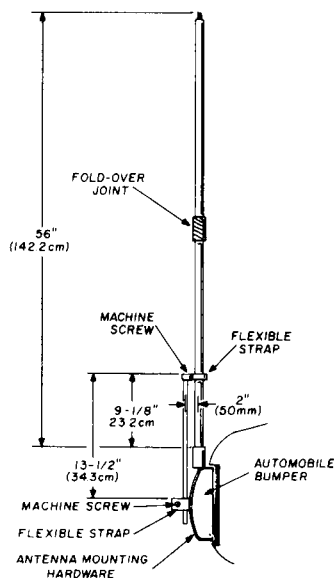


fig. 1. Illustrates simple modification of a low-band mobile antenna to permit use on two meters. Newtronics Hustler is shown.

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 ($10 \div 2 = 5$). 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 (200×5) and 500 Hz (100×5), 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 scalars 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.

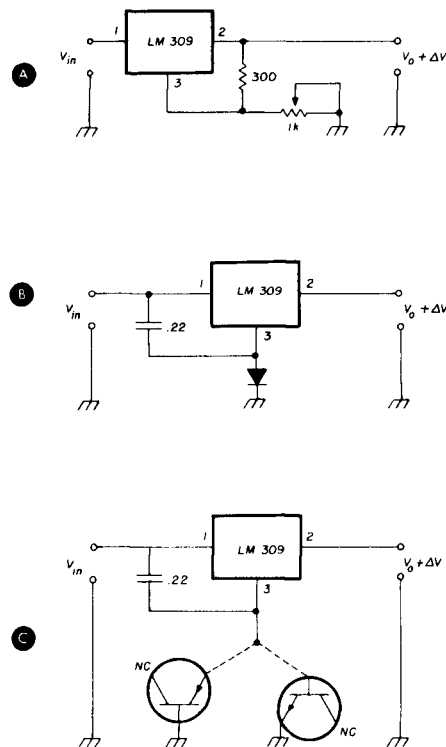


fig. 2. Voltage-regulator circuits. (A) illustrates poor means of obtaining other than characteristic output voltage from LM309 regulator (not recommended). (B) shows a simple way to obtain a different output voltage from the LM309 while maintaining good load regulation. (C) illustrates use of a transistor 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 μ F 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 containers (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 1 1/2 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

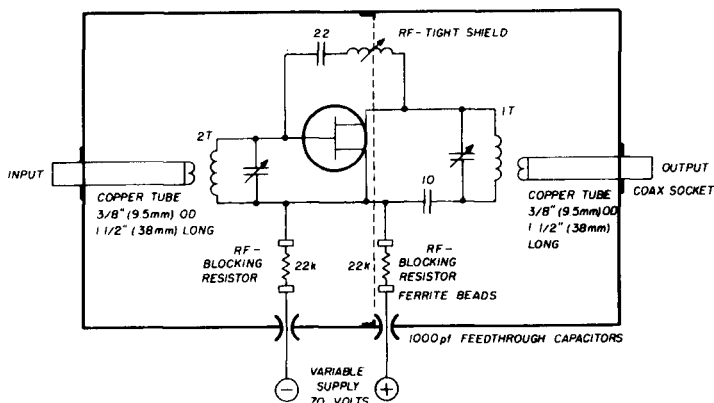


fig. 3. Vhf rf amplifier which has been designed to eliminate problems of coupling unwanted signals into the circuit through parallel current paths.



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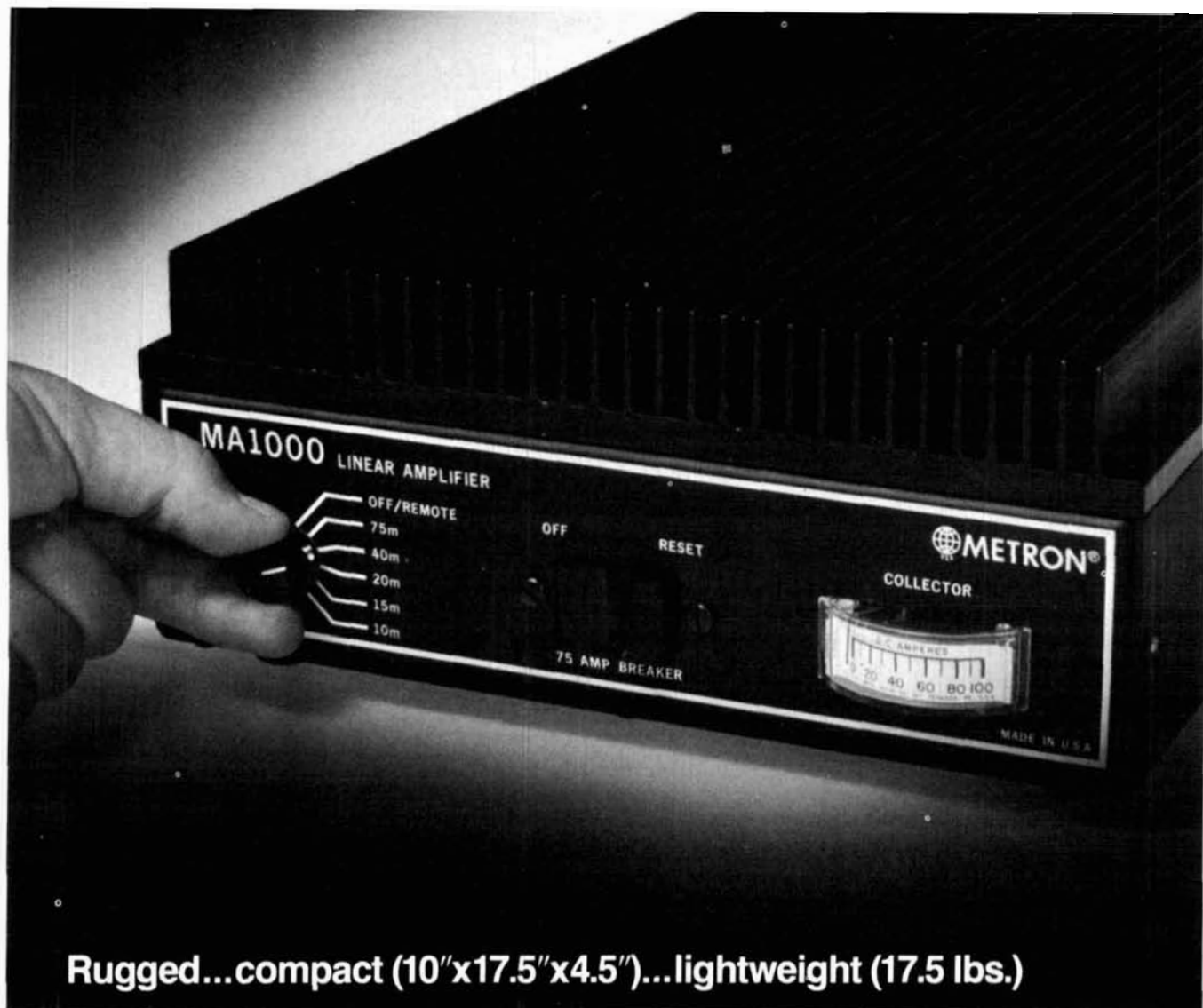
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short circuits

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 μ F, 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.

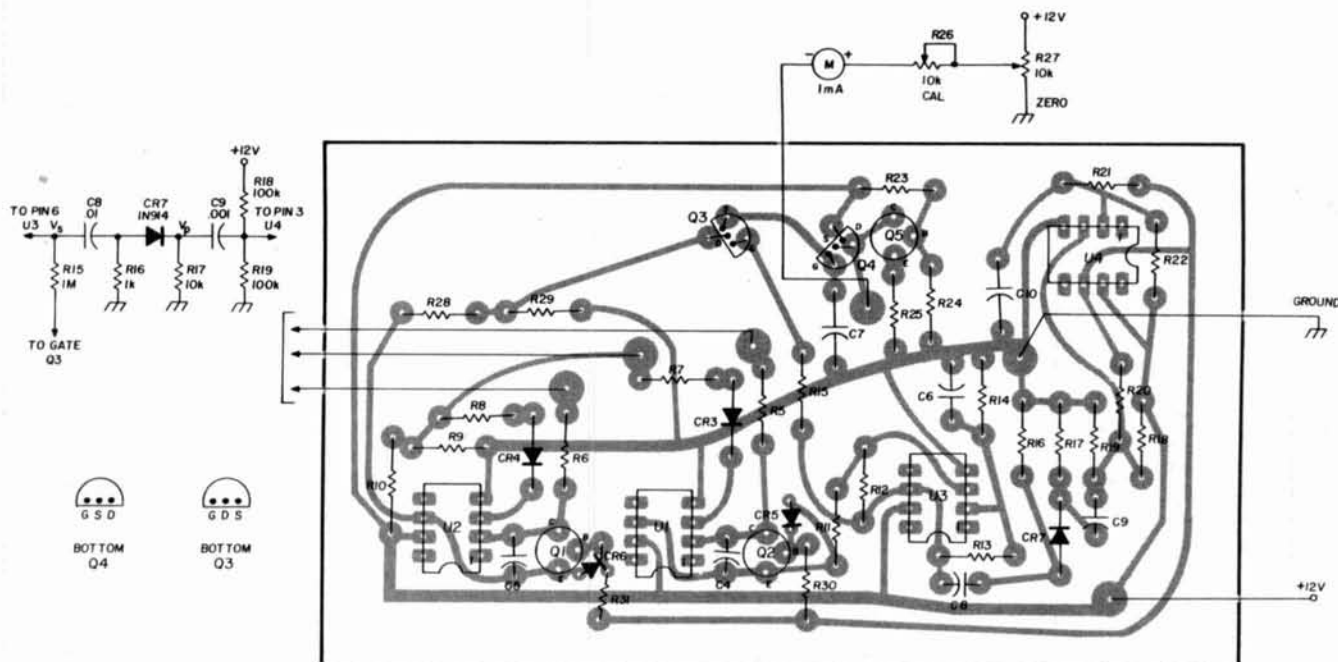


fig. 1. Parts placement and corrected board layout for the simple computing vswr indicator by WB9CYY.

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

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

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.

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.

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 .1 μ F 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 inadvertently 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.

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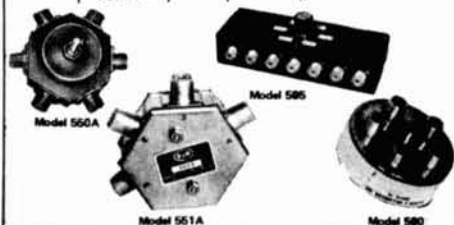


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550A-2	12.50	2	Radial	
551A	17.50	2	Radial	Special 2 pole, 2 position switch used to switch any RF device in or out of series connection in a coaxial line. See figure (lower).
556	.95	—	—	Bracket only, for wall mounting of radial connector switches.
590	17.95	5	Axial	
590G	17.95	5	Axial	Grounds all except selected output circuit.
592	16.50	2	Axial	
595	18.50	6	In-line	Grounds all except selected output circuit.



DENTRON

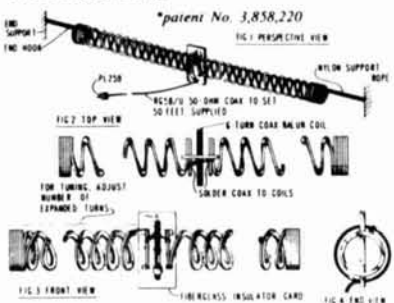
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Ideally suited for applications where excellent DC stability is important, such as CB transmission, small Ham radio transmitter, and high quality eight-track car stereos. Can be used to trickle-charge 12 volt car batteries.

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Line/Load Regulation	20 mV	50 mV
Ripple/Noise	2 mV RMS	5 mV RMS
Transient Response	20 uSec	
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Current Limit	6 Amp	
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Case: 3 1/2" (H) x 5 1/2" (W) x 6 1/2" (D) Shipping Weight: 6 lbs.

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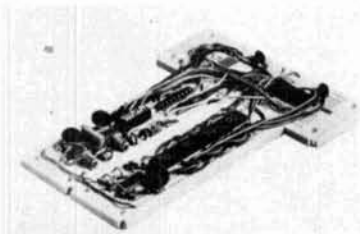
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NEW products

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 *Experimenter™ 300* and *Experimenter 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. *Experimenter 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. *Experimenter 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 *Experimenter* 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 *Experimenter* 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 *Experimenter* 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 *Experimenter 600* measures 2.4" (6cm) wide (as opposed to 2.1" (5.3cm) for *Experimenter 300*), because of the wider center channel that accommodates microprocessor type DIP IC's. Both sockets also feature alpha-numerically designated tie-points, aiding in circuit design and testing, as well as circuit tracing. Vinyl-backed to prevent accidental shorts, CSC *Experimenter* 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 *Experimenter* 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 $\pm(0.02$ 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 $\pm(0.15$ 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 $\pm(0.1$ 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 $\pm(0.25$ per cent of reading + 0.25 per cent of range).

Resistance range is 10 milliohms to 20 megohms with a mid-range accuracy of $\pm(0.02$ 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.

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.



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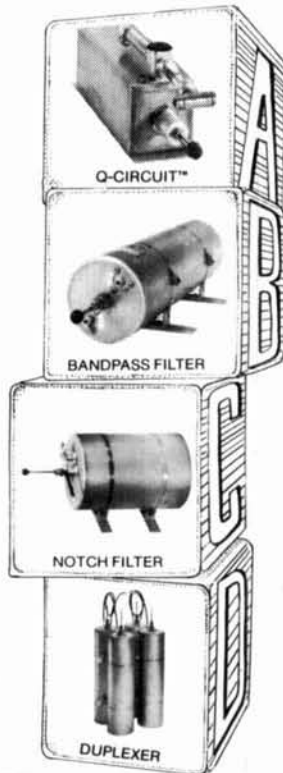


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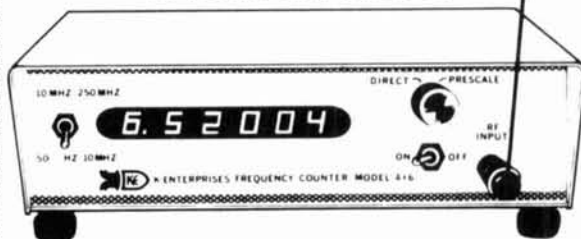
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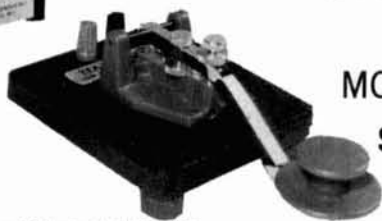
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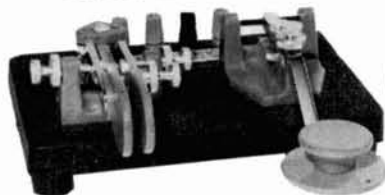
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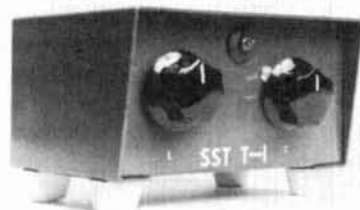
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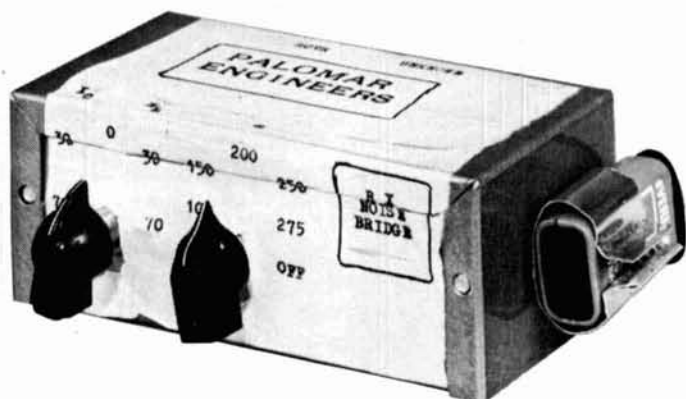


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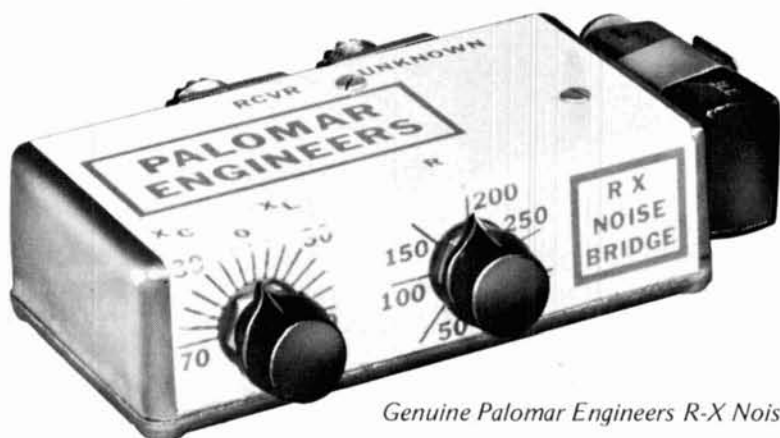
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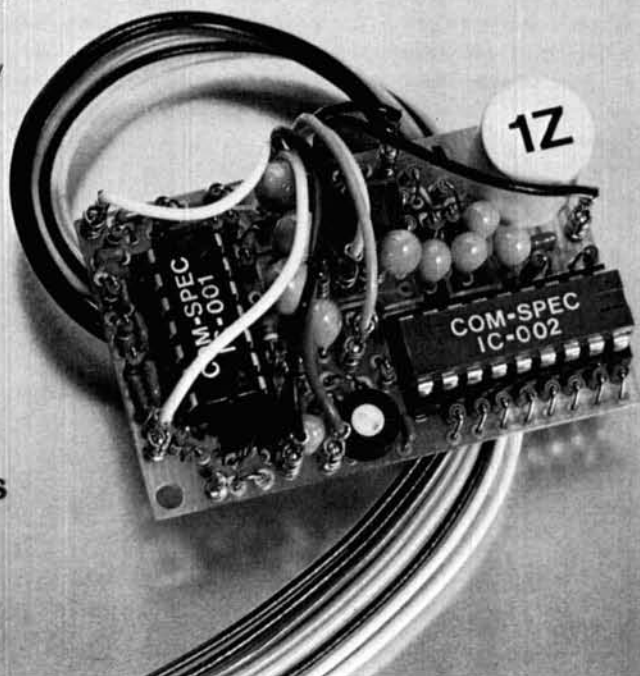
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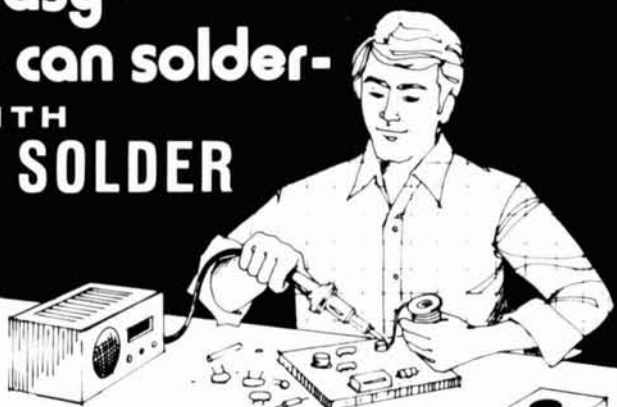
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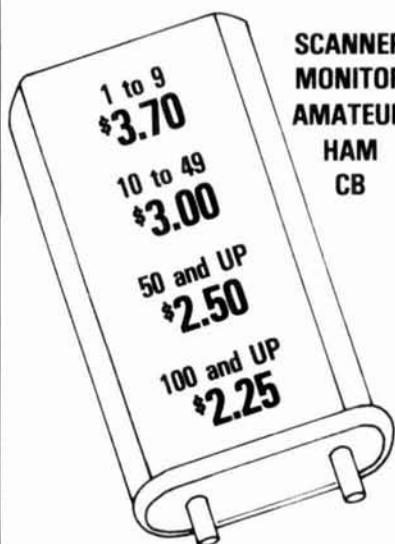
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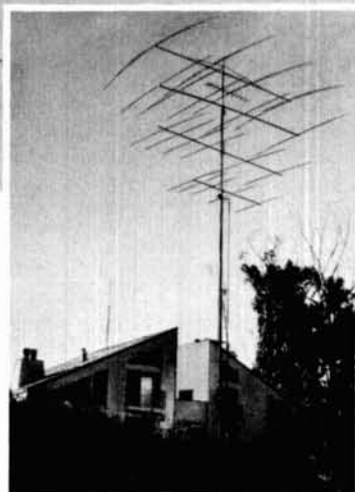
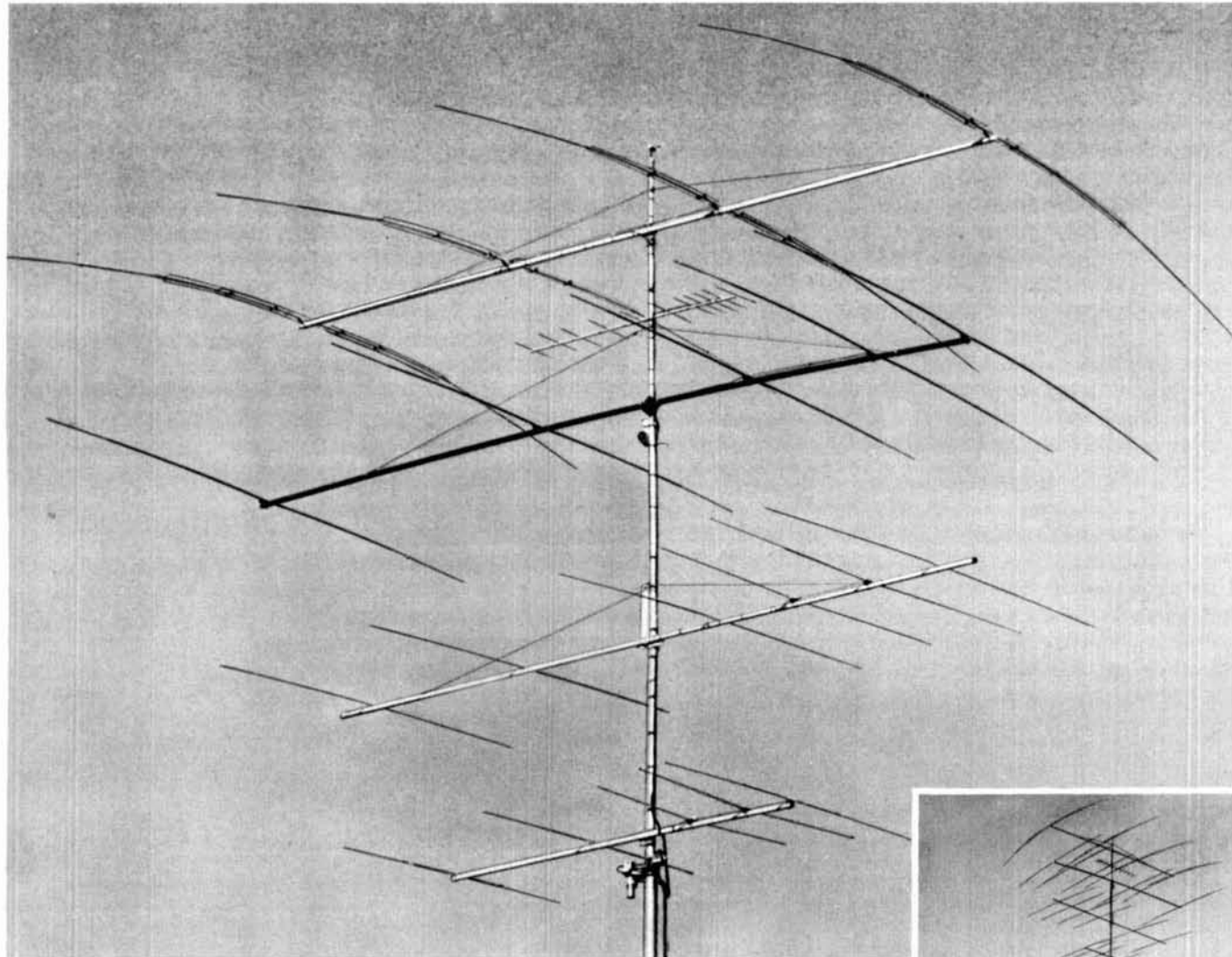
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After careful consideration, Don chose KLM mono-banders, top to bottom; **five beams**, topped by a 4 element 40, a 5 element 20, a 6 element 15, a 5 element 10 and an 11 element 2 meter beam. Mel and

Mike of KLM are indeed proud that their high performance antennas were selected on a merit basis over others considered by Don Schliesser.

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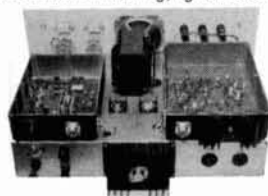
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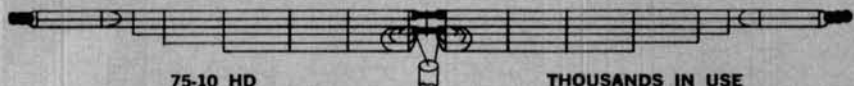
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80-40 HD	80/40 + 15	69	57.50
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75-40 HD (SP)	75/40	66	57.50
75-20 HD	75/40/20	66	66.50
75-20 HD (SP)	75/40/20	66	66.50
75-10 HD	75/40/20/15/10	66	74.50
75-10 HD (SP)	75/40/20/15/10	66	74.50
80-10 HD	80/40/20/15/10	69	76.50

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High accuracy; ideal as laboratory instruments.

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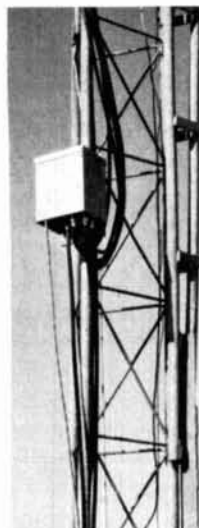


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2	20	25
4	30	30

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- .3 Microvolt Sensitivity for 20 dB Quieting
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- Battery Indicator
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2.5 WATT
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- Tone Options
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- Leather Cases
- Mobile Amplifier and Battery Charger



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- 6 Channel Operation
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 - 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
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 - Unbreakable Lexan Case
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- Weight: 1 lb. 4 oz. less Battery
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SPECS.**

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 - All Crystals Plug In
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 - Weight: 1 lb. 4 oz. less Battery
 - Battery Indicator
 - Size: 8 7/8 x 1 3/4 x 2 7/8
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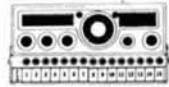
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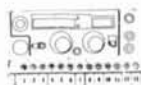
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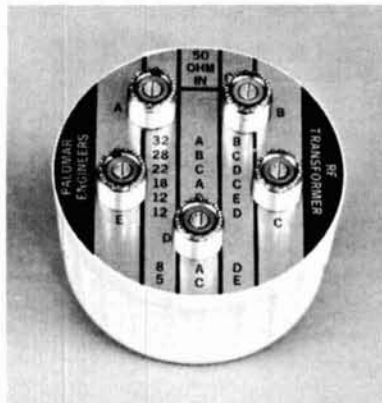
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741 or 709 Pin DIP.....	.25
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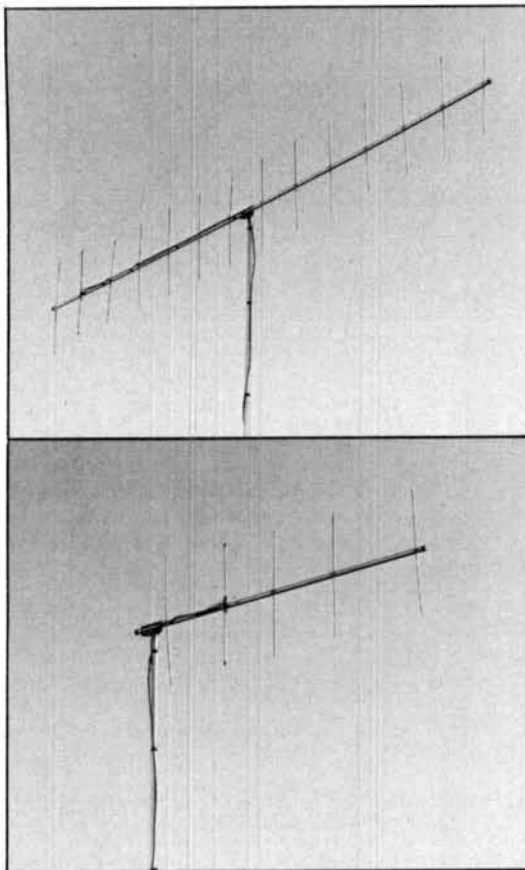
Completely redesigned for greater strength and corrosion resistance. So they last longer.

Newly engineered for greater performance and maximum efficiency. So they work harder, your transceiver works better.

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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.

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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**

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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 3/4"	75"	43 1/2"
Longest element	39 1/2"	40 1/4"	39 5/8"	40 1/4"
Turning radius	95"	75 1/8"	73"	43 1/2"
Wind survival	80 mph	80 mph	80 mph	80 mph
Mast diameter	1 1/4"-1 5/8" O.D.	1 1/4"-1 5/8" O.D.	1 1/4"-1 5/8" O.D.	1 1/4"-1 5/8" O.D.
Boom diameter	1 1/4" O.D.	1 1/4" O.D.	1 1/4" O.D.	1 1/4" 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
1/2 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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Or your Clegg 22'er, Ameco TX-62, Polycom 2 or PC-62, Johnson 6N2, Heath Seneca VHF-1, or Hallicrafters SR-34.



Why throw away that old AM 2-meter rig? Why spend \$300 for a new FM transceiver when you have a working AM rig gathering dust? The Palomar Engineers FM'er plugs in (no rewiring or modification required) and puts your old AM transmitter on FM.

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Works with the Gonset Communicator I (Gooney Bird), II, III, IV, GC-105 and other rigs listed. For 2-meter band only. Requires HC-6/U crystal and 9-v transistor battery (not supplied).

Get on FM at a tenth the cost of a new rig. Use the plug in Palomar Engineers FM'er that has been proven in daily use by MARS and Civil Defense nets nationwide. Send for free brochure.

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flea market

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JANEL 6 meter F.E.T. converter, I.F. 285 MHz \$60.00. James Gysan, W1VYB, 53 Lothrop St., Beverly, MA 01915.

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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.

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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. Stanwick. 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, Ogleby, 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.

AUDIO COMPRESSOR

AN/GSA-33 — Five identical plug-in compressor amps with power supply in 19 inch rack. All solid state, 600u in & out, great for auto patch and phone patch. Weighs less than 30 lbs. Built like a battleship. \$34.95

Documentation available for above.

ARR-41/R-648 Collins Airborne version of R-390. Same outstanding performance. Mechanical filters in IF, Digital Tuning, 1 kHz readout, 28 VDC. Easily converted to 115VAC, 190-500 kHz, 2-25 MHz. \$265.00

AN/USQ-18 Digital time code generator - provides parallel and serial time data - all solid state with internal standard and WWV auto-start - more info on request. \$275.00

SRR-13A RCVR 2-32 MHz THIS CRITTER IS IMMACULATE! Looks and smells new with some spares, connectors to make test cables and complete documentation. \$425.00

206 MHz AND 2.3 GHZ SOLID STATE RECEIVING SYSTEM With weather-proof preamp. 3.7 dB NF @ 206 MHz, 7 dB NF max. @ 2390 MHz. 4.8 GHz preamp included in weather-proof housing (8.7 dB NF). All units except preamp 19" std. rack mount. Complete documentation avail. w/equipment. \$375.00

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(We were only able to obtain 2 more)

AM/URM-23 SUMMATION BRIDGE — measures RF power between 1 & 4 GHz with attenuators and bolometer. Unit complete with manual. \$95.00

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TRAGIC WASTE OF RF

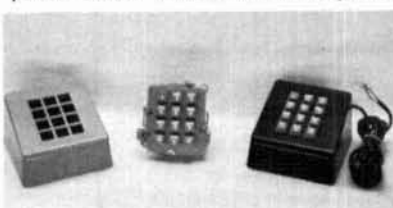
could be your fate as precious watts zig-zag round the world to shower just a little — or little or none — on that hoped for DX station. BUT WE HAVE AN ALTERNATIVE — THE JOYSTICK VFA (Variable freq. ant.), which gives low angle, omnidirectional, harmonic free radiation on all bands 160 thru 10 (+ MARS and receive on all BC & SW). Stalwarts W6TYP and G4DJY achieved notable results in contests — just to mention two of the many who have sent glowing reports of the VFA in use, often in poor QTH and/or under QRP.

SYSTEM 'A' \$75.00 250W P.E.P. &/or Receiving Only
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Air Mail cost included (each system 3 sections easily assembled to make unit 7' 6" long. Matching ATU.) Not only will you save space but you will save \$\$\$ at present low exch. rate and by buying direct UK manuf. Rush your order — Mastercharge or check, or ask for brochure.

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12 Button touch-tone pads calibrated and guaranteed 90 days (abuse excluded) with diagram \$14.00
Attractive plastic mounting box with brackets \$4.75
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Complete working system with speaker in housing for acoustic coupling with power switch \$39.95



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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, ± 10 PPM worst case, from 0° to + 55°C!, 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 board 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 1/2 PPM stability. \$79.95

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Optional 12VDC power receptacle and cord assembly \$15.00 (on preassembled counter only)

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- Sealed weatherproof Construction
- Stainless steel mounting hardware.

The proven and dependable Palomar engineers 5 Kw PEP (2 Kw CW CCS) balun is now available for mounting on your rotary beam. With a ratio of 1:1 the balun couples coaxial cable to 50 or 75 ohm balanced antennas. An adjustable U bolt provides convenient mounting to a 2" mast or boom.

The wire leads from the balun are brought out for direct connection to the beam's driven element so there are no solder lug connections to go bad in the weather.

ONLY PALOMAR BALUNS HAVE ALL THESE FEATURES

- RF toroidal core for highest efficiency.
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- Stainless steel hardware. Won't rust.
- Epoxy filled case. Absolutely waterproof.
- White case to reflect the sun.
- Lightning protection built-in.
- Wideband 1.7-30 MHz.

Send for free brochure.

How many lightweight baluns have you burned out already? Install the balun that will stay up there working year after year.

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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. In-door 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 frequencies; 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.

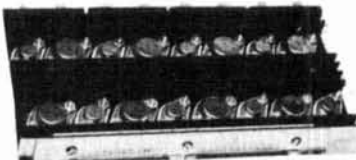
THE EASTERN CONN. AMATEUR RADIO ASSOC. — K1MUJ — will hold their 4th annual Flea Market on May 22, 1977 at Point Breeze Rest, Webster, Mass. Time will be from 10:00 AM to whenever. Dealer fee will be \$5.00. Admission for buyers will be 50¢ per person. Free parking. Take Rt. #52 to Exit 1 in Webster 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.

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SOLID STATE POWER SUPPLY — 12 VDC @ 5 Amp output; input 115 V 60 Hz. Front panel has voltage adj., running light, reset, & fan. Size: 9 1/2 x 7 x 14 1/2". Shpg. Wt.: 35 lbs. Removed from computer. #0502655 **\$39.50**
Same as above - 24 V 5.5 A; #0516-332 **\$39.50**



TRANSISTOR CONTROL ASSEMBLY — with eight NPN 100 V T0-3 and eight NPN 60 V T0-66 Transistors, associated Emitter Resistors and Diodes. 5 lbs. #345-0025575 **\$5.00**

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The DRAKE TR-33C



\$229.95

Amateur VHF FM Transceiver

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 \pm 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 μ V for 20 dB noise quieting. • **Selectivity:** +30 kHz adjacent channel rejection greater than 75 dB. • **Modulation acceptance:** at least \pm 7 kHz. • **Inter modulation Rejection:** 70 dB referenced to sensitivity 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 \pm 7 kHz deviation, factory set at \pm 5 kHz. • **Separate microphone gain and deviation adjustments** • Drake 1525EM Push Button Encoding Mike can be used direct with no modification.

- **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 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 60Hz 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.
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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, 1/2 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 K4 CB, 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, WA1GW, 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.

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- 1 MC14410CP
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- And all other parts for assembly. NOTE: Touch Tone Pad not included! \$15.70

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- 1 95H90DC
- 1 2N5179
- 2 UG-88/u BNC's
- 1 Printed Circuit Board
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- 1 11C90DC
- 1 2N5179
- 2 UG-88/U
- 1 MC7805CP
- 1 Bridge
- 1 Printed Circuit Board and all other parts for assembly. 82S90 add \$5.70 to total. \$59.95

Fairchild 3817 Clock Kit from Ham Radio, Feb. 1976, Pg. 26 — All parts included except transformer and case. 12 hour \$24.95 24 hour \$29.95

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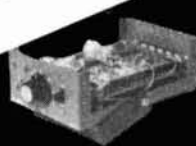
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Specifications:

Output Power	10 W peak
Drive, 10 meters	3/4 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
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Also Available:

144 MHz SSB Transverter, MMt 144 \$214.95

146 MHz

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Fmt440 Specifications:	
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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

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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 receiver pre-amplifier (2.5 dB NF). T/R switching is automatic by an internal VOX circuit; no changes are needed to your existing transceiver.

ceive 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 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.

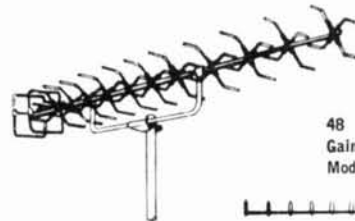


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144-148 MHz

Model 8XY/2M	\$39.95
Gain 9.5dB in each plane, 50Ω feed.	
For OSCAR communications add Circular polarization harness, PMH/2C	\$9.70
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AMCOMM S225 SYNTHESIZER TRANSCIVER

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: 7 1/4" wide x 2 1/4" high x 11 1/2" deep (overall)
 Weight: 4 1/2 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 ± 5 PPM from -20°C to $+60^{\circ}\text{C}$.
 Audio frequency response: $+20\text{dB}$ to -80dB 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 — $\pm 600\text{KHz}$, -600KHz , $\pm 1\text{MHz}$, or -1MHz for each channel.
 Frequency control system: Digital synthesized
 Intermediate frequency: 21.4MHz
 Sensitivity (usable): $35\mu\text{V}$, 12dB Sine \Rightarrow 50% Audio, 0.5uV minimum for 20dB
 Modulation acceptance bandwidth: $\pm 7.5\text{KHz}$ minimum
 Local oscillator frequency stability: $\pm 5\text{PPM}$
 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 225 Synthesizer Transceiver 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.



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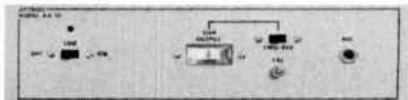
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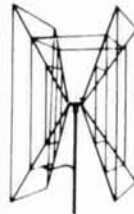
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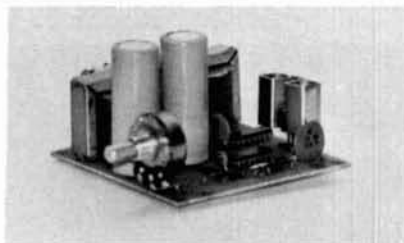
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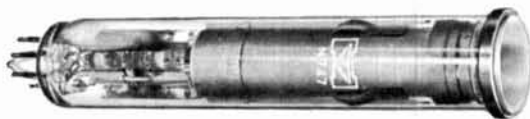
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1N3600 6/S1	2N2906 10 5/2	2N4360M 2/S1	MPF5015 3/S1	LM790CN 29
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The GT-46 features quality construction and materials, with the stability of the Guyed System.

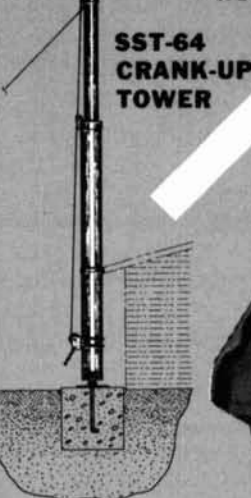
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WR 500 ROTOR

WR 1000 ROTOR

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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	138	42	48	189.00
M203	20	8.5	20	30	19	3	36'0"	20'6"	5.25	105	35	40	128.00
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
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	10	8.5	20	30		3	18'0"						

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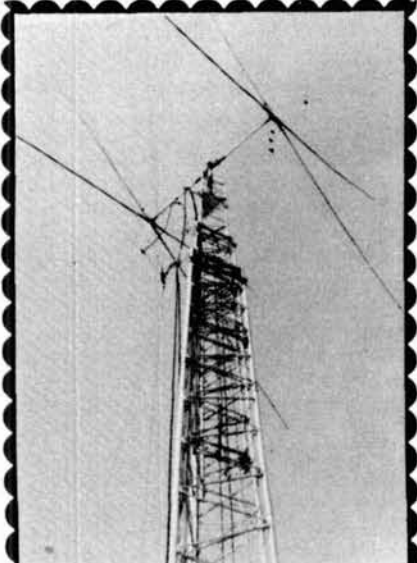


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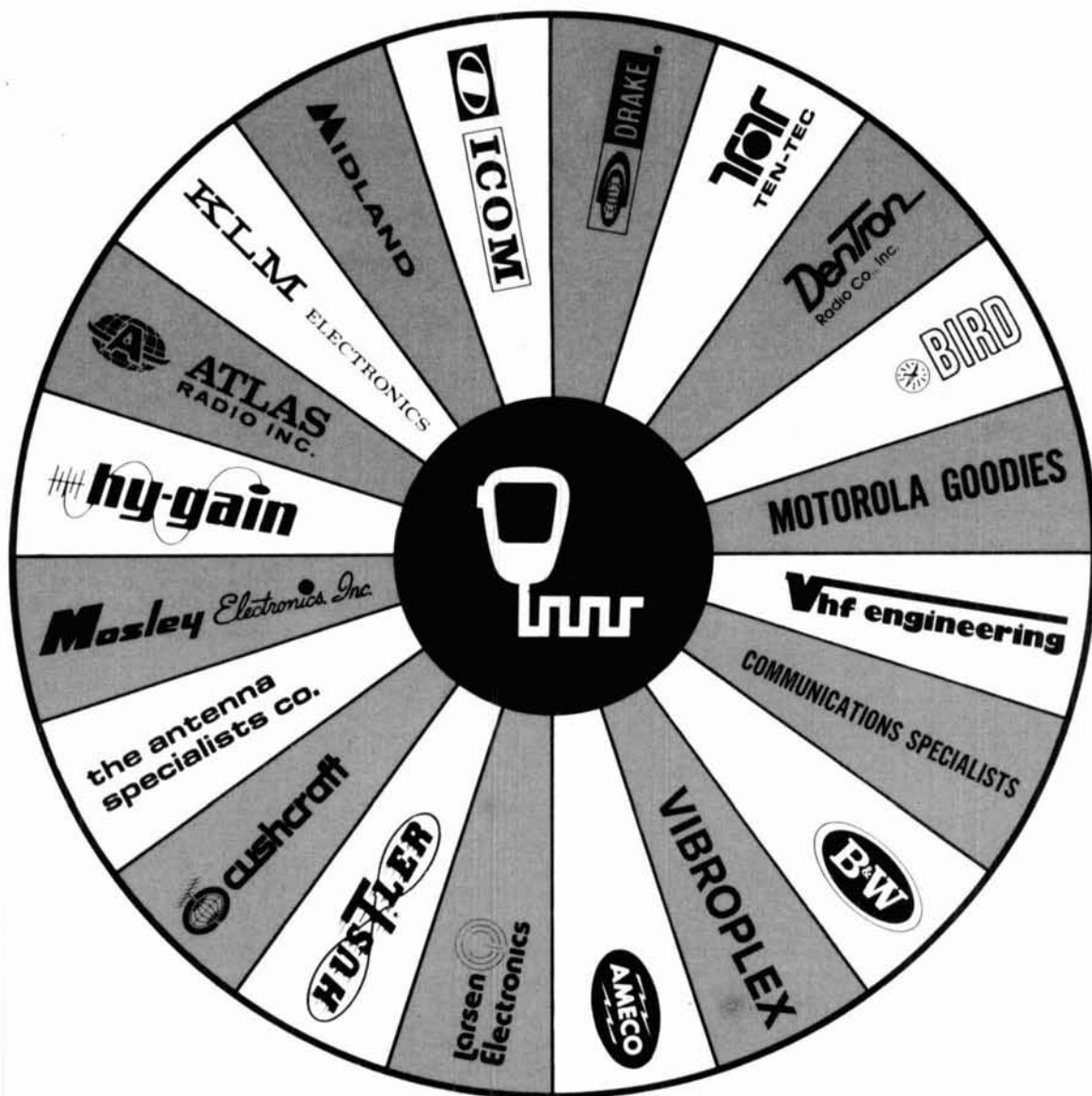
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FOR THE BUILDER THAT WANTS THE BEST. FEATURING 12 OR 24 HOUR TIME - 29-30-31 DAY CALENDAR. ALARM, SNOOZE AND AUX. TIMER CIRCUITS

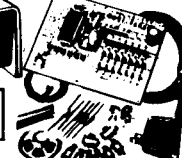
Will alternate time (8 seconds) and date (2 seconds) or may be wired for time or date display only, with other functions on demand. Has built-in oscillator for battery back-up. A loud 24 hour alarm with a repeatable 10 minute snooze alarm, alarm set & timer set indicators. Includes 110 VAC/60Hz power pack with cord and top quality components through-out.



7001C DISPLAY



7001 B DISPLAY



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, Cor X - \$7.95

KIT - 7001B WITH 6 - .5" DIGITS \$39.95
 KIT - 7001C WITH 4 - .6" DIGITS & 2 - .3" DIGITS FOR SECONDS \$42.95
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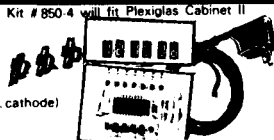
KITS ARE COMPLETE (LESS CABINET) WITH PC BOARDS, POWER SUPPLY, IC & SOCKET, 16 TRANSISTORS, 9 SWITCHES AND ALL REQUIRED PARTS. ALL 7001 KITS FIT CABINET I AND ACCEPT (OPTIONAL) QUARTZ CRYSTAL TIME BASE KIT # TB-1

5-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-MMS314 Clock Chip (24 pin)
- 13-Transistors
- 3-Switches
- 6-Capacitors
- 5-Diodes
- 9-Resistors
- 24-Molex Pins



\$1195 QTY ea. 1-5
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\$995 QTY ea. OR MORE

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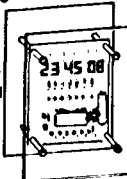
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- All parts included



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745113	1.40
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745139	1.50
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16	28	25
18	31	28
24	50	45
28	60	55
40	75	70

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7448	.95
75491	.65
75492	.65

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2N3415	TO-9	5/1	100
2N3704	TO-92	5/1	100
2N4400	TO-92	5/1	100
2N4129	TO-92	5/1	100
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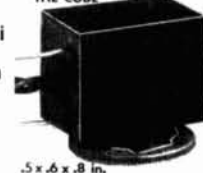
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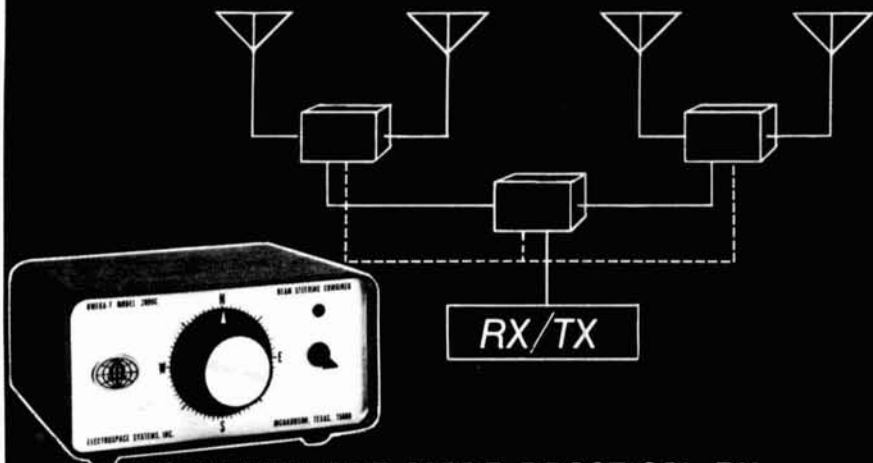
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2 ELEMENTS OR 4 ELEMENTS



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Broadband, 1.8-30MHz. Can be used
with any type antennas - verticals, dipoles, beams.

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Apollo Products-Little Giant Trans Systems Tuner Kit — \$122.50

Designed and engineered after "Apollo" — "Little Giant" 2500X-2, for an "engineered performance" Trans Systems Tuner and Adaptations of the Lew McCoy Transmatch, with power handling at the KW plus level!



Kit includes:

- 1 200 pfd wide-spaced variable with isolantite insulation rated 3,000 volts
- 1 200 pfd dual section parallel condenser isolantited
- 2 finger-grip pointer knobs 2" diam. white indented
- 1 pvc insulated shaft couplings ¼ to ¾
- 3 SO-239 coax chassis connectors. Tunes 52 ohm or 52-300-600* or random wires

- 1 heavy inductance for 10-15-20-40-80 meters
- 6 pvc stand-offs, 4 for condensers and 2 for inductance
- 1 HD switch for band catching 10 thru 80 meter coverage
- 1 pkg 12-gauge tinned round wire
- Cabinet included — Apollo "Shadow Boxes" M Kit includes Schematic. Recommend parts layout.
- INFO NOTE *377 OHM and **600 OHM "Open wire spaced ladder line" air dielectric. *53 x wire diam. **84 x wire diam. info only — not supplied.

Apollo Products, Box 245, Vaughnsville, Ohio 45893 419-646-3495
Subsidiary "Little Giant Antenna Labs"

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THE *Little* GIANT BEAM ANTENNA

A COMPLETELY NEW ANTENNA

Here is an ultra compact beam antenna which can be tuned to any frequency between 7.0 and 14.5 MHz. Weighing only 18 lbs. this antenna may not outperform a full sized beam but it sure will give you your share of DX and stateside contacts. Will handle 1 KW over a 100 kHz bandwidth.

- Fully weather proof
- Mounts easily on TV masting
- Figure 8 pattern

- Hi-Q, attenuates harmonics
- Comes assembled & tested

LITTLE GIANT MODEL 100X1000-40

Other models available for 10, 15 & 20 meters

Little Giant Antenna Labs, Box 245, Vaughnsville, Ohio 45893

Subsidiary "Apollo Products" Village-Twig Co.

419-646-3495

only 27 inches high
by 22 inches wide

KITS 10-40 \$94.50

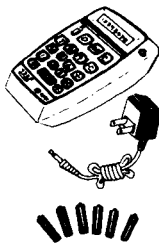
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Add \$3 trans.

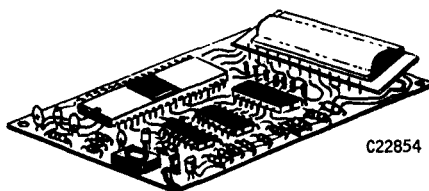
SEMICONDUCTORS & MORE!

COMPLETE CALCULATOR OFFER SPECIAL C22857 \$1195

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



2
FOR
\$150

C22854

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 4 1/2" L. x 2 3/4" 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 1/8" thick glass over ceramic substrate. The displays we have are used, excellent condition. Compare elsewhere up to \$3.50 each. No sockets available.

TUBES									
2C39	\$2.00	4X150G	10.00	6080WB	3.00	7289	2.50		
2E26	3.50	4CX250B	20.00	6146	3.00	7645	5.00		
3B24WB	3.00	35T	15.00	6146W	4.00	8950	5.50		
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		
4X150A	13.00	832A	3.00	6528A	7.00				
		5894	25.00	6939	7.00				

I.C.'s									
AM9050EDC	\$2.00	1404A	2.00	74121L	2/1.00	MC1488L	1.25		
MM5262N	2.00	LM340K-24	1.50	74S200L	2.00	LM741CH	4/1.00		
C8008-1	5.00	LM337	1.00	MC7908CP	1.00	LM747CH	4/1.00		
P3101A	2.00	MM521WB	1.50	MC7818CK	1.50	MC75150L	2/1.00		
715AH	2.00	LM301AN	3/1.00	MC4001P	2.00	DM74LS154N	1.75		
		AMS6003	3.00	MC2360G	2.00				

DIODES & LINEARS									
1N2508	\$0.65	1N4040	.45	1N4757A	5/1.00	1N5887B	5/1.00		
1N914	30/1.00	1N1202	.40	1N4999	.65	1N5892B	5/1.00		
1N1602	.65	1N754A	5/1.00	1N5271B	5/1.00	1N5894B	5/1.00		
1N1828	.65	1N3050	1.00	1N5276B	5/1.00	1N5895B	5/1.00		
1N2804B	1.00	1N4719	.60	1N5278B	5/1.00	1N4148	30/1.00		
		1N4749A	5/1.00	1N5862B	5/1.00	1N823	5/1.00		
		1N4754A	5/1.00	1N5890B	5/1.00				

SPECIALS OF THE MONTH

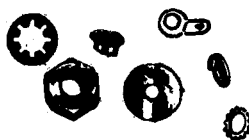
TRW RF TRANSISTORS PT3551C 15W output 12.6V @ 175 MHz. Same as 2N6081 but has no Stud \$3.50 or 10/\$20.00

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
15¢ each or 10/\$1.00

NEW Motorola Full Wave Bridges
MDA952A-4 8 Amps 400V \$3.00
MDA962-4 10 Amps 400V \$5.00
MDA970-3 4 Amps 200V \$2.00

SEMICONDUCTOR MOUNTING HARDWARE ASSORTMENT



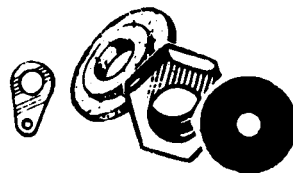
100 PIECES OF
SEMICONDUCTOR
HARDWARE \$1

STUD RECTIFIER MOUNTING KIT

Prepackaged mtg. kits for most stud mounting rectifiers and zener diodes

C22540

3 for 49¢



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
PT3551C	175	12.5	15W	J	\$ 6.00

TUBES

2C39	\$ 2.00
3B28	\$ 4.00
4X150G/8172	\$ 10.00
811A	\$ 6.95
832A	\$ 5.00
6146W	\$ 4.00
7289	\$ 2.50
4-00A	\$150.00

SCR & TRIACS

2N4160	\$1.00
2N4170	\$1.00
2N4441	\$.75
2N4444	\$1.00
2N5060	\$.30
MAC21-1 25V 25A	\$1.00
MAC21-2 50V 25A	\$1.50
MAC21-3 100V 25A	\$2.00
MAC21-5 300V 25A	\$3.00
MAC21-6 400V 25A	\$3.50

KMC RF TRANSISTORS

K6008	\$1.00
450mw 3000MHz Vcc12	\$2.50 each or 5/\$10.00

BIRD POWER SENSOR

RFL-5W & FWD-5W	\$12.00
4C5 100-250MHz	\$12.00
4D5 200-500MHz	\$12.00

Acrodyne Industries, Inc.
Solid State RF Power Amp.
Model CWA-120B 145-172 MHz
35W output. \$35.00

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Feather fan model 113	\$6.00
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F-18X 6.3VCT @ 6 amps	\$3.00
F-21A 6.3VCT @ 10 amps	\$4.95
F-22A 6.3VCT @ 20 amps	\$6.50
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89059 24V @ 2 amps	\$3.00

TRANSISTORS

2N2431K	5/\$1.00	2N336 JAN	2/\$1.00
2N2907A	5/\$1.00	2N499A JAN	\$1.00
2N3250A	5/\$1.00	2N502B JAN	\$1.00
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
2N5194	\$.75	2N2060 JAN	2/\$1.00
MM3002	\$.75	2N914	10/\$1.00
MM4000	\$.75	2N2494	2/\$1.00
MM4003	\$.75	2N290A	4/\$1.00
2SC458	5/\$1.00		
2SD235	2/\$1.00		

DIODES

1N914	30/\$1.00
1N4148	30/\$1.00
1N2061	10/\$1.00
1N2070A	8/\$1.00
1N4001	10/\$1.00
1N4002	8/\$1.00
1N4006	4/\$1.00
1N5160	\$1.00

Electrolytic Cap's

3000MFD @ 200VDC	\$2.00
1800MFD @ 25VDC	\$1.25

I.C.'s

7401, 7402, 7408, 7420, 74H11, 74H53 @ 7/\$1.00; 74121, 74145, 74193 @ 3/\$1.00; LM380N8 \$7.99; LM565CH, LM567CN @ \$2.00 each; LM380N \$1.29; NE555V \$.40; 825129 \$2.00; MC1488L \$2.00; MM5262N \$2.00; TMS-2600J \$4.00; TMS4050NL-2 \$5.00; TMS4060NL \$5.00; MC1489L \$2.00; 2102AL-4 \$1.25; P1103 \$1.00; C8008-1 \$5.00; MC6820L \$5.00; AY51013 \$4.99; C1702A \$6.50; 1M5623CJE \$2.00

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AUDIBLE CONTINUITY TESTER KIT

Measures continuity and resistance to 2K. Test LED's, diodes & transistors. Less Speaker. Requires 6 to 12 volts, (batteries not included). **\$1.95**

WARBLE ALARM KIT

Emits a piercing dual tone blast that is impossible to ignore. Great with our Sender Receiver Kit. All components and quality PC Board included. Speaker and power switch not included. (3-15V) **\$2.50 (kit)**

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:

Output adjustable from 3 to 30 Volts DC
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

KIT INCLUDES:

Transformer
Heatsink (drilled)
Semiconductors (diodes, transistors, etc.)
All Components (resistors, caps)
Transistor mounting hardware & insulators
Drilled & plated PC Board
Wire

\$49.95

add **\$3.70** for postage

MINI GRANDFATHER CLOCK KIT

The most fascinating kit we have ever offered features: *Large LED Simulated swinging pendulum matches tick-tock sound* Electronic tone chimes the hour (ie: 3 times for 3 o'clock)* Quality components & 2 PC boards measuring 4.5" x 6.5"* All CMOS IC construction* Transformer provided, no case included* Large 1/2" LED readouts. **\$44.00 Postpaid**

BULLET SUPER STAR PS-01A **\$14.95**

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.

ULTRASONIC SENDER-RECEIVER KIT **19.95**

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]).

AUTOMATIC TIME OUT CIRCUIT for ultrasonic or mechanical switch alarms. Provides a five second entry delay, sounds alarm for one minute, then re-arms itself. Requires 6-15 VDC. **\$3.95**

TEN-TEC ULTRAMATIC KEYS

MODEL KR50

- SUPERLATIVE "FEEL" 5-50 GRMS PADDLE FORCE
- AUTOMATIC OR MANUAL WEIGHTING
- DIT AND DAH MEMORIES WITH SEPARATE DEFEATS
- "STRAIGHT KEY" OVERRIDE FOR QRS OR TUNE-UP
- GUARANTEED FOR LIFE BEARING PIVOTS

A sparkling new keyer with a host of exciting features. A powerful aid to cleaner, more articulate CW that is relaxing to use and a joy to copy.

The paddle assembly will delight the CW purist as well as the recent graduate from a bug or hand key. The superlative "feel" is attained by a magnetic return force, instantly adjustable to exactly the right touch for you.

Weighting, the ratio of dit and dah (bits) lengths to the spacing between them, is either automatically or manually varied. In the automatic position, it is programmed to lengthen the bits at slow speed for enhanced smoothness and decrease them as you advance the speed, for highest articulation. Or, it can be adjusted to a constant value.

The KR50 is versatile. Dit and dah memories are provided for full iambic (squeeze) keying. Either dit or dah, or both, may be turned off for operation as a conventional type keyer. Self-completing characters at all times.

A convenient "Straight key" is built-in for QRS sending or tune-up. Also an internal side-tone and 115VAC/12VDC operation is provided.

The KR50 is designed to have a permanent place in your shack for the years, perhaps decades, ahead. An investment in the enjoyment of CW.

PRICE \$110.00



KR20-A

Paddle has unique principle with excellent feel for rhythmic CW. Characters are self-completing. Bit weighting is optimized for normal speeds. Manual key button conveniently located for hand sending. Side tone signal, Reed relay. Plug-in circuit boards. 115VAC or 6 to 14 VDC. HWD 2 1/2" X 4 1/2" X 8 1/4", Wt. 2 1/2 lbs.

PRICE \$67.50

KR1-A

This is the paddle mechanism used in the KR50. Requires 6-14 VDC for adjustable electromagnetic paddle return force. Adjustable contact spacing. For iambic or conventional keyers. "Straight key" button. Housed in an attractive metal case with cream front panel, walnut vinyl top. Size: 2" X 4" X 6", Wt. 1 1/2 lbs.

PRICE \$35.00

KR5-A

Similar to the KR20A but without monitor signal and AC power supply. A great value. For 6-14 VDC operation. Size HWD 2" X 4" X 6". Weight: 1 1/2 lbs.

PRICE \$38.50

KR2-A

The paddle used in the KR20A. Single paddle for non-iambic keyers. "Straight key" button conveniently located. cream aluminum case with walnut vinyl top. Size: 2" X 4" X 6". Weight: 1 1/2 lb.

PRICE \$15.00

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ICOM



IC-22S

146 MHz FM 10 W
TRANSCIVER



IC-245

146 MHz FM 10 W
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**IMMEDIATE DELIVERY
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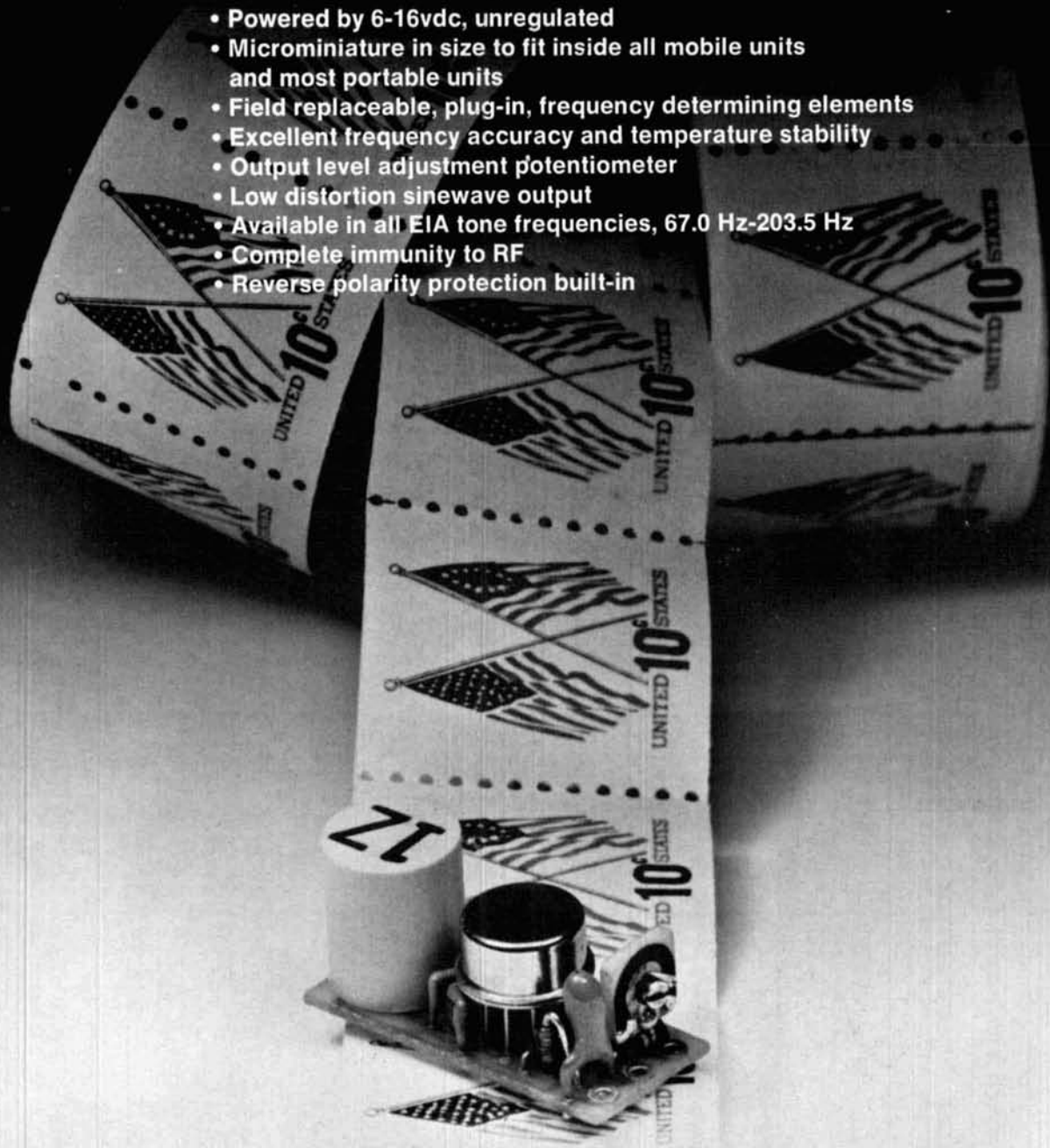
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ME-3 microminiature tone encoder

Compatible with all sub-audible tone systems such as: Private Line, Channel Guard, Quiet Channel, etc.

- Powered by 6-16vdc, unregulated
- Microminiature in size to fit inside all mobile units and most portable units
- Field replaceable, plug-in, frequency determining elements
- Excellent frequency accuracy and temperature stability
- Output level adjustment potentiometer
- Low distortion sinewave output
- Available in all EIA tone frequencies, 67.0 Hz-203.5 Hz
- Complete immunity to RF
- Reverse polarity protection built-in



\$29.95 each

Wired and tested, complete with K-1 element

communications specialists

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(714) 998-3021



K-1 FIELD REPLACEABLE,
PLUG-IN, FREQUENCY
DETERMINING ELEMENTS

\$3.00 each

DIODES/ZENERS				SOCKETS/BRIDGES				TRANSISTORS, LEDS, etc.			
1N914	100v	10mA	.05	8-pin pcb	.25	ww	.45	2N2222	NPN		.15
1N4004	400v	1A	.08	14-pin pcb	.25	ww	.40	2N2907	PNP		.15
1N4005	600v	1A	.08	16-pin pcb	.25	ww	.40	2N3740	PNP	1A 60v	.25
1N4007	1000v	1A	.15	18-pin pcb	.25	ww	.75	2N3906	PNP		.10
1N4148	75v	10mA	.03	22-pin pcb	.45	ww	1.25	2N3054	NPN		.35
1N753A	6.2v	z	.25	24-pin pcb	.35	ww	1.25	2N3055	NPN	15A 60v	.50
1N758A	10v	z	.25	28-pin pcb	.35	ww	1.45	T1P125	PNP	Darlington	.35
1N759A	12v	z	.25	40-pin pcb	.50	ww	1.95	LED Green, Red, Clear			.15
1N4733	5.1v	z	.25	Molex pins .01	To-3 Sockets	.25	D.L.747	7 seg 5/8" high com-anode		1.95	
1N5243	13v	z	.25	2 Amp Bridge	100-prv	1.20	XAN72	7 seg com-anode		1.50	
1N5244B	14v	z	.25	25 Amp Bridge	200-prv	1.95	FND 359	Red 7 seg com-cathode		1.25	
1N5245B	15v	z	.25				HP276	com-cathode		1.25	

C MOS		- T T L -									
4000	.15	7400	.15	7473	.25	74176	1.25	74H72	.55	74S133	.45
4001	.20	7401	.15	7474	.35	74180	.85	74H101	.75	74S140	.75
4002	.20	7402	.20	7475	.35	74181	2.75	74H103	.75	74S151	.35
4004	3.95	7403	.20	7476	.30	74182	.95	74H106	.95	74S153	.35
4006	1.20	7404	.15	7480	.55	74190	1.75			74S157	.80
4007	.35	7405	.25	7481	.75	74191	.35			74S158	.35
4008	1.20	7406	.35	7483	.95	74192	1.65	74L00	.35	74S194	1.05
4009	.30	7407	.55	7485	.95	74193	.85	74L02	.35	74S257(8123)	.25
4010	.45	7408	.25	7486	.30	74194	1.25	74L03	.30		
4011	.20	7409	.15	7489	1.35	74195	.95	74L04	.35		
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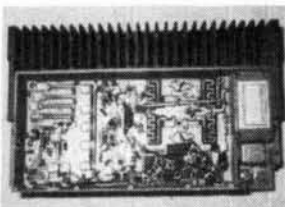
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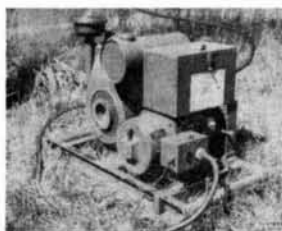
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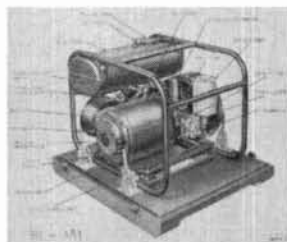
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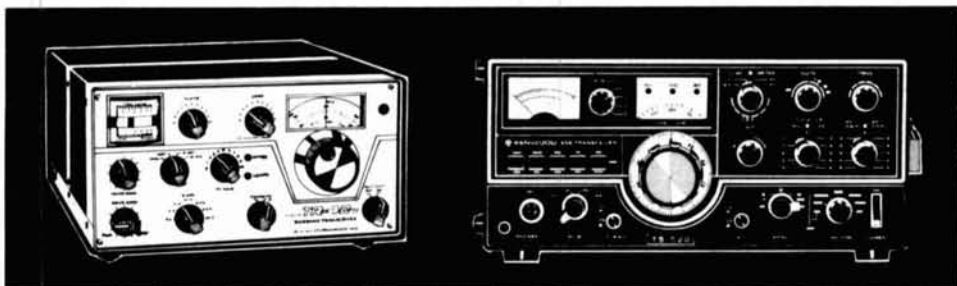
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