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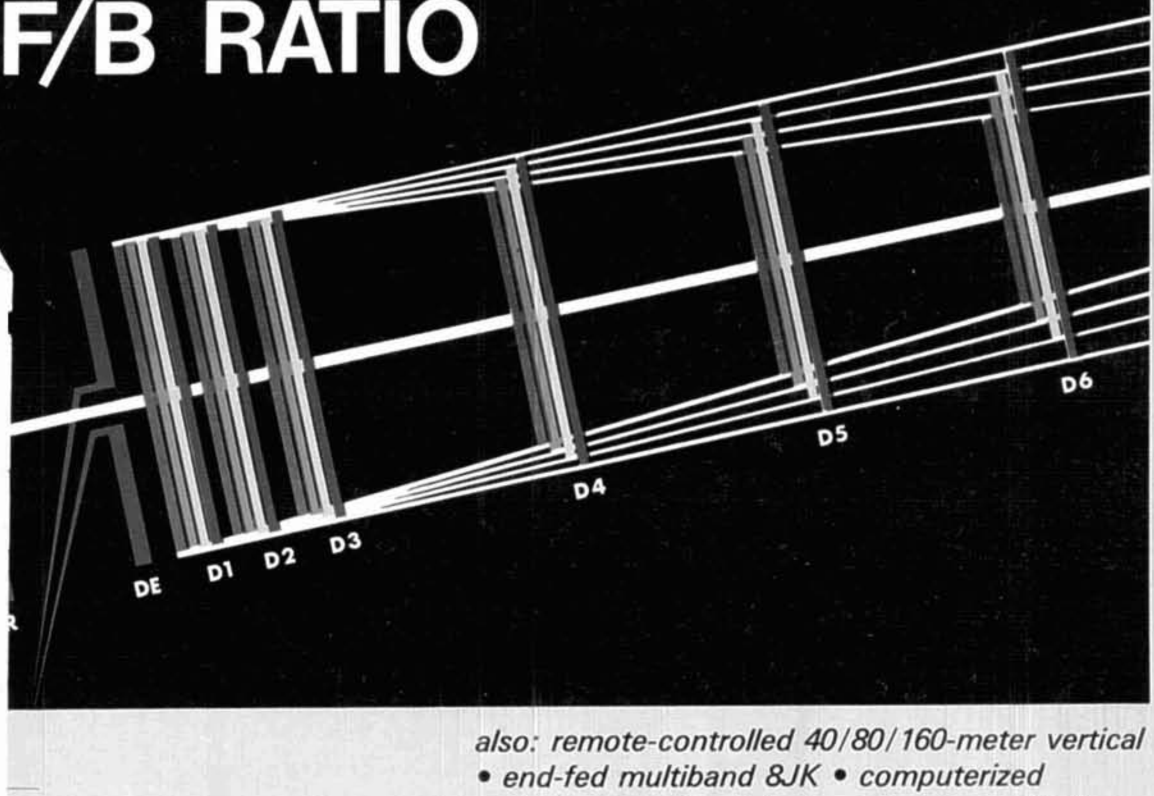
ANNUAL ANTENNA ISSUE

ham radio magazine

YAGI ELEMENT TAPER AFFECTS GAIN & F/B RATIO



also: remote-controlled 40/80/160-meter vertical • end-fed multiband 8JK • computerized antenna matching • high-performance dipole • branch-line hybrids • simple wire plow • and the conclusion of K2BT's series on vertical phased arrays

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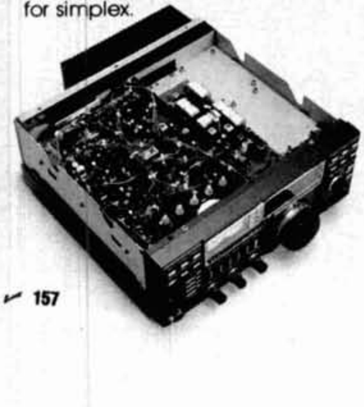

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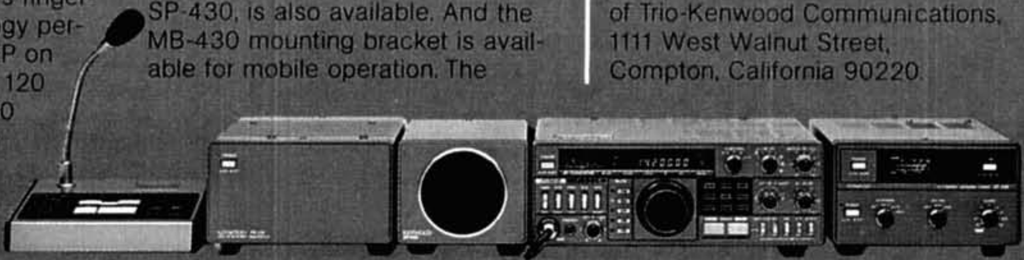
TS-430S Optional Accessories: In typical KENWOOD fashion, there are plenty of optional accessories for this great HF transceiver. There is a special power supply, the PS-430. An external speaker, the SP-430, is also available. And the MB-430 mounting bracket is available for mobile operation. The AT-250 automatic antenna tuner was designed primarily with the TS-430S in mind, and for those who prefer to "roll their own," the AT-130 antenna tuner is available. The FM-430 FM unit is available for FM operations. The YK-88C (500 Hz) or YK-88CN (270 Hz) CW filters, the YK-88SN SSB filter, and the YK-88A AM filter may be easily installed for serious DX-ing. An MC-60A deluxe desk microphone, MC-80 and MC-85 communications microphones, an MC-42S mobile hand mic., and an MC-55 8-pin mobile microphone, are available, depending on your requirements. TL-922A linear amplifier (not for CW QSK), SM-220 station monitor, PC-1A phone patch, SW-2000 SWR/power meter 160 ~ 6 meter, SW100A SWR/power/volt meter 160-2m, HS-4, HS-5, HS-6, HS-7 headphones, are also available.

More information on the TS-430S is available from authorized dealers of Trio-Kenwood Communications, 1111 West Walnut Street, Compton, California 90220.



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contents

REFLECTIONS

One year ago . . .

It's hard to believe a year has passed since we put together the 1983 annual antenna issue. That was my first May special as Editor-in-Chief (though I had joined *ham radio* in the fall of the previous year). Gracing the pages of that issue was the start of a series of articles on vertical phased arrays that promised to examine in detail every important aspect of that subject from design through construction. Most appropriately, the final article in that series appears in this special antenna issue. I would not for a moment suggest that it is either easy reading or the answer to everyone's antenna requirements, but as the author has repeatedly stated, the series takes the mystery out of antenna development and squarely places that topic into the realm of science. Though the author has primarily concentrated on the 75-meter band (where his interests lie — and considering the present sunspot cycle trend, it's not a bad idea), the concept he presents is well suited for use on other bands. It's a series I heartily recommend reading and rereading.

While still on the subject of verticals, how would you like to be able to remotely control a fine performing antenna on your three favorite low bands: 160, 80, and 40? Robert Leo, W7LR shows you how with his 70-foot vertical that uses inexpensive irrigation pipe and a five position switching control head and RF deck. It's simple and effective, and with a flick of a switch, gives you *full* coverage of the three bands without any retuning . . . a very nice addition, I might add, to any installation that uses a no-tune synthesized transceiver.

From the United Kingdom comes an ingenious and quite effective design for an antenna and tuner that enables operation on the three highest bands (20, 15, and 10). R.C. Marshall, G3SBA, shows how an old standby antenna, an "8JK," can be end-fed to provide performance comparable to that of the standard center-fed version. The more remarkable aspect of his development is a sophisticated antenna control unit that enables the operator to step through each of the bands in narrow segments using a BCD switching circuit. The original motivation for this elaborate design was the author's need for an unobtrusive, high performance three-band antenna installation. Food for thought for those with small lots and big ambitions (DX, that is).

On a different angle, *ham radio* received an innocent enough sounding call several months ago from a gentleman who said that he had carefully read Lawson's series on Yagis for the HF bands and would be interested in providing a somewhat similar presentation for the VHF/UHF bands. From subsequent conversations with Stan Jaffin, WB3BGU, it soon became obvious that not only had he thoroughly understood Lawson's series, but that he'd also investigated the works of several prominent VHF/UHF designers including Kmosko and Johnson, Greenblum, Tilton, Viezbicke and Knadle. With the aid of a computer (a mainframe, I believe), he generated a series of tables and associated patterns which examined in fine detail the effect of iterating Yagi parameters for the enhancement of gain and front-to-back ratio. His first article, appearing in this issue, is concerned with the 2-meter band with emphasis on the weak signal segment. Very methodically various director tapering schemes are shown and logical conclusions drawn. The series will continue over the next several months, with the same care given to the examination of Yagis for the 220 and 432 MHz bands. Like Lawson's series, Stan's is not meant for casual reading, but rather for use by experimenters who wish to build a strong foundation in their understanding of Yagi antenna design.

While in the VHF/UHF World; Joe Reisert, W1JR, one of our featured columnists, has done it again. The no-nonsense delivery of information he's famous for has carried into this special antenna issue. In his column on page 110, he examines the "slightly" important area of performance parameters. Gain, beamwidth, front-to-back ratio, sidelobes and VSWR are defined and their interrelationships explored. He doesn't stop there, but continues to discuss other areas of considerable importance to the antenna designer such as feed systems, wind load, structural strength and preventive maintenance. In the second part of his article — of special interest to those who attend antenna measuring contests — Joe shows how one can actually determine gain and come pretty close with an estimate once the major side lobe levels are known. In reading the article perhaps you'll recognize several of the common mistakes that can turn a VHFer's hair a lighter shade of white.

Sometimes it appears that very few new antenna ideas are generated, and that recent developments are old concepts introduced to meet new needs. A case in point is what's known as a "stretch" or phase compensated dipole. The concept, first introduced in the 40s and possibly a decade earlier, illustrates a technique whereby the addition of series capacitors, periodically located throughout an antenna's legs, create a uniform current distribution over the entire length of the radiator. The particular version explored by David Atkins, W6VX, sports a low angle of radiation, high efficiency and wideband performance.

This annual antenna issue continues with techniques using just a GDO, noise or RF bridge — or more elaborately, a microcomputer — to match simple antennas.

For those intrigued with verticals, a large ground radial system is a must and W7IV shows you how it can be done with the use of a home-built wire plow.

Naturally pleased with this month's useful editorial content, we also take considerable satisfaction in setting a new *ham radio* record: because of the outstanding support of you, our readers, and our advertisers, this issue sets an all-time record for advertising space sales. To all involved, a hearty THANK YOU.

Remember, I always have room for just one more manuscript. If you have an idea for an article you'd like to write, send it in or stop by the *ham radio* booth at the Dayton Hamvention, April 27-29. Let's talk about it.

Rich Rosen, K2RR/1
Editor-in-Chief

presstop de W9JUV

TOP ARRL OFFICES WERE SHAKEN UP IN A STRONGLY CONTESTED ELECTION March 26. Elected to League presidency was First Vice President Larry Price, W4RA, while Great Lakes Division Director Len Nathanson, W8RC, was named First Vice President. Gar Anderson, KØGA, retained his Vice Presidency, while Southwestern Division Director Jay Holladay, W6EJJ, was also elected a Vice President. Out entirely is Carl Smith, WØBWJ, who had moved up to President from First Vice President after the death of Vic Clark, W4KFC, in November.

Just What This Means To The League's Future is hard to gauge as yet, though some knowledgeable League observers believe it's just the beginning of a period of internal strife and major policy shifts. It's no secret that many of the staff have been very unhappy over recent changes in work schedules, and the new administration is not believed to be very sympathetic to their complaints.

AN UNCOORDINATED REPEATER HAS BEEN SHUT DOWN by the FCC in southern California. The action came after the operator of a coordinated repeater (to which the uncoordinated repeater had caused interference) and the area coordinator, TASMA (the Two Meter Area Spectrum Management Association), filed complaints with the FCC. Cited in the FCC's action was a policy letter written last April by the FCC's Jim McKinney to WA2DHF of the Tri-State Repeater Group, in which he stated that in cases of interference the FCC would support coordinated repeaters and the organizations that provided their coordination.

IT'S ALMOST A HORSE RACE TO SEE WHICH VEC WILL ADMINISTER the first Amateur exams under the new Volunteer Exam Program. DARA plans to give exams at the Dayton Hamvention the last weekend in April, the Anchorage Amateur Radio Club is believed to be on about the same timetable, and the DeVry ARS plans its first exam session by May 8 at DeVry's Chicago campus. The proposal of a sixth VEC, "VEC Region Four, Inc.," has also been accepted for the fourth call area, but a fifth district group's proposal has been returned for revision.

The FCC's Proposal To Permit Reimbursement Of VEC Expenses was released March 9, with a Comment due date of April 16 and Reply Comments due May 1. In it the Commission proposed letting either the VEC or VE collect the fee, with the VEC setting up procedures by which VEs could also be reimbursed for their expenses. Despite the unusually short comment period on this NPRM, Commission procedures make it unlikely that VECs can actually begin collecting fees before late summer. Since the ARRL directors have taken the firm position that they won't make their VEC proposal to the FCC until fees are in place, other VEC programs will be up and running in much of the country before the League can even start its own. Even the work the League has already done on the volunteer program isn't being utilized. When one of the newly appointed VECs approached the League recently with the suggestion that the VECs already in place and the League share their efforts on the exam question and answer pool, in order to assure uniform exams throughout the country, that VEC was told "the League has invested a lot of time and money in that effort and doesn't feel it can share it!" A further unknown factor is the new League administration, which could make radical changes in the direction the League is taking in the VEC program.

A Volunteer Amateur Exam Program In Those Parts Of The Country not yet represented by a VEC will become a must before much longer, with or without the ARRL. The FCC's intention is to get out of Amateur license exams entirely before the end of 1984, with the exception of possible special review exams for Amateurs whose licenses are suspect.

THE CHICAGO AREA FCC-AMATEUR 2-METER INTERFERENCE COMMITTEE held its second meeting March 14, drawing repeater representatives from all over northern Illinois and southeast Wisconsin. DFing techniques and equipment, both Amateur and FCC, were discussed at some length, and the Commission representatives distributed forms they'd like used for documentation and reporting of jamming problems.

This Program Is Being Watched By Washington As A Possible Prototype for the long-awaited program to incorporate Amateur volunteers in the FCC's enforcement effort. At present the Chicago Field Office wants to know about on-going interference problems, but on an "organized" basis through designated representatives of each repeater.

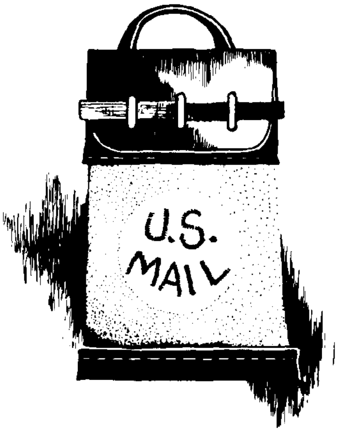
The Group Voted Unanimously To Continue The Program, and expressed very positive sentiments toward the Chicago Field Office people and their willingness to work with and for the area Amateur community. The next meeting will probably be held in June.

FULL PRIVILEGES ON THE 1900-2000 kHz PORTION OF 160 METERS were restored to U.S. Amateurs in a March 22 FCC action, which noted that Canadian Loran-A operation on 160 has ended.

W2NSD's PROPOSAL TO REQUIRE CW RETESTING OF ALL AMATEURS has been rejected by the FCC as being "without merit" and "not presenting any new or novel issues...."

A PROPOSAL TO GIVE NOVICES ALL-MODE PRIVILEGES ON 220 MHZ is being prepared for FCC submission in mid-May by WA2MCT/5 and WD5DON. Rationale for the proposal, which would limit Novices to 233.40-233.75 MHz, is to improve usage of the band while allowing Novices to take part in public service activities and gain "hands-on" experience with other modes.

AMATEUR STATIONS WILL BE PERMITTED IN THE OLYMPIC VILLAGES in Los Angeles after all, it now appears. After drawn-out, on-and-off negotiations due largely to concerns about security, the Olympic Committee has agreed to permit three stations in the competitor's compounds. A limited number of volunteer operators, all subject to detailed security clearances, will be permitted to operate the stations and provide a communications link back home for those Olympic competitors whose countries permit it.



comments

smoke signals

Dear HR:

In response to Fred Norvick's comment on heat sinks (Comments, Octoer, 1983), the use of a capacitor in the power line feeding a heat sink cooling fan might cause the fan to increase speed to the point that it might start sending "smoke signals." If the added capacitance and the inductance (of the fan) are (series) resonant at 60 cycles, only the ohmic resistance remains in the circuit, causing the fan to draw more current than it is designed for. You will have to experiment with different capacitor values to find the one that will make the fan rotate more slowly. I increase fan speed in my 2-meter linear (4X250A) during the SSB transmit cycle and let it "coast" during receive periods.

Rudolf Frank, DJ4BZ
Burgkirchen, Germany

AM update

Dear HR:

In Bill Orr's comments on "ancient modulation" in the February issue of *ham radio* (page 65), Bill correctly points out how Amateur Radio voice quality has deteriorated since the advent of SSB. Today, even on VHF-FM, a medium fully capable of extremely good audio quality, voices typically sound more like they are coming from tin can telephones than from sophisticated communications equipment. Many of the most expensive HF and VHF transceivers, loaded with all the latest "bells and whistles," come equipped with cheap CB-style hand mikes and tiny speakers. The prevailing philosophy seems to have been that in Amateur Radio, voice quality does not matter. Certainly we can do better than that.

I must take issue with one statement in Bill's article, however. Users of AM have not "gradually retreated to obscure regions of 160 and 10 meters." AM activity can be heard daily on most of the HF bands. AM'ers, now a minority, tend to operate within certain portions of the bands, much in the same manner as RTTY and SSTV operators. The most commonly used AM frequencies are 1880-1900, 1985, 3860-3890, 7160, 7285-95, 14286, and 29,000-29,200 kHz. If anything, there has been a renewed interest in Amateur AM in recent years. It is interesting to note in looking through the ads that AM is being increasingly included on the newer "all-mode" transceivers. Moreover, some of the latest rigs are capable of very decent voice quality on AM and SSB. The Amateur equipment market is extremely cost competitive, yet the inclusion of AM on a transceiver must add considerably to its selling price. The major Amateur equipment manufacturers are large companies with worldwide markets. It is inconceivable that marketing research data would not be a factor in the design of their products. These manufacturers simply would not drive up the cost of their transceivers by including the AM mode if they were not convinced that there is a substantial demand for Amateur equipment with AM capability.

Most AM'ers are particularly interested in voice quality; some of the AM signals heard on the ham bands would put many broadcast stations to shame. There has already been some Amateur experimentation with pulse duration modulation, and AM'ers routinely use advanced techniques such as equalizers, delay/reverb (not CB-style echo boxes), and other processing techniques. Many AM operators use older equipment they have refurbished themselves, and there are even some home-built stations on the air! Modern AM techniques have not completely bypassed Amateur Radio. The "Amateurs" in our ranks who deride those of us who operate and experiment with amplitude modulation usually turn out to be individuals who take pride in their ignorance.

Donald Chester, K4KYV
Woodlawn, Tennessee

volunteer examiners: keep standards high

Dear HR:

I am concerned about the honesty of the Volunteer Examination Program. Right now we have many licensed "Amateurs" who could not pass an honest General Class examination. I have suggested to the ARRL that all volunteer examiners be Extra Class with at least 10 years of experience, and furthermore, that the volunteer examiners be required to affirm and certify that they meet the requirements for Extra Class in all respects, including code and theory, and that improper conduct in the administration of the examination would lead to license revocation. The ARRL has not yet responded to these suggestions.

The government recognizes that the skilled Amateur is a valuable asset. During the war all of the Electronic Field Engineers at Raytheon were Amateurs. (Clark Rodimon from ARRL Headquarters headed up this group.) The four senior people in the Bureau of Ships Radar Design Branch were Amateurs. At that point you knew what to expect of an Advanced or General Class Amateur, but I doubt if the same standards are applicable today.

I.L. McNally, K6WX
Sun City, California

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(See "Publisher's Log," April, 1984, page 6, for details.)

603-878-1441

applied Yagi antenna design
part 1: a 2-meter classic revisited

Computer model analyzes, updates Kmosko-Johnson designs

The Yagi antenna model developed by the late James Lawson, W2PV, provided a rigorous method for exploring Yagi antenna design and performance.[1] Because his primary interest was the HF region, Lawson's nine-part series[2] emphasized the two-through six-element Yagis that, because of boom length, are useful mainly below 30 MHz; the ability of his model to measure the performance of the multi-element and multi-wavelength Yagis found in VHF and UHF applications, however, was also discussed.[3]

This series adapts Lawson's model for use with specific VHF and UHF antenna designs. A computer model is used to optimize forward gain and front-to-back (F/B) ratios for the weak signal area of given VHF/UHF bands. Each resulting antenna design can be polarized either horizontally or vertically, or stacked for enhancement of specific performance parameters.

basic technical parameters

Several technical assumptions underlie the analyses in this series. First, all Yagi antenna designs are based on non-conductive booms. Methods for conversion of element lengths to round or square conductive booms are readily available.[4] Second, a non-reactive driven element is used; this means a self-impedance value of 73+j0. Third, antenna feeding methods are left to the user's discretion; any number of proven feeding methods are available for VHF and UHF Yagis.[5] Finally, wherever it is possible, common intervals such as 0.125 or 0.0625 inches are used for Yagi antenna elements or iterations. Few Radio Amateurs can readily measure and cut antenna elements to smaller tolerances, and the use of computer iteration assures finding optimized lengths at these intervals. However, as stated above, the driven element is an exception and will be stated to the nearest 0.000001 inch.

The purpose of this series is to provide analyses of Yagi antenna designs for application above 50 MHz. There is no real limit to the number of iterations that can be run against a given antenna design. However, the practical side of any design effort requires that some sort of sampling be made, particularly in terms of the analyses that are performed and the select few that are reported. This is the rationale for limiting this first article to six variations of a basic design, with each variation presented in terms of gain and F/B optimization.

the classic Kmosko-Johnson design

One of the best known designs for a 144 MHz antenna was published 28 years ago.[6] Combining variable director spacing, tapered elements, and a 3.44 wavelength boom, this design represents the results of a long empirical process on the part of James Kmosko, W2NLY, and Herbert Johnson, W6QKI, the designers. Another version of this same antenna, but with different reflector length and spacing as well as a different element mounting method, was published later.[7] As the original design is more widely known, it is the one selected for computer analysis.

Table 1 contains the original Kmosko-Johnson antenna dimensions and wavelength values for 144.0 MHz. The element diameter is 0.09375 inches, and each element is spotwelded across the diagonal of a 0.75 inch square metal plate. The plate is screwed to the top of a 1.25 inch diameter aluminum boom.

Conversion of this antenna to its non-conducting boom equivalent presented several problems. While information for preliminary estimates was available,[8] it was decided to sidestep the issue via the use of the brute force computer iteration method.

As the design frequency was also to be shifted to 144.5 MHz, initial iterations of reflector and director lengths were made across a wide range of values. The element diameter remained as in the original design; two samples of the intermediate results are presented in **table 2** and **table 3**.* Because the designers

*In reading these and the tables that follow, it should be noted that only the length of the first director is specified. Each table's title contains the tapering scheme to apply to subsequent directors.

By **Stanley Jaffin, WB3BGU**, 800 Stonington Road, Silver Spring, Maryland 20902

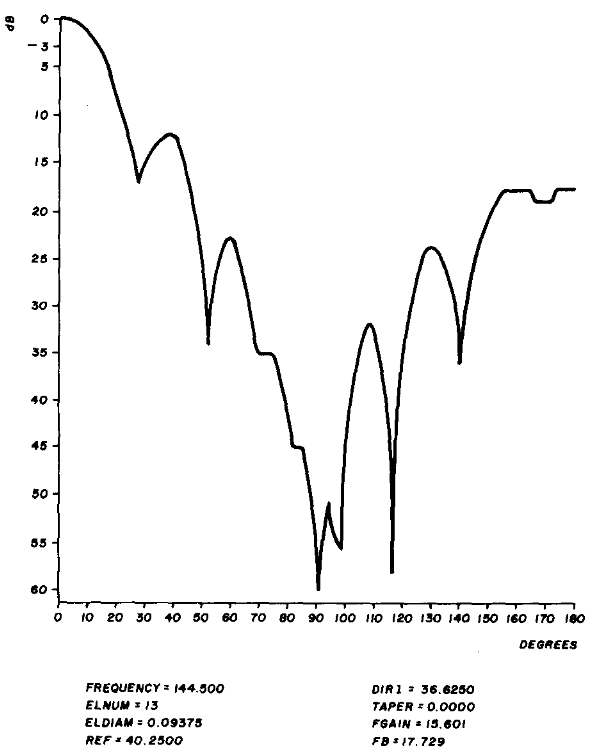


fig. 1. Plot of the zero taper, gain optimized antenna.

asserted that their non-tapered antenna was in fact the optimal gain antenna, locating the parasitic element lengths for maximum gain at the new design frequency would result in a comparable antenna.

In terms of the actual antenna undergoing computer iteration, the designers specified that to move the design frequency within the 2-meter band, only the element lengths had to be changed. The spacing between the elements for frequencies between 144.0 and 148.0 MHz remains the same as at 144.0 MHz. Therefore, the experimental 144.5 MHz antenna was used as a standard for comparison, as shown in **table 4**. The apparent changes in element spacings are due to slight shortening in wavelength at the new design frequency. The lengths of the parasitic elements are supplied with each iteration.

Frequency response parameters are provided for each of 12 optimized antennas. Since 144.5 MHz is the design frequency and the designers specifically showed how performance was made to drop dramatically above 146.0 MHz, a range of 142.5 to 146.5 MHz is used. Each frequency performance table contains nine data points, with 144.5 MHz as the frequency center.

computer-designed Kmosko-Johnson antennas

Performance measurements were supplied for

table 1. Original Kmosko-Johnson antenna design for 144.0 MHz.

	element	length (inches)	element spacing (λ)	cumulative length (λ)*
1	reflector	41.500	0.0000	0.0000
2	driven	39.500	0.2440	0.2440
3	director 1	37.750	0.0854	0.3294
4	director 2	37.625	0.0915	0.4209
5	director 3	37.500	0.0915	0.5124
6	director 4	37.375	0.1952	0.7076
7	director 5	37.250	0.3904	1.0980
8	director 6	37.125	0.3904	1.4884
9	director 7	37.000	0.3904	1.8788
10	director 8	36.875	0.3904	2.2692
11	director 9	36.750	0.3904	2.6596
12	director 10	36.625	0.3904	3.0500
13	director 11	36.500	0.3904	3.4404

*cumulative length (λ) of antenna.

tapers of 0.000, 0.125, and 0.25 inch. The last was a special taper wherein the first three directors used a 0.125 inch taper and the remaining directors tapered at 0.25 inch.

In order to analyze the Kmosko-Johnson design more thoroughly, and to illustrate the ease and utility of computer-based Yagi antenna design, three additional tapers (0.0625, 0.1875, and 0.25 inch) are included. Here, 0.25 is a linear taper applied equally to directors two through eleven.

E-plane (cartesian) plots (**figs. 1-13**) are presented for the Yagis in each tapering procedure and are calculated at 144.5 MHz. A computer line printer served as the output device, with the attendant limitations of the standard 11 × 14 7/8-inch page size. The dB range is 0 to 60, with calculated values in excess of 60 shown as 60 dB. For some antennas this may indicate a trough instead of a null, but little accuracy is lost as nulls of this magnitude are rarely achieved in practice. The degree range is 0 to 180, with every second degree (0,2,4,6, and so on) being plotted. Because computer printers are discrete output devices, only full integer dB values can be plotted, meaning that 10.75 dB at 100 degrees is printed with an "E" (for E-plane) at 11 dB at 100 degrees. A skilled artist (WA9MXB) has drawn curves in place of the discrete E's; these are the fine plots that appear as **figs. 1** through **13**. The plots in the rest of this series are generated in a similar manner.

General observations are presented after the discussions of the major attributes of each of the six tapers. As has often been the case with antennas, there are no absolutes. Often the "best" antenna is more a function of the station operator than of any of the antenna's electrical or mechanical attributes.

taper = 0.000

The designers specified that a zero taper resulted in an optimized forward gain and a comparatively poor F/B. **Table 5** depicts the iteration producing the zero taper's optimum gain of 15.601 dBi (**fig. 1**), and **table 6** depicts the iteration producing the F/B optimization of 32.918 dB (**fig. 2**). The differences in reflector and director length indicate that these are in fact two

table 2. Iteration of the Kmosko-Johnson antenna with a reflector length of 39.75 inches at 144.5 MHz.

director 1 (inches)	gain (dBi)	F/B (dB)
36.500	15.199	11.426
36.625	15.277	11.559
36.750	15.351	11.796
36.875	15.421	12.174
37.000	15.486	12.750
37.125	15.542	13.619
37.250	15.583	14.952
37.375	15.593	17.112
37.500	15.546	21.106
37.625	15.385	32.100
37.750	14.998	23.112

table 3. Iteration of the Kmosko-Johnson antenna with a reflector length of 41.375 inches at 144.5 MHz.

director 1 (inches)	gain (dBi)	F/B (dB)
36.500	14.968	12.975
36.625	15.075	13.204
36.750	15.182	13.545
36.875	15.288	14.038
37.000	15.388	14.745
37.125	15.476	15.766
37.250	15.538	17.285
37.375	15.577	18.953
37.500	15.492	23.907
37.625	15.302	29.637
37.750	14.903	22.009

table 4. Baselined antenna at 144.5 MHz with fixed parasitic element spacings and parasitic element lengths supplied during iteration.

	element	length (inches)	element spacing (λ)	cumulative length (λ)
1	reflector	—	0.0000	0.0000
2	driven	39.320721	0.2449	0.2449
3	director 1	—	0.0857	0.3306
4	director 2	—	0.0918	0.4224
5	director 3	—	0.0918	0.5142
6	director 4	—	0.1959	0.7101
7	director 5	—	0.3918	1.1019
8	director 6	—	0.3918	1.4937
9	director 7	—	0.3918	1.8855
10	director 8	—	0.3918	2.2773
11	director 9	—	0.3918	2.6691
12	director 10	—	0.3918	3.0609
13	director 11	—	0.3918	3.4527

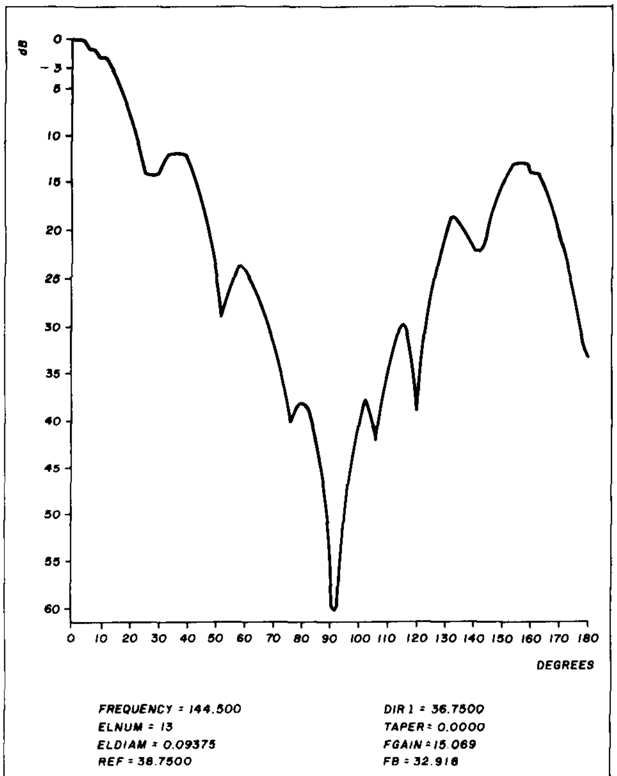


fig. 2. Plot of the zero taper, F/B optimized antenna.

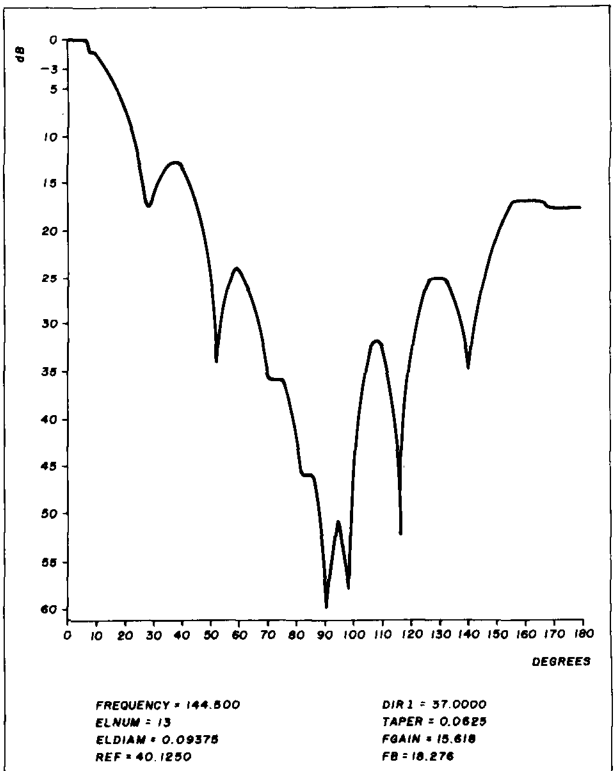


fig. 3. Plot of the 0.0625 taper, gain optimized antenna.

table 5. Maximized gain iteration for taper of 0.000 with a reflector length of 40.250 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
36.500	15.540	15.365
36.625	15.601	17.729
36.750	15.543	19.153
36.875	15.190	15.053
37.000	14.230	9.410
37.125	11.340	6.648
37.250	9.259	−0.370†
37.375	5.347	−4.911
37.500	1.635	−8.585
37.625	0.580	−8.842
37.750	1.319	−7.336

table 6. Maximized F/B iteration for taper of 0.000 with a reflector length of 38.750 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
36.500	13.248	21.148
36.625	15.190	17.977
36.750	15.069	32.918
36.875	14.744	18.295
37.000	13.996	9.756
37.125	12.430	4.130
37.250	9.601	−0.571
37.375	5.489	−4.758
37.500	1.348	−7.580

table 7. Frequency response parameters for gain maximized antenna with a 0.000 taper.

frequency	gain (dBi)	F/B (dB)
142.5	15.259	11.162
143.0	15.344	12.022
143.5	15.440	13.266
144.0	15.537	15.126
144.5	15.601	17.729
145.0	15.524	18.591
145.5	15.082	13.846
146.0	13.920	8.321
146.5	11.736	3.390

table 8. Frequency response parameters for F/B maximized antenna with a 0.000 taper.

frequency	gain (dBi)	F/B (dB)
142.5	14.872	9.832
143.0	14.989	11.304
143.5	14.508	12.832
144.0	15.104	17.813
144.5	15.069	32.918
145.0	14.844	18.294
145.5	14.113	9.726
146.0	12.310	3.985
146.5	9.032	−0.944

† This computer model calculated negative F/B because the rear lobe radiated greater amplitude than the forward lobe.

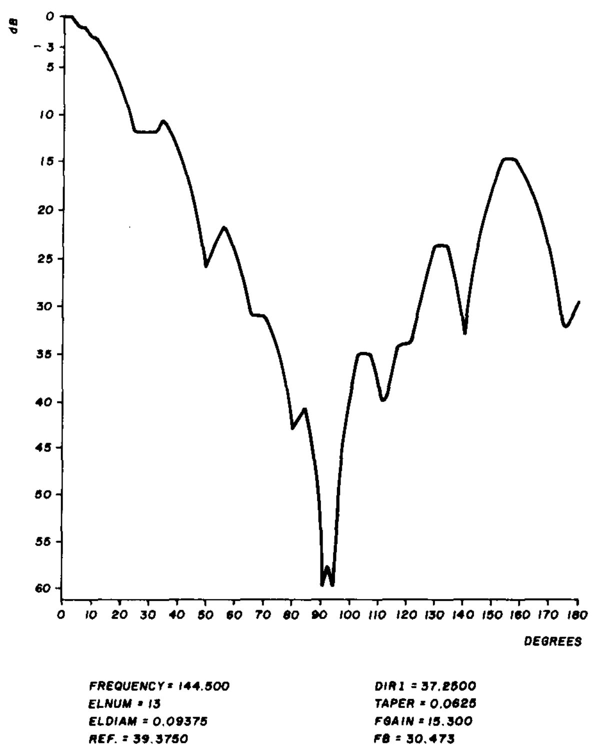


fig. 4. Plot of the 0.0625 taper, F/B optimized antenna.

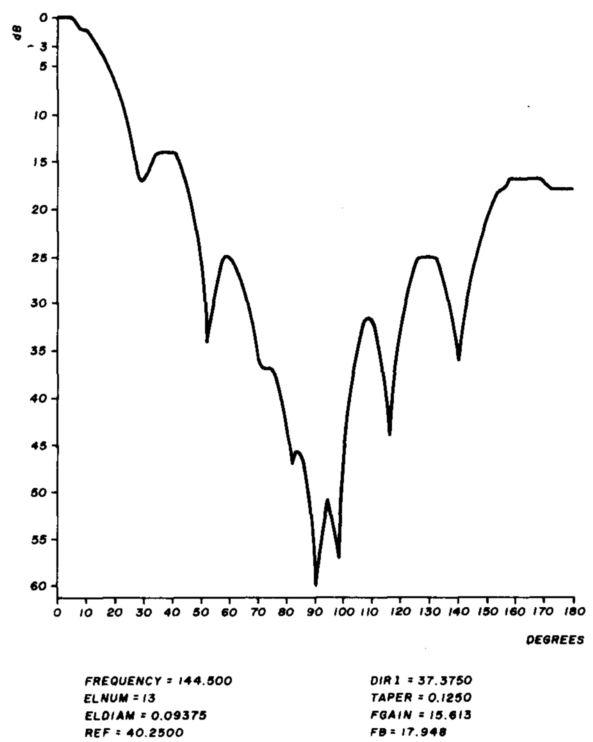


fig. 5. Plot of the 0.125 taper, gain optimized antenna.

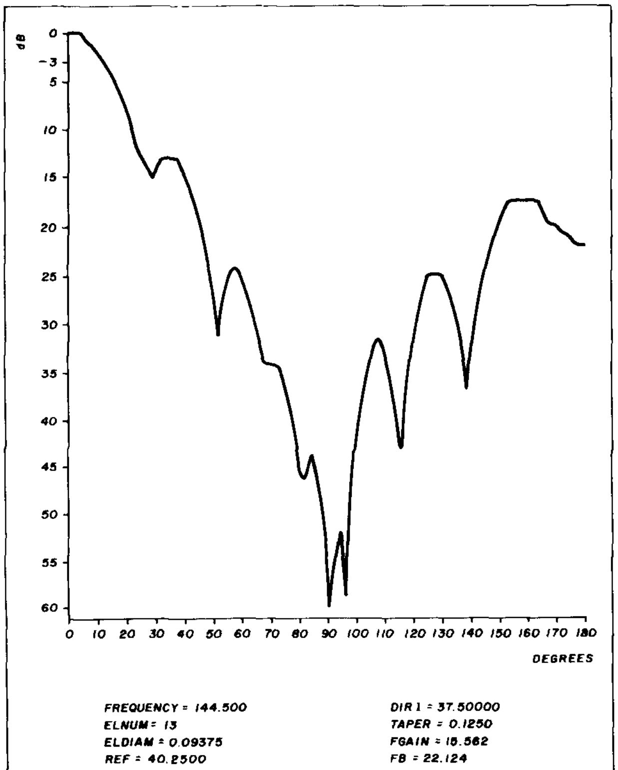


fig. 6. Plot of the 0.125 taper informational antenna.

significantly different antennas. **Table 7** presents the optimized gain antenna's computer performance across the 4 MHz bandwidth, and **table 8** does likewise for the F/B optimized antenna. Using this taper, a superior design frequency F/B ratio can apparently be obtained at a sacrifice of only 0.5 dB in gain.

taper = 0.0625

This antenna was not presented by the designers and is totally a product of computer iteration. **Table 9** presents this antenna's optimized gain iteration for 15.618 dBi (**fig. 3**), and **table 10** does likewise for the optimized F/B iteration for 30.473 dB (**fig. 4**). As was the case with the zero taper, these two optimized antennas are significantly different antennas. **Table 11** presents the gain optimized antenna's performance across the 4 MHz bandwidth, and **table 12** does likewise for the F/B optimized antenna. Compared to the zero-taper antenna, this antenna can be optimized to a slightly higher gain or to a higher F/B ratio within the weak signal area part of the band.

taper = 0.125

Of the three antennas they presented, the designers specified this antenna (**fig. 5**) as their best all-around performer. ***Table 13*** *presents the optimization iteration that produced the highest gain and F/B calcula-*

table 9. Maximum gain iteration for taper of 0.0625 with a reflector length of 40.125 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
36.500	15.345	12.341
36.625	15.454	11.532
36.750	15.510	13.955
36.875	15.581	15.538
37.000	15.618	18.276
37.125	15.573	23.686
37.250	15.344	24.391
37.375	14.742	15.243
37.500	13.474	9.103
37.625	11.192	4.135
37.750	7.587	−0.538

table 10. Maximum F/B iteration for taper of 0.0625 with a reflector length of 39.375 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
36.500	15.330	11.114
36.625	15.399	11.803
36.750	15.460	12.798
36.875	15.510	14.395
37.000	15.533	17.195
37.125	15.491	23.497
37.250	15.300	30.473
37.375	14.778	15.783
37.500	13.579	9.177

table 11. Frequency response parameters for gain maximized antenna with a 0.0625 taper.

frequency	gain (dBi)	F/B (dB)
142.5	15.341	11.401
143.0	15.422	12.240
143.5	15.503	13.435
144.0	15.577	15.248
144.5	15.618	18.276
145.0	15.565	23.786
145.5	15.288	22.055
146.0	14.580	14.019
146.5	13.168	8.283

table 12. Frequency response parameters for F/B maximized antenna with a 0.0625 taper.

frequency	gain (dBi)	F/B (dB)
142.5	15.306	11.839
143.0	15.391	13.622
143.5	15.451	16.556
144.0	15.455	22.877
144.5	15.300	30.473
145.0	14.756	15.518
145.5	13.421	8.826
146.0	10.878	3.697
146.5	6.892	−1.099

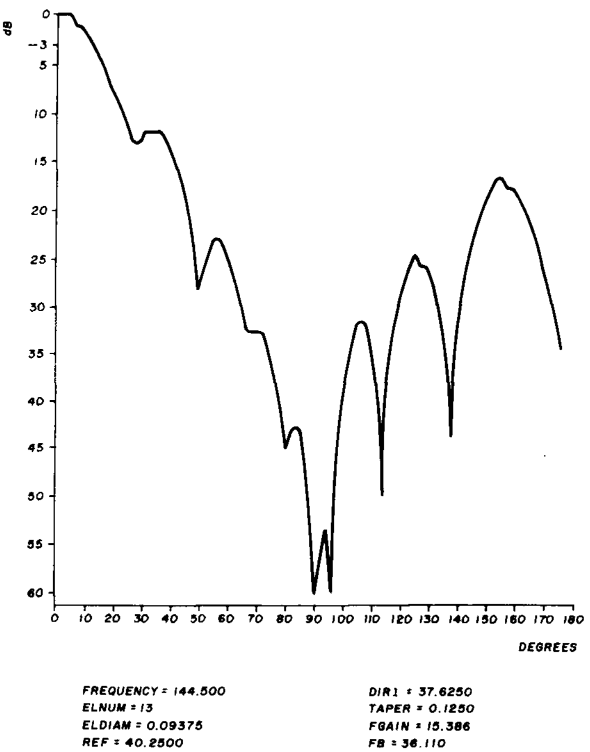


fig. 7. Plot of the 0.125 taper, F/B optimized antenna.

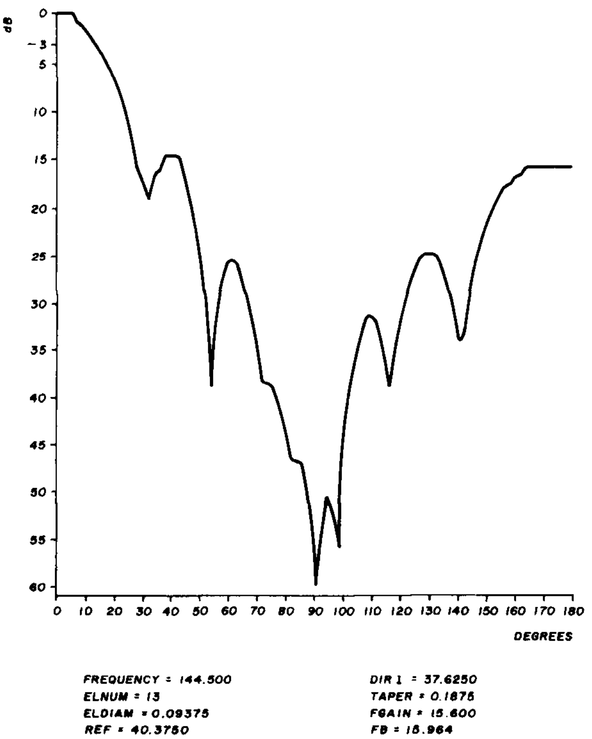


fig. 8. Plot of the 0.1875 taper, gain optimized antenna.

table 13. Maximized gain and F/B iteration for taper of 0.125 with a reflector length of 40.250 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
36.500	15.156	12.144
36.625	15.241	12.282
36.750	15.324	12.524
36.875	15.404	12.909
37.000	15.481	13.494
37.125	15.548	14.377
37.250	15.598	15.734
37.375	15.613	17.948
37.500	15.562	22.124
37.625	15.386	36.110
37.750	14.982	23.407

table 14. Frequency response parameters for gain maximized antenna with a 0.125 taper.

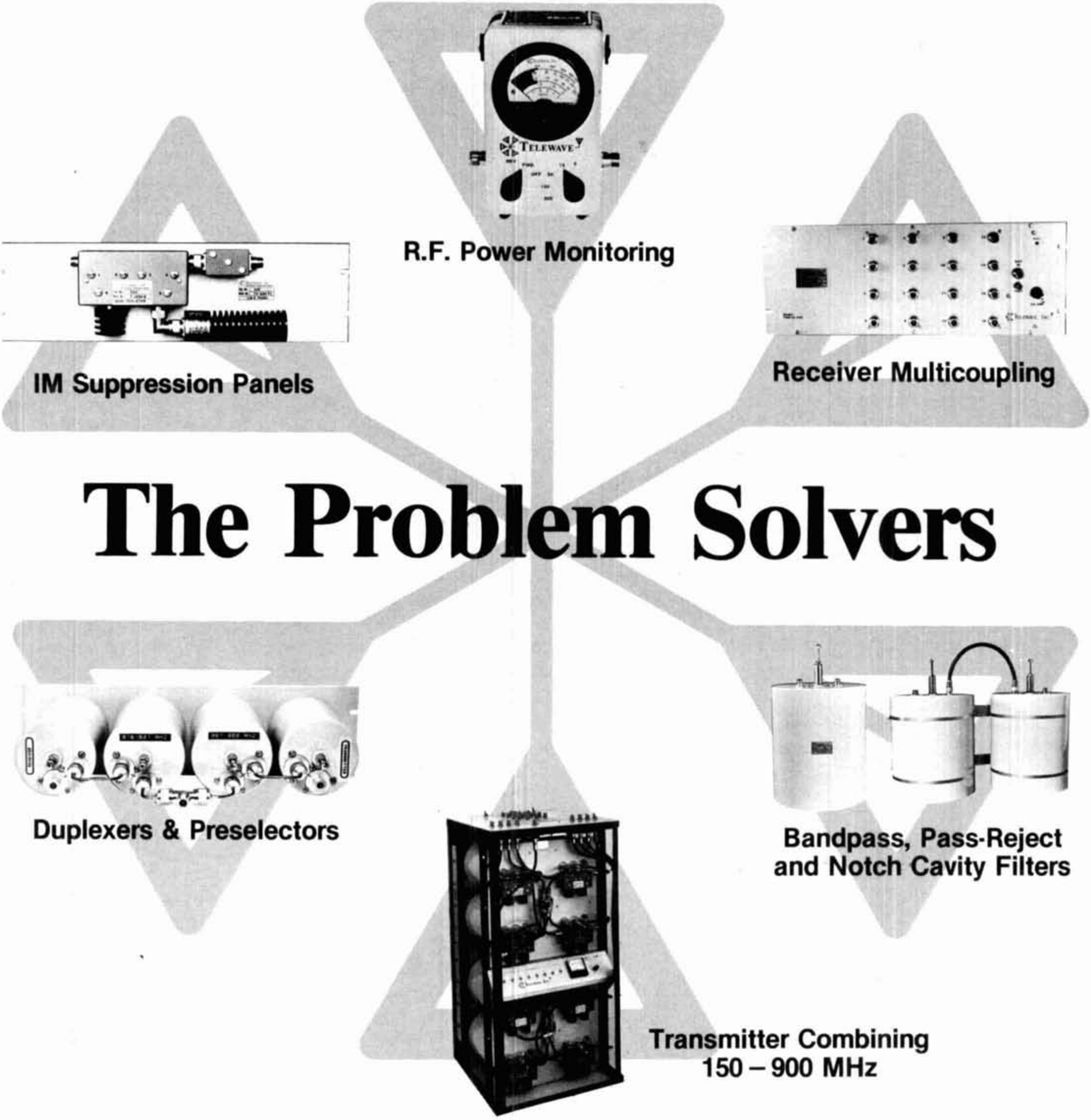
frequency	gain (dBi)	F/B (dB)
142.5	15.409	12.006
143.0	15.481	12.794
143.5	15.546	13.879
144.0	15.597	15.457
144.5	15.613	17.948
145.0	15.554	22.586
145.5	15.353	36.116
146.0	14.902	22.227
146.5	14.014	14.837

table 15. Frequency response parameters for the "informational" antenna with a 0.125 taper.

frequency	gain (dBi)	F/B (dB)
142.5	15.473	12.544
143.0	15.540	13.618
143.5	15.593	15.171
144.0	15.613	17.609
144.5	15.562	22.124
145.0	15.370	36.809
145.5	14.925	22.548
146.0	14.035	14.849
146.5	12.286	9.831

table 16. Frequency response parameters for F/B maximized antenna with a 0.125 taper.

frequency	gain (dBi)	F/B (dB)
142.5	15.529	13.351
143.0	15.584	14.877
143.5	15.609	17.257
144.0	15.566	21.623
144.5	15.386	36.110
145.0	14.952	22.941
145.5	14.066	14.902
146.0	12.326	9.816
146.5	8.892	5.353


R.F. Power Monitoring
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The Problem Solvers
Duplexers & Preselectors
Bandpass, Pass-Reject
and Notch Cavity Filters
Transmitter Combining
150 – 900 MHz

table 17. Maximized gain iteration for taper of 0.1875 with a reflector length of 40.375 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
36.500	15.571	14.823
37.625	15.600	15.964
37.750	15.592	17.662
37.875	15.526	20.356
38.000	15.369	25.303
38.125	15.051	38.017
38.250	14.392	25.944
38.375	12.946	29.015
38.500	9.932	17.654

table 18. Maximized F/B iteration for taper of 0.1875 with a reflector length of 40.625 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
37.500	15.563	15.153
37.625	15.596	16.300
37.750	15.590	17.990
37.875	15.524	20.638
38.000	15.367	25.413
38.125	15.051	39.162
38.250	14.397	27.566
38.375	12.935	20.931
38.500	9.828	17.129

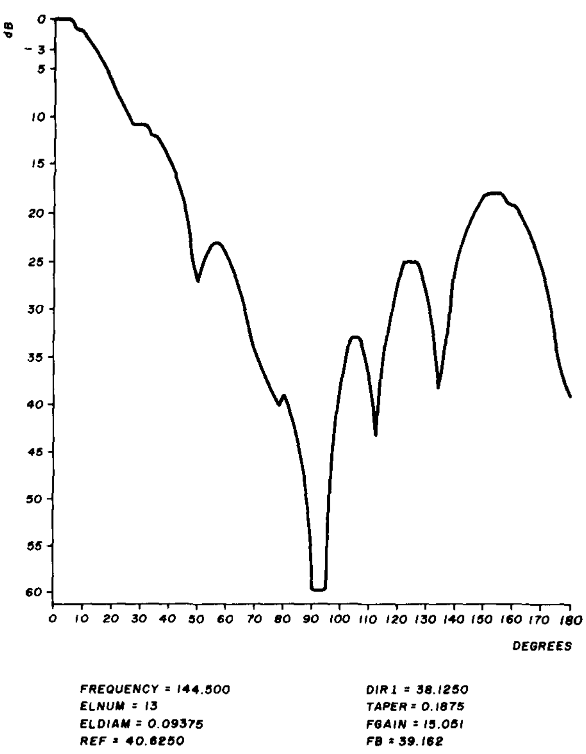

fig. 9. Plot of the 0.1875 taper, F/B optimized antenna.

tions of 15.613 dBi and 36.110 dB, respectively. These two antennas appear to be similiar because each optimized value lies directly next to an antenna with a director 1 length of 37.500 inches.

Frequency response calculations are provided for all three antennas. **Table 14** presents these calculations for the gain-optimized director length. This antenna's gain is virtually identical to its 0.0625 tapered counterpart, but its excellent F/B peak occurs far from the design frequency. **Table 15** presents the informational antenna's frequency response characteristics (**fig. 6**), which when compared to the gain optimized antenna, indicate a slightly lower gain and an excellent F/B ratio somewhat closer to the design frequency. **Table 16** presents the F/B optimized antenna's (**fig. 7**) frequency response calculations. They include a slightly lower gain than the gain optimized antenna and an excellent F/B at the design frequency and across the weak signal area. The designers' contentions for this antenna are largely supported by the computer iterations.

taper = 0.1875

This antenna, not presented by the designers, is a product of computer iteration. **Table 17** presents the gain optimized iteration for 15.600 dBi (**fig. 8**), and **table 18** presents the F/B optimized iteration for 39.162 dB (**fig. 9**). These two antennas are very dif-

table 19. Frequency response parameters for gain maximized antenna with a 0.1875 taper.

director 1 (inches)	gain (dBi)	F/B (dB)
142.5	15.389	12.283
143.0	15.458	12.861
143.5	15.520	13.608
144.0	15.571	14.602
144.5	15.600	15.964
145.0	15.590	17.904
145.5	15.517	20.841
146.0	15.342	25.865
146.5	14.994	39.126

table 20. Frequency response parameters for F/B maximized antenna with a 0.1875 taper.

frequency	gain (dBi)	F/B (dB)
142.5	15.593	15.293
143.0	15.588	16.761
143.5	15.536	20.048
144.0	15.379	25.109
144.5	15.051	39.162
145.0	14.356	28.320
145.5	12.702	21.392
146.0	8.963	14.093
146.5	2.610	4.235

table 21. Maximized gain iteration for taper of 0.25 (linear) with a reflector length of 40.625 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
37.625	15.479	14.317
37.750	15.535	14.871
37.875	15.570	15.619
38.000	15.572	16.625
38.125	15.529	17.973
38.250	15.424	19.764
38.375	15.224	22.055
38.500	14.848	24.520
38.625	14.060	25.524
38.750	12.332	22.659

table 22. Maximized F/B iteration for taper of 0.25 (linear) with a reflector length of 39.750 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
37.500	15.420	12.601
37.625	15.471	13.028
37.750	15.506	13.627
37.875	15.520	14.466
38.000	15.506	15.652
38.125	15.454	17.378
38.250	15.348	20.059
38.375	15.154	24.938
38.500	14.784	43.202
38.625	14.006	25.211
38.750	12.344	17.292

table 23. Frequency response parameters for gain maximized antenna with a 0.25 (linear) taper.

frequency	gain (dBi)	F/B (dB)
142.5	15.421	13.148
143.0	15.525	13.779
143.5	15.536	14.474
144.0	15.570	15.420
144.5	15.572	16.625
145.0	15.525	18.120
145.5	15.407	19.816
146.0	15.175	21.245
146.5	14.713	21.394

table 24. Frequency response parameters for F/B maximized antenna with a 0.25 (linear) taper.

frequency	gain (dBi)	F/B (dB)
142.5	15.405	14.944
143.0	15.383	16.913
143.5	15.308	19.852
144.0	15,141	25.027
144.5	14.784	43.202
145.0	13.993	27.017
145.5	12.251	20.323
146.0	8.938	15.485
146.5	4.032	8.960

fig. 10. Plot of the 0.25 linear taper, gain optimized antenna.

ferent antennas. **Table 19** presents the gain optimized antenna's frequency response parameters, and **table 20** does likewise for the F/B optimized antenna. Both tables reflect gain figures that have fallen from comparable 0.125 taper antennas, but optimized F/B ratios have risen slightly.

taper = 0.25 (linear)

This antenna, also not presented by the designers, is another product of computer iteration. **Table 21** presents the gain optimized iteration for 15.572 dBi (**fig. 10**), and **table 22** does likewise for the F/B optimized value of 43.202 dB (**fig. 11**). These two antennas are significantly different. **Table 23** presents the gain optimized antenna's frequency response parameters, and **table 24** does likewise for the F/B optimized antenna. Within the 2-meter weak signal area, the gain optimized 0.25 (linear) antenna is virtually identical to its 0.1875 counterpart. This is also substantially true for the F/B optimized antennas for these two tapers.

taper = 0.25 (special)

The designers specified this antenna as having the best bandwidth characteristics of the three antennas they presented. No other rationale was specifically given for the somewhat unusual tapering. **Table 25**

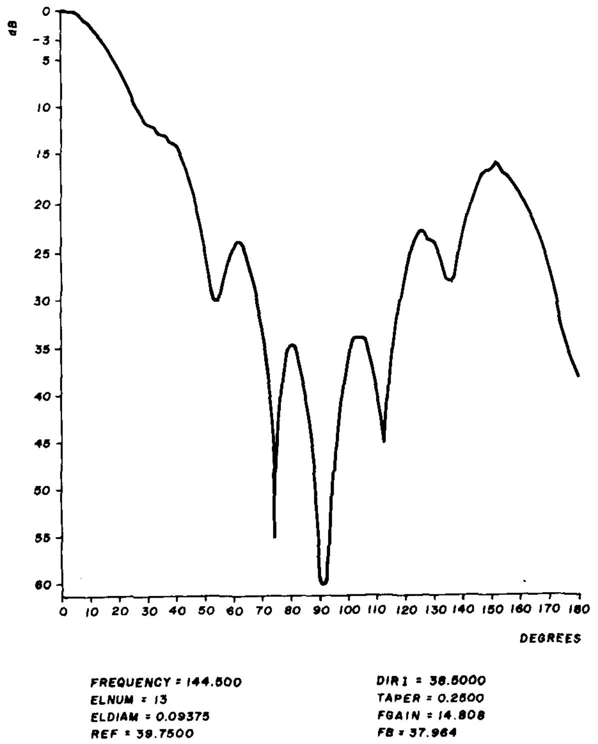

fig. 11. Plot of the 0.25 linear taper, F/B optimized antenna.

presents the gain optimized iteration for 15.573 dBi (**fig. 12**), and **table 26** does likewise for the F/B optimized iteration for 45.281 dB (**fig. 13**). **Table 27** presents the gain optimized antenna's frequency response parameters, and **table 28** does likewise for the F/B optimized antenna. When optimized for gain this antenna is quite similar to its 0.25 linear taper counterpart, but when optimized for F/B, this antenna has slightly more vectorial cancellation than its 0.25 linear taper counterpart.

computer iteration: summary

In terms of obtaining an optimized forward gain, any of the gain optimized antennas are satisfactory. The maximum calculated gain was realized with the 0.0625 taper antenna, one of the three antennas created solely by computer iteration. A very close second was the designers' 0.125 taper antenna. However, there is more to Yagi antenna selection than finding the absolute maximum forward gain among antennas that all have excellent forward gain.

A long Yagi should provide a sharp pattern for rejecting unwanted signals. This pattern should exist across the entire weak signal area. For the most part *this is not the case* with the F/B optimized antennas. With the possible exception of the zero taper Yagi, these Yagis are single frequency antennas, meaning

table 25. Maximized gain iteration for taper of 0.25 (special) with a reflector length of 40.5 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
37.500	15.524	14.331
37.625	15.564	15.021
37.750	15.573	15.963
37.875	15.540	17.252
38.000	15.446	19.024
38.125	15.261	21.456
38.250	14.913	24.637
38.375	14.200	27.554
38.500	12.619	25.724
38.625	9.461	18.102
38.750	4.606	9.264

table 26. Maximized F/B iteration for taper of 0.25 (special) with a reflector length of 40.0 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
37.500	15.527	13.709
37.625	15.555	14.421
37.750	15.556	15.420
37.875	15.518	16.836
38.000	15.423	18.905
38.125	15.239	22.129
38.250	14.894	28.033
38.375	14.194	45.281
38.500	12.676	26.475
38.625	9.693	18.000
38.750	5.115	9.767

table 27. Frequency response parameters for gain maximized antenna with a 0.25 (special) taper.

frequency	gain (dBi)	F/B (dB)
142.5	15.409	12.698
143.0	15.472	13.248
143.5	15.526	13.939
144.0	15.563	14.823
144.5	15.573	15.963
145.0	15.539	17.420
145.5	15.435	19.205
146.0	15.226	21.079
146.5	14.813	22.092

table 28. Frequency response parameters for F/B maximized antenna with a 0.25 (special) taper.

frequency	gain (dBi)	F/B (dB)
142.5	15.463	16.081
143.0	15.394	18.454
143.5	15.235	22.110
144.0	14.904	28.787
144.5	14.194	45.281
145.0	12.578	28.781
145.5	9.242	18.969
146.0	3.994	8.522
146.5	−2.248	−0.753

fig. 12. Plot of the 0.25 special taper, gain optimized antenna.

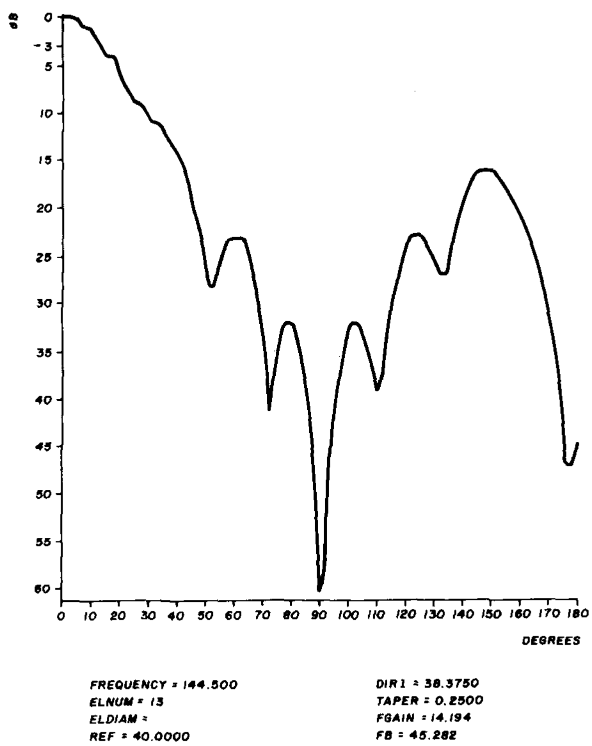

fig. 13. Plot of the 0.25 special taper, F/B optimized antenna.

their excellent F/B ratios are the result of single frequency vectorial cancellation. Their main lobes are broader and less clearly defined as compared to their gain optimized counterparts. While a high F/B is commendable, interfering or other unwanted signals do not always originate from the rear of a rotating antenna. A sharp main lobe peaks the desired signal and the Yagi's overall pattern reduces unwanted signals. For these reasons none of the F/B optimized Yagis would be the antenna of choice.

The zero, .0625, 0.125, and 0.1875 tapering procedures provided the highest optimized gains. In terms of the definition of the main lobe and the reduced amplitude of the first minor lobe, the 0.1875 gain optimized Yagi would be an antenna of choice. The calculated differences among these gain optimized Yagis are small and unlikely to be measurable in practice. While none of these Yagis has a notable F/B, their patterns are clean and have well defined nulls. The stacked Yagis at WB3BGU have a pattern similar to these single optimized Yagis. During the January 1984 VHF Sweepstakes, two important multipliers were worked in successive QSO's. One was from the front of the array (5-9), the other from the rear (5-1). A higher F/B would have resulted in the loss of the second multiplier. The array's clean pattern did noticeably reduce contest-level QRM.

Computer iteration has also helped underscore the use of even slight director tapering in long Yagis. Tapering up to approximately 0.55 degrees (0.125 inch at 144.5 MHz) appears to contribute to optimizing both gain and F/B ratios. Even when loops instead of rods are used for the reflector and driven element, a director taper of 0.125 inch (at 144.5 MHz) has been empirically found to provide maximum gain.[9]

It is also worth noting that in spite of the designers' claims to the contrary, tapered director Yagis require a longer first director than a comparable non-tapered Yagi. Arbitrarily tapering non-tapered director lengths that have been optimized for gain or F/B will result in measurably less gain and considerably less F/B. Tapering requires a distinct protocol for directors that when followed can result in a Yagi with superior performance levels.

Other problems with the designers' claims were found. Kmosko and Johnson made unusually high gain claims for their antennas. None of the iterations substantiated these claims. However, the designers do state that they never measured the actual gain of their antennas, but relied on a gain formula based on half power points. This inaccurate method always overstates forward gain. The measured gain for the NBS 3.2 wavelength antenna is 13.2 dBd. If based on the formula Kmosko and Johnson used, this same gain would be given as 15.53 dBd. It is also interesting to note that the designers stated they made careful pattern plots of what they found to be optimal designs.

It is hard to believe that a measurement as basic as actual forward gain would not have been made along with the rather tedious plots. Some of the problems attendant with reproducing the results the designers state for their antennas have also been mentioned by Reisert.[10]

An interesting comparison can be made between the NBS 3.2 wavelength Yagi and the above mentioned Kmosko-Johnson gain optimized Yagis. The NBS Yagi had a calculated forward gain of 15.20 dBi while the designers' Yagis averaged 15.60 dBi. The difference in gain is more than could be expected on the basis of the increased boom length (0.24 wavelengths). The variable parasitic element spacing used in the designers' antenna provided higher forward gain figures with a comparable minor lobe structure. The NBS Yagi provides the higher F/B, and measurably so. The 144 MHz operator concerned about F/B and desiring a shorter boom might opt for the NBS Yagi.

Computer iteration has been used to explore a large range of the larger total number of possibilities of the Kmosko-Johnson design. Selections made from among the twelve optimized antennas is a function of the user's needs and desires. There is no such thing as the single best antenna for everyone.

to be continued

The balance of this series will address individual VHF and UHF antenna designs. Next month I'll present new findings on the Greenblum antenna design approach, as illustrated by a long Yagi specifically designed for the 220 MHz band.

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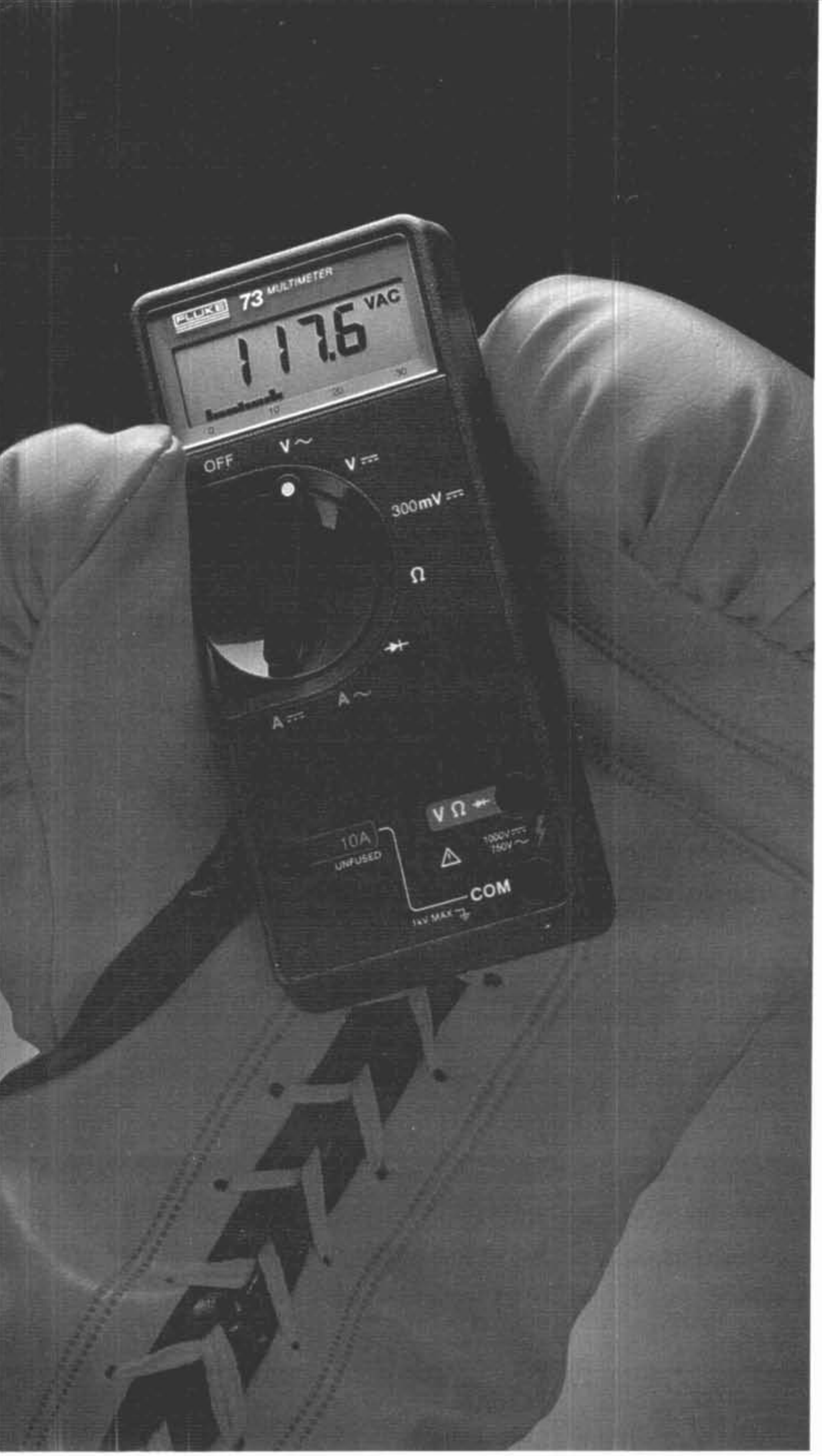

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The stretch dipole, classified as a version of the Franklin antenna by E.A. Laport of RCA,[1] offers the following advantages:

- Low angle radiation as a vertical antenna.
- Higher efficiency (because its radiation resistance is at least twice as high as a quarter-wave monopole or dipole).

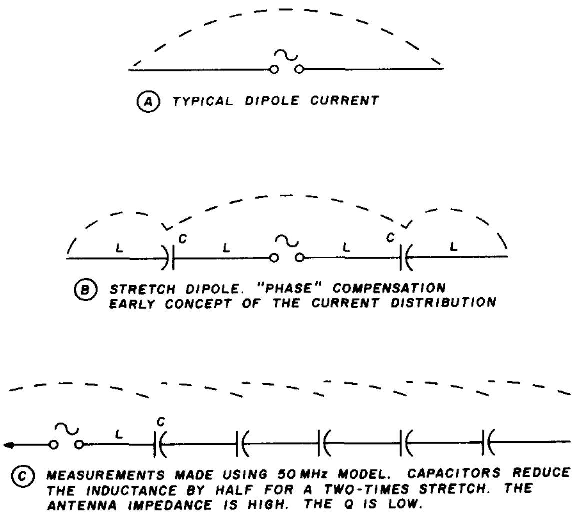

fig. 1. Examples of stretch dipoles and their respective current distributions.

- Proximity to trees, towers, downspouts, and other antennas does not affect performance unless these structures are resonant at the operating frequency.
- Shape is not too important; the stretch dipole can be bent to fit into a confining area.
- The voltage and current are low compared to a quarter or half-wave antenna fed with the same power (input).
- The bidirectional pattern (figure-eight) is narrower, corresponding to higher gain.
- Sidelobes do not exist at the design frequency, because there is no phase reversal.
- It provides wideband performance.
- Deep nulls exist off the ends.

antenna development

Forty years ago the technique of phase compensation in antennas was introduced.[1,2] Patents were applied for in both the United States and the United Kingdom. In 1960 F.J. "Dud" Charman, G6CJ, derived and tested antennas stretched to four times their normal length (**fig. 1**).[3] Recently W4FD and W4ATE produced the CCD design, which uses up to 48 sections and 46 capacitors.[4] VK5NN has built several of the twelve-section versions with a two- and three-times stretch.[5] The greater the stretch factor, the greater the gain because of the narrower figure-eight pattern.

The logic used in the design of this antenna stems from increasing the inductance of a radiator by a factor, (in my case, two), then reducing this inductance with capacitive reactance equal to half this amount. If twelve sections are used, each joined by a capacitor, each wire length is 360 degrees divided by 12, or 30 degrees long. Its inductance can be found by using published curves[2] or the formula:

$$L(\mu h) = 0.00508\,\ell\,[2.303\,\log_{10}(4\,\ell/d - 0.75)]$$

where both ℓ and d are in inches.

By David Atkins, W6VX, 130 North Westgate Avenue, Los Angeles, California 90049

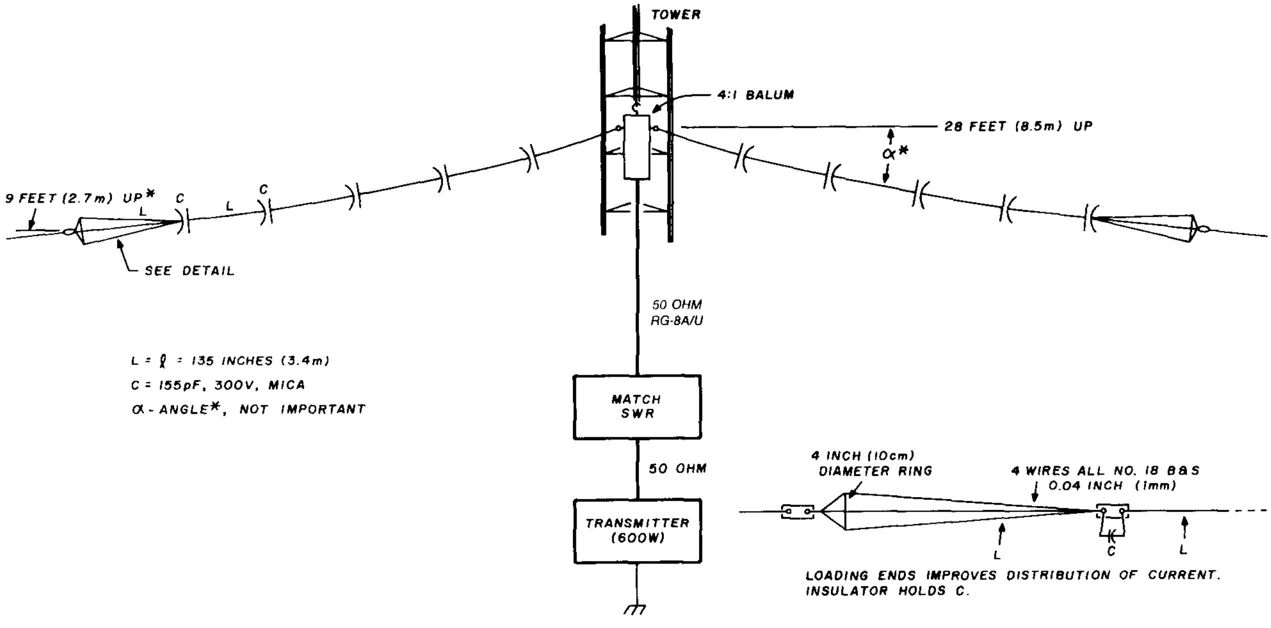

fig. 2. The 7 MHz stretch dipole measuring 132 feet in length can be supported from a tower in an inverted Vee configuration.

construction

Three different antennas were built. The first was designed for 40-meter operation at two-times stretch with an overall length of 132 feet (40.2 m) — see **fig. 2**. The second antenna, built to test the distribution of current and voltage, is also a two-times stretch dipole for operation on 6 meters. It was suspended at 6 feet (1.8 m) for convenience in measuring. (**Fig. 1C** shows the current distribution measured.) A GDO was coupled to a 300 ohm twin-lead, one wavelength feed via a 1:4 miniature balun. The current test meter used is shown in **fig. 3**. The third antenna was designed for 2-meter operation and features the same two-times stretch. Built using ceramic NPO 5 percent capacitors, this antenna is enclosed in 3/4 inch (2.5 cm) outer diameter thin-wall plastic conduit. End caps support the antenna within. A 3/4-inch "T" fitting at the center holds the third piece of conduit. An end-cap is drilled and terminals supplied for the 300 ohm twin-lead feeder, (see **fig. 4**).

For the lower frequency antennas, **fig. 5** gives values of section lengths in inches. Choose a frequency at the bottom of the graph. Where this value meets the "ℓ" line, read the wire length at the right edge of the chart. The wire size, plus or minus a size, is not critical, as the antenna is fairly wideband. Smaller diameters lower the chosen frequency slightly; No. 18 is a good choice. The capacitor values may be chosen for the same frequency by using the "C" line.

If the chosen frequency is off the graph, interpolation will give the desired values. For instance, for 144 MHz, use 14.4 MHz and divide the values by 10. For 7 MHz, use 70 and multiply by 10.

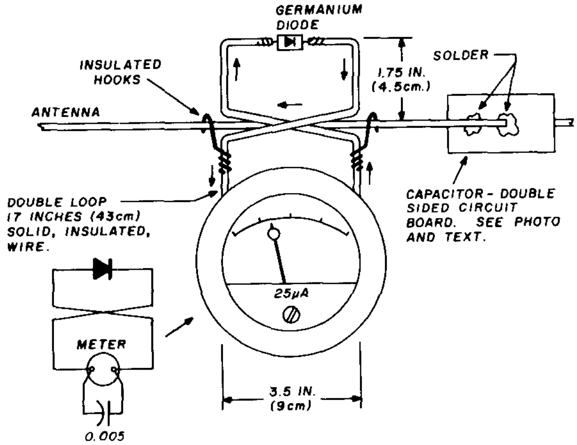

fig. 3. Current pickup used for 50 MHz measurements.

capacitors

The 40-meter full-wave dipole uses 300 volt mica capacitors. If micas are not available, double-sided circuit board makes a fine substitute. (So do the NPO ceramics.)

I measured a sheet, and it came to 18 pF per square inch. It is Polyclad-M, and 0.059-inch (1.5 mm) thick. This comes to 8.3 square inches, at 40 meters. Each piece would be, for example, 1.25 inches wide by 6.66 inches long (3.2 by 17 cm). The value should be approximately 150 pF. Measure any of this double-sided circuit board, because it can vary from type to type as much as 3 to 1. Solder the sections of wire to the center of the boards, and again just in from the narrow dimension as shown in **fig. 3**.

I weatherproofed the capacitors using a mixture of one part resin (the kind used by violinists and sold in music stores) to two parts beeswax. This clings even in hot weather. It is best to heat the mixture (over low to moderate heat) over water — preferably in the top of a double boiler — and dip the assembled junctions into the solution when the temperature reaches approximately 150 degrees F (63 degrees C). Dip each piece for 5 seconds; remove; allow to drip and cool well away from the flame or burner, and then dip it again quickly, lowering it in and pulling it out almost immediately. This builds up the coating. This weatherproofing is used on the capacitors for all three antennas.

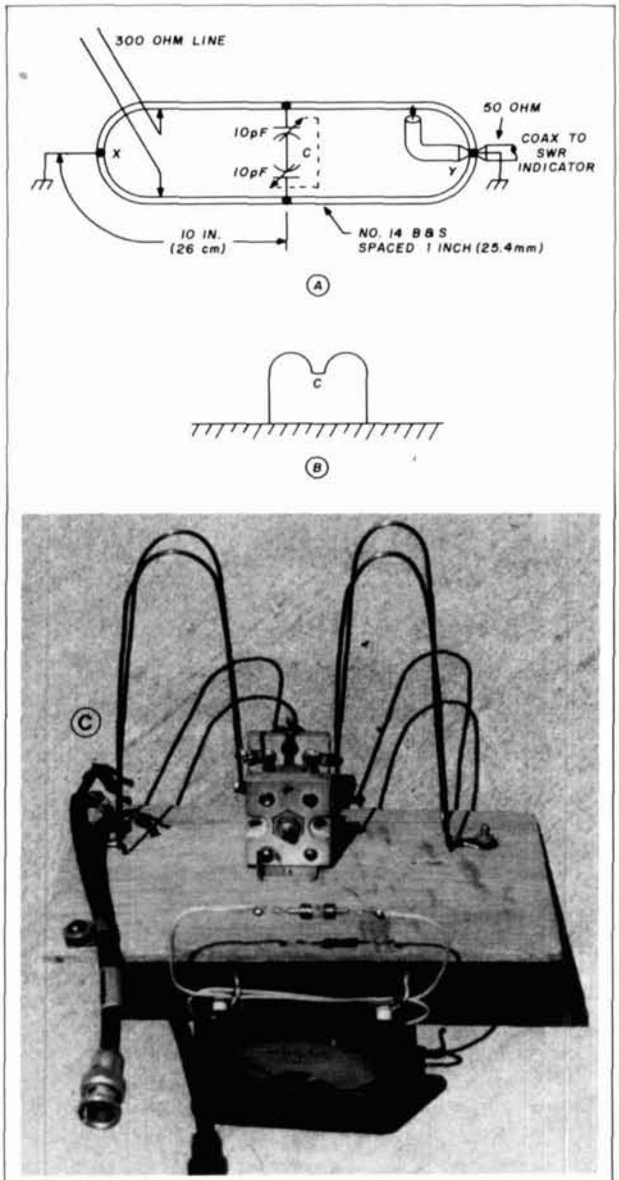

fig. 4. (A) Matching device transforms 50-ohm coaxial cable to 300-ohm open-wire feeders using a 40-inch (1.2 mm) conductor. Points X and Y are grounded and may be spaced 5 inches (13 cm) apart by bending the lines into inverted U's as illustrated in (B). The capacitor *C* is not grounded. (C) photo illustrates *U*-shaped matching device, capacitor, and current probe.

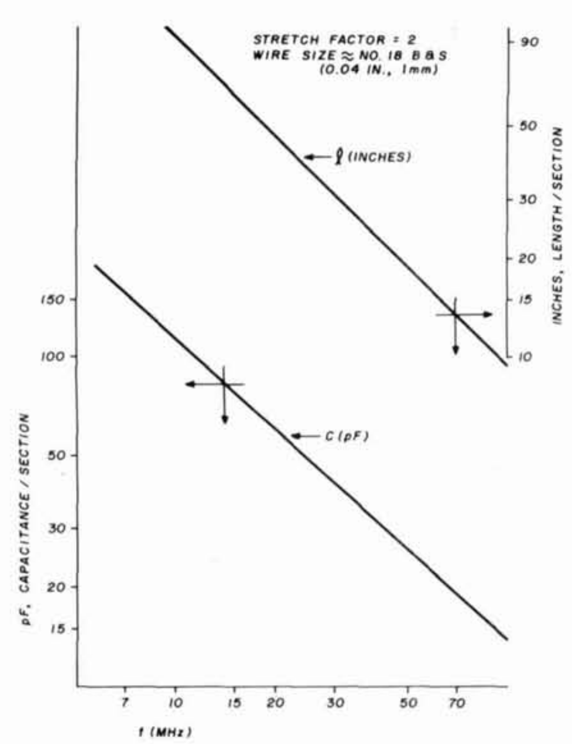

fig. 5. Chart can be used to determine section lengths and required capacitances.

conclusion

I have experimented with a version of the phase-compensated wire antenna with a stretch factor of two. This two-times factor keeps the size practical from 7 MHz upward. Half of this antenna may be used as a vertical against ground-mounted radials or a counterpoise. The feed is higher impedance, resulting in lower heat losses in both the wire and ground. End loading helps develop uniform current at the top or ends in a full-wave horizontal or vertical dipole. These antennas may be used on all frequencies above the design band. The toroidal pattern, however, changes and minor lobes develop with increased frequencies due to changes in L and C reactances. A trans-match is a necessity.

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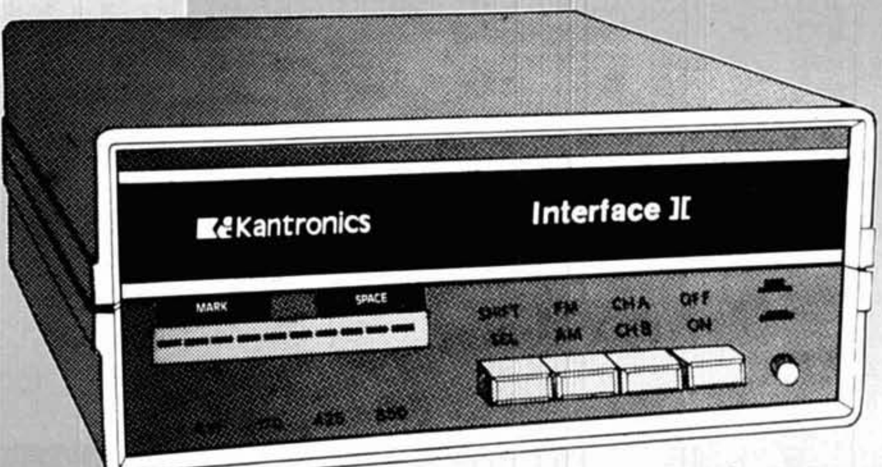

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remote-controlled 40, 80, and 160-meter vertical

70-foot irrigation pipe and switched L,C components provide 3-band coverage

A vertical antenna with an extensive ground system is effective on 40, 80, and 160 meters because it has a low angle of radiation; a horizontal antenna would have to be very high to achieve the same low radiation angle.

This article describes a vertical antenna system that I have designed, built, and tested. It operates over the entire 40, 80, and 160-meter bands and features remotely switched antenna base matching networks controlled from a simple box at the operating position.

The antenna is built from two 40-foot lengths of 4-inch diameter thin-wall irrigation pipe, available for approximately $35 per length. One length is left uncut; the other is cut into two pieces, one 30 feet long and one 10 feet long. The antenna is constructed from the 30 and 40 foot pieces joined together for a total height of 70 feet. The remaining 10-foot section is cut lengthwise, spread over the antenna sections, and clamped with four hose clamps to join the two main sections of the antenna.

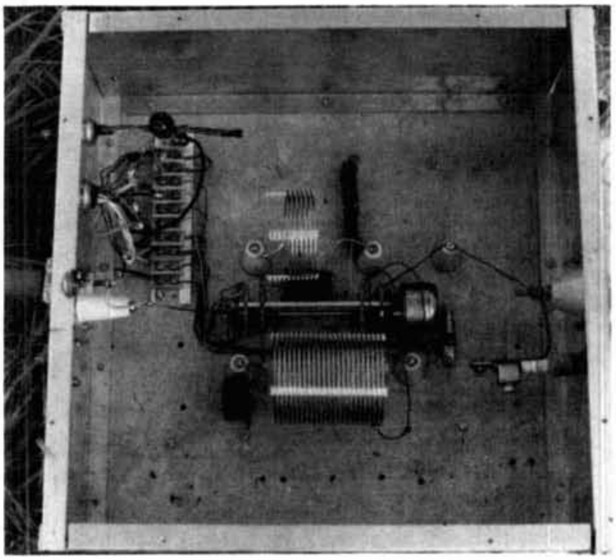

fig. 1. Large metal enclosure houses matching networks, Ledex solenoid and switch wafers while preserving high-Q of coils.

The bottom of the antenna is about a foot off the ground, bolted to a short piece of PVC pipe — positioned in the center of a 2-foot square of aluminum and sunk approximately one foot into the ground. The ends of the radial wires are bolted to the aluminum square. For efficient operation, about fifty 100-foot radial wires are used as a good ground mat. Guys are set at 10-foot intervals, with four nylon cords at each level. (S-shaped metal hooks can be used to fasten around the hose clamps and around guy thimbles, which in turn secure the nylon guys. The hook ends should be squeezed down so that they don't come loose from either the clamps or the thimbles. Black plastic tape wrapped around the nylon guy knots helps prevent the knots from working loose.)

installation

The antenna is light but quite flexible, so be sure to erect it on a calm day, with plenty of helpers. For safety's sake, check for nearby power lines that could be hit if the antenna gets away from you. I used a husky helper pulling a rope threaded through a pulley near the top of a temporary 25-foot mast to help raise the antenna. Another helper pushed from below (a temporary light A-frame might help here), and several helpers held nylon guys to prevent side sway. A bolt through the PVC pipe and near the bottom of the antenna provides a pivot point; I put a 2-foot piece of round wooden fence post inside the bottom of the antenna so that tightening the bolts there wouldn't squash the tubing.

matching networks

The 70-foot length of antenna is close to a quarter wavelength on 80 meters, about one-eighth wavelength on 160 meters, and about a half wavelength on 40 meters. It is therefore necessary to use matching networks at the base of the antenna on all three bands. The networks are remotely switched from the shack

By Robert Leo, W7LR, 6790 South Third Road, Bozeman, Montana 59715

by *means* of a Ledex solenoid that turns a wafer switch, moving the shaft one position — a 45-degree rotation for each pulse. The switch wafers connect any one of the three networks and provide position information to illuminate appropriate indicator lamps in the shack. The five positions required by the three switch wafers coincide with the Ledex rotation positions.

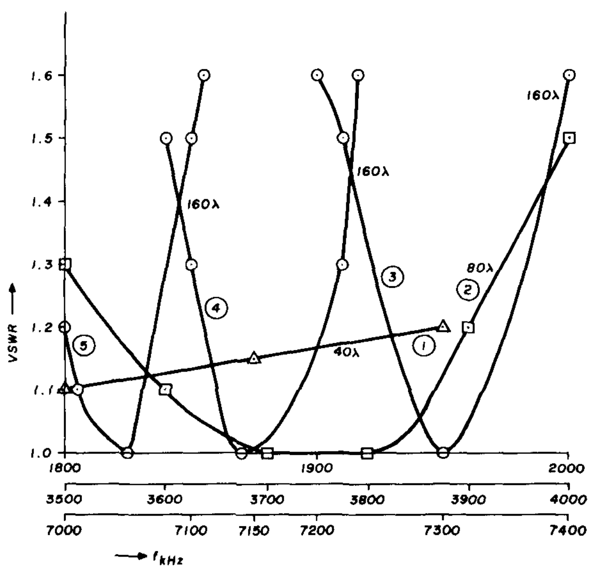

fig. 2. Five separate VSWR plots versus frequency of the 70-foot vertical and matching networks are illustrated with "1" for 40 meters, "2" for 80 meters, and "3" through "5" for the 160-meter band. Notice how flat both the 40 and 80-meter curves are.

The fixed component networks for 40 and 80 allow the antenna to be used over those entire bands without retuning and with a low VSWR. For 160 meters, the same kind of network is used over the entire band, but requires three coil taps that must be switched in to maintain low VSWRs for that band. The five switch positions are used as follows: one for 40, one for 80, and three for 160. In order to design the matching networks, it is necessary to obtain an estimate of the antenna base impedance for each band from handbook charts. The 70-foot antenna is inductive over the 80-meter band, with the resistive part of the impedance close to 50 ohms. It can be matched over the entire 80-meter band with nothing more than a series capacitor. For 40 and 160 meters, L networks are necessary.

I used a Smith chart to plot the antenna base impedance for the 80-meter band; that plot showed high VSWR at the high end of the band. Using a series capacitor changed the impedance plot so that the VSWR was always less than 2.0:1 over the entire band. Selection of the optimum size of series capacitor for these

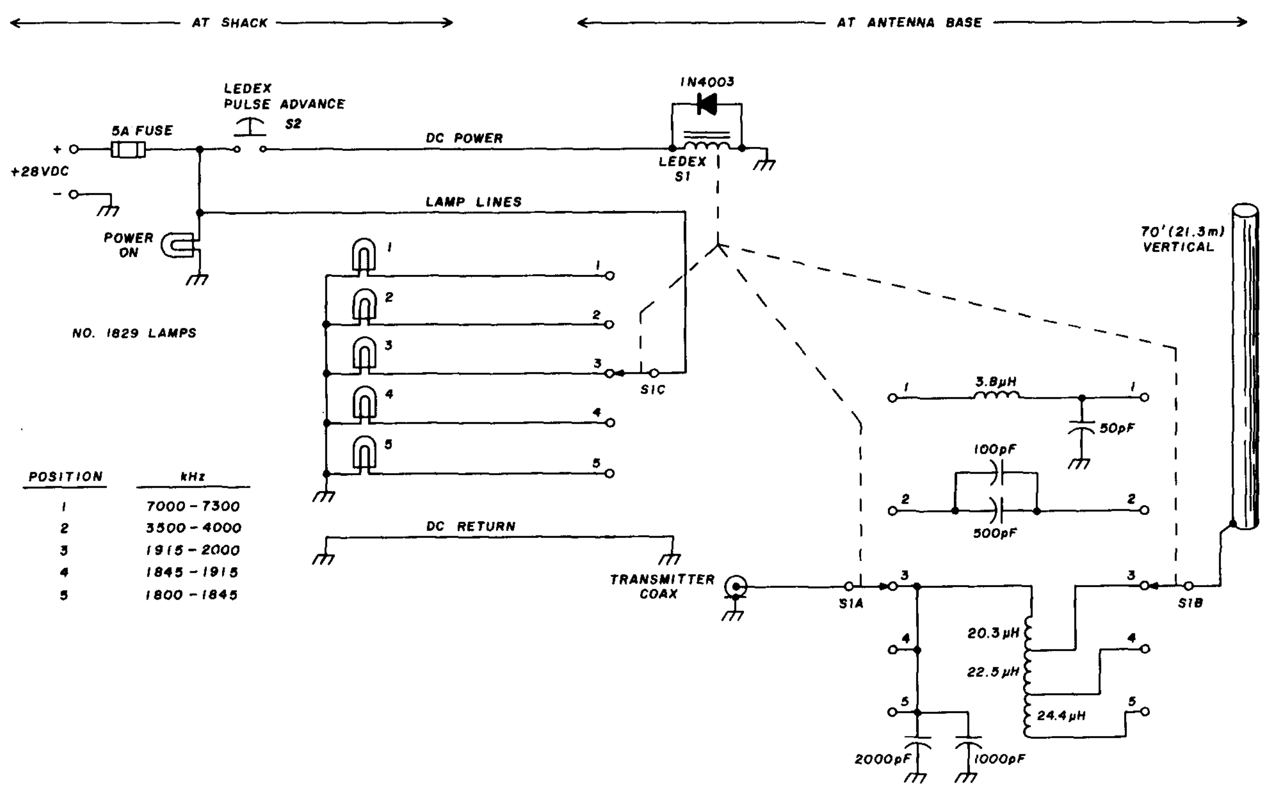

fig. 3. Schematic of control and RF circuit wiring.

Smith chart plots to give the least band edge VSWR provided an estimate of what size capacitor should be tried at the antenna base during field tests. Both the plots and the field tests showed that 600 pF was optimum. The 40 and 160-meter L networks were designed using standard handbook information.

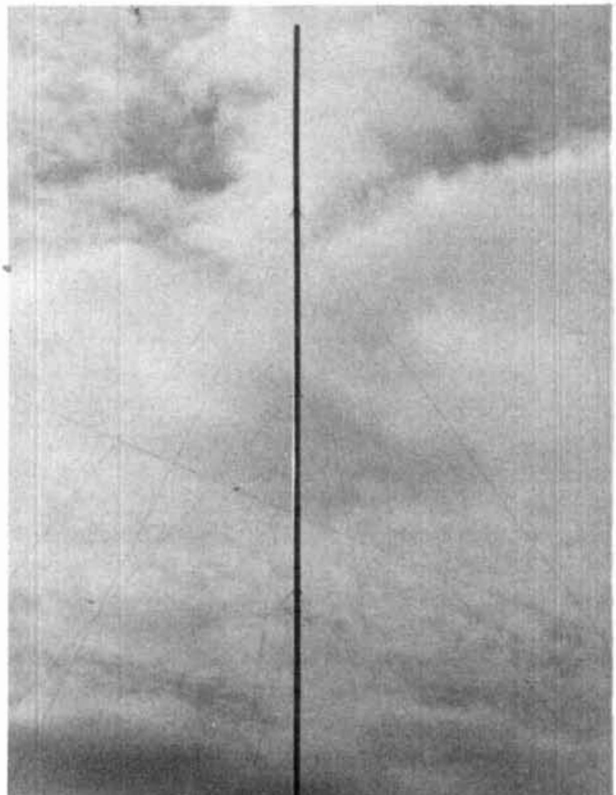

fig. 4. Four-inch irrigation pipe provides good mechanical and electrical performance for the 70-foot vertical.

network values

To refine the network values, I built a test network for each band and then tuned or changed each one for minimum VSWR over each band at the base of the antenna, using a small exciter and a VSWR meter. Next I measured the network component values and then built the final networks.

I made a final check of the VSWR at the base of the antenna using these final networks, and found that some pruning was still necessary. The tap locations on the 160-meter coil are quite critical. On my coil the tap for the 1800 to 1845 kHz segment was at the very end of the coil; the 1845 to 1915 kHz tap was about 1-1/2 turns from the end; and the 1915 to 2000 kHz tap was about 3 turns from the end. As **fig. 1** shows, a large metal enclosure houses the networks, Ledex, and switch. This box helps preserve the high *Q* of the coils by keeping metal surfaces some distance from the coils and also preserves essentially the same tuning for the L networks regardless of whether the box cover is on or off, so that you can tune with the cover off and still have the same tuning when the cover is replaced. As shown in the handbooks, the VSWR is lower back in the shack than out at the antenna, and in my case I find that for a 200-foot length of coax between antenna and shack, the maximum

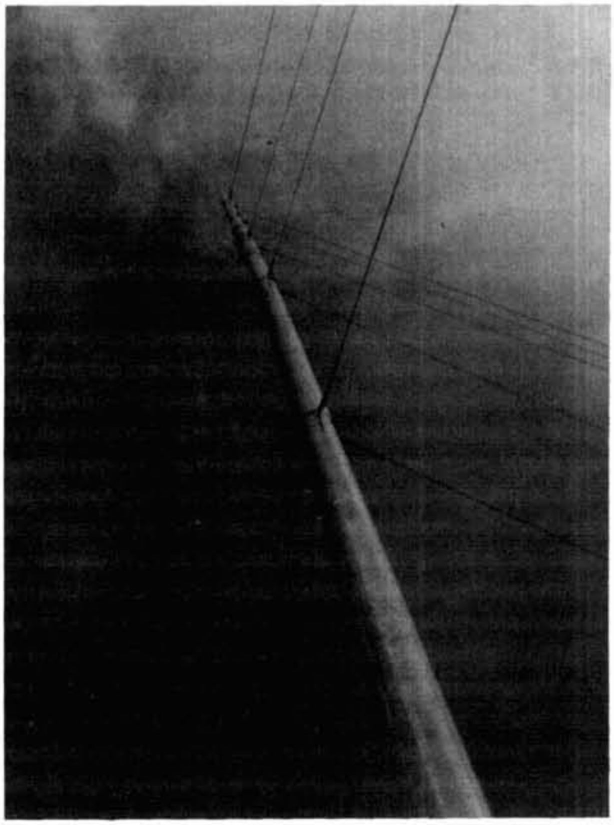

fig. 5. Six separate sets of four guy wires are fastened to the vertical at 10 foot intervals using S-shaped metal hooks and hose clamps.

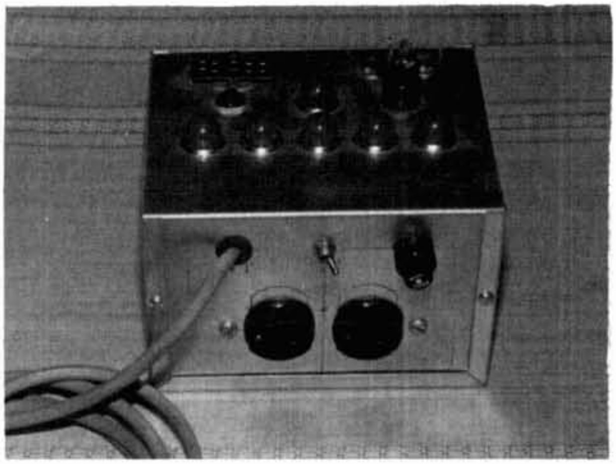

fig. 6. Simple control box allows for almost instantaneous no-tune band change.

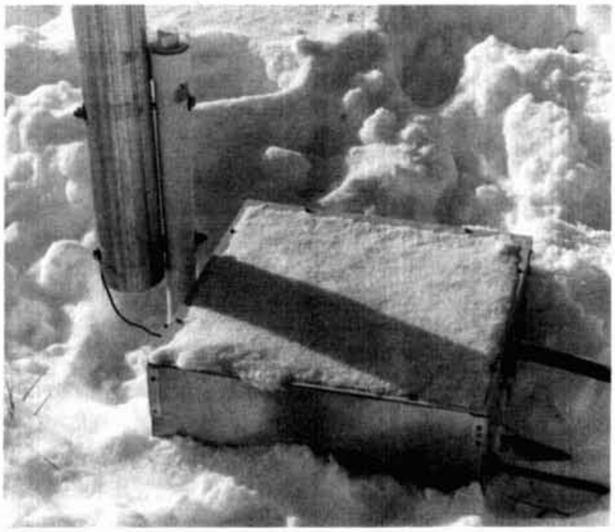

fig. 7. The remote control box should be located as close as possible to the base of the vertical.

VSWR at the shack is 1.6:1, as shown in **fig. 2.** I used surplus RG-17 coax cable to reduce losses over such a distance.

Fig. 3 provides the schematic of the networks and control system. **Fig. 4** shows the 70-foot vertical from a distance, while **fig. 5** is a view of the antenna from below. **Fig. 6** shows the control box, **fig. 7** the antenna base.

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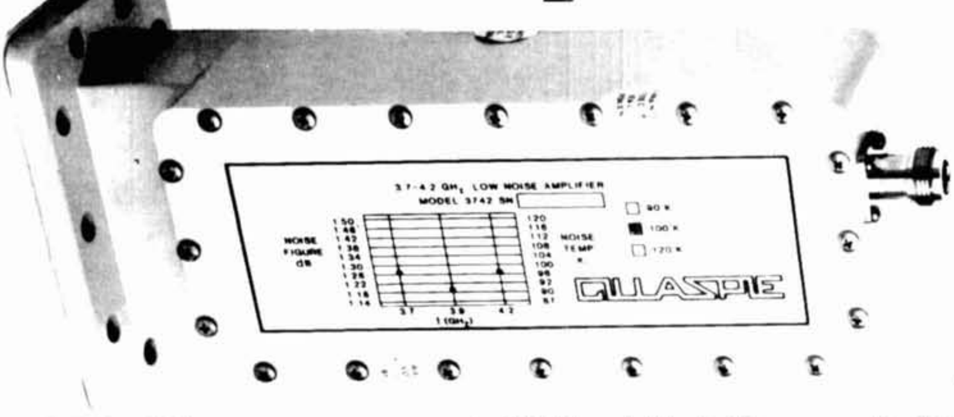

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vertical phased arrays: part 6

Building the array and measuring performance

In this final article of my series on vertical phased arrays I will discuss some of the practical aspects of putting up an array — how to build it, how to construct networks, and how to take measurements. I will also address a few questions readers have raised about my previous articles.

siting elements: with respect to the world

Situating elements by eye can be deceiving. Having said this, I am absolutely certain that some will try it, nevertheless. Hopefully, you will discover any errors before a large radial ground system has been installed. Unlike adjusting the elements of a rotatable Yagi, adjusting the spacing of a ground-mounted vertical phased array is a major undertaking that may require several weeks of effort. If you know the variation from true north that your magnetic compass tells you is north, fine. Otherwise, the best way is to line up with the north star, Polaris. This star is easy to locate; the outer two stars outlining the dipper of the Big Dipper form a pointer to Polaris. I have a 4-square array whose major lobes are turned off of the desired directions because I failed to determine the local magnetic variation. Sources for this information include your local airport, any office of the FAA, or persons associated with private aviation. Determine whether the variation is east or west. Generally, this variation will be *west* for those located east of a line running through Chicago and Miami and *east* if located west of that line. For example, at New York City the variation is approximately 12 degrees west. This means that true north for a magnetic compass pointing at north is 12 degrees rotated clockwise toward the east. This variation from true north slowly changes with time; if your information is more than 10 years old, find a more recent source.

Since most of these arrays have half-power beam widths of 90 degrees or more, why be so concerned over a few degrees? For forward gain small errors in pointing do not matter much; we are more interested in the directions in which the beam should *not* be pointing. Just as with Yagis, it is far easier to determine the *direction of nulls* than maxima. This is important diagnostic information: to the extent that these are in the directions and reduced with respect to forward gain as predicted, we have a reliable validation of the design.

siting elements: within the array

Accurately locating the elements of an array, particularly if they are not to be in line, isn't as easy as it might appear. Getting the correct angles is the problem. Euclid had the right idea; three points not in a straight line uniquely define any triangle. Using wire with little or no stretch (steel or aluminum fence wire is excellent), carefully measure out three lengths, each equal to a side of any triangle that outlines all or part of your array. Join the ends, and with two helpers, pull the wires taut, you'll have three points accurately located with respect to each other. If your array is triangular, you're all set. If it's a 4-square, you have only to locate the fourth element with the same wire triangle by turning it over on its diagonal. Triple-check

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table 1. Single 80-meter element tubing requirements.

quantity	length		diameter		wall		cumulative height	
3	10′	(3.05 m)	1-1/2″	(3.81 cm)	0.125″	(3.18 mm)	30′	(9.14 m)
1	10′	(3.05 m)	1-1/4″	(3.18 cm)	0.125″	(3.18 mm)	39′4-1/2″	(12.00 m)
1	8′	(2.44 m)	1″	(2.54 cm)	0.057″	(1.45 mm)	46′8″	(14.22 m)
1	8′	(2.44 m)	7/8″	(2.22 cm)	0.057″	(1.45 mm)	54′2″	(16.51 m)
1	8′	(2.44 m)	3/4″	(1.91 cm)	0.049″	(1.24 mm)	61′8″	(18.80 m)
1	4′	(1.22 m)	1/2″	(1.27 cm)	0.049″	(1.24 mm)	63′6″	(19.35 m)

Additional material requirements for a single element.

2	15″	(0.38 m)	1-1/4″	(3.18 cm)	0.125″	(3.18 mm)	mating inserts
1	24″	(0.61 m)	1-1/4″	(3.18 cm)	0.125″	(3.18 mm)	extender
1	18″	(0.46 m)	7/8″	(2.22 cm)	0.049″	(1.24 mm)	reinforcement
7	S.S. helical hose clamps approximately 2 inches (5.08 cm) OD						
9	S.S. 1/4″ - 20 1/2″ screws						
8	S.S. 8-32 1/2″ screws						
1	0.250″ (6.36 mm) female quick disconnect terminal						
1	0.250″ (6.36 mm) male quick disconnect terminal						
1	SO-238 UHF female terminal						
12″ (30.5 cm) flat tinned copper braid							
500′ (152.4 m) 1/8″ (3.18 mm) nylon woven cord							
7800′ (2377 m) PVC insulated No. 24 solid copper wire (100 0.3 wavelength radials)							

everything to be sure, because array element layout is one of the few *physical* items under your complete control among the factors determining array symmetry. In prior articles I showed that electronic beam switching requires every element to operate *identically* in each of the *different* electrical positions of the array. This is a severe requirement; the best we can hope for is to get within 5 percent of meeting it, realizing that reaching within 10 percent results in a significant loss in F/B performance.

For those who may want to check array patterns, I have observed that reception of a 1-watt signal source located between a 1/4 to 1-mile distance is consistent with the pattern that is seen at the vertical angle of maximum radiation (but without QSB). However, at 20 miles this is no longer true because high vertical angle reflections predominate, sometimes so strongly that a positive F/B is seen.

monopole construction

After much experimentation with a variety of ways to put together tubular quarter-wave length ground-mounted 80-meter vertical elements, I hit upon a method of construction which has held up for over six years. It's relatively inexpensive, but has withstood the rigors of northeastern winters, including icing followed by 80 MPH winds. After failures with lighter designs I decided that, at least for 80 meters, any tubular construction must be able to withstand being raised in one piece. If a vertical can withstand such stress, then it should also be able to survive high winds, icing, and even the temporary loss of one or two of its nine guys.

Table 1 lists dimensions of aluminum tubing that, when assembled into a quarter-wave element, will meet this criterion. Included with the table is a complete list of materials for a single element. If care is taken not to raise the antenna abruptly, it will stand tall and straight — despite all appearances to the contrary — as it is brought upright.

All tubing will telescope into its next larger diameter mating member except the lower 1 1/2 inch (3.81 cm) diameter lengths. For two of these lengths, a 15-inch (38.1 cm) section of 1 1/4 inch (3.18 cm) diameter 0.125 inch (3.18 mm) wall tubing is bolted (using three 1/4 - 20 screws) at one end with 7 1/2 inches (19.05 cm) protruding, forming a mating junction with the next lower identical diameter tubing. The 1-inch (2.54 cm) diameter length of tubing requires a 15-inch (38.1 cm) length of 7/8 inch (2.22 cm) diameter tubing to be inserted for its entire length at the lower end to act as reinforcement because of the abrupt change in wall thickness at this junction. All lighter tubing is drilled and tapped for stainless steel 8-32 screws at two places spaced about 5 inches (12.7 cm) apart, at junctions. This is necessary to prevent the development of intermittent continuity after a few months due to wind vibration. The tubing, having little weight in this part of the vertical, cannot be depended upon to maintain good contact by gravity.

This element will resonate at approximately 3800 kHz. Inevitably, multiple elements will not resonate at precisely the same frequency even though they are identical in physical length. For exact matching of resonant frequencies, a 2 foot (61 cm) length of the 1 1/4 inch (3.18 cm) diameter 0.125 inch (3.18 mm) wall tubing is used at the bottom of the vertical. This piece has tapped holes every 2 inches (5 cm) for a stainless steel 1/4 inch-20 screw, which determines the amount of its length that can be inserted into the bottom of the vertical. This may be adjusted as measurements dictate.

Flat braid [approximately 12 inches (30.5 cm)] is doubled, a 0.250 inch (6.36 mm) female quick disconnect terminal soldered at one end, and clamped to the bottom of the vertical with a helical hose clamp. I wrap PVC electrical tape around this to keep the doubled braid together. This makes a flexible, low inductance connection to the feeder. The coax termination is an SO-238 UHF female connector to which is soldered a male 0.250 inch (6.36 mm) quick disconnect terminal. The reason for these terminals will become quite obvious as measurements begin.

Glass bottles, corked to prevent accumulation of rain, may be used as standoff insulators for the verticals, since the necks happen to fit within the element base.

guy wires

Three sets of three guys, one set every 16 feet (4.88 m) from the base, are connected by two hose clamps at each attachment point. One clamp acts as a backstop for the clamp immediately above it, which clamps around the nylon guys. The nylon guy ends are tied with their own guy and also with one of the adjacent guys as additional insurance (falling tree branches can tear away the first tie but the fall, once arrested, seldom takes out the second tie). The attachment areas are waterproofed with PVC tape.

An element is raised by threading one of the three middle guys (usually made longer than those adjacent, specifically for this purpose) through a pulley which may be as low as 35 feet (10.7 m) from the ground. Since my array is among trees, I chose one to serve as a ginpole — which, of course, requires a real ginpole if you have no trees. Identify all guys with their ground anchor location, and lay them out so that no crossovers will be necessary later. During raising, the two remaining middle guys should be controlled by helpers to restrain the element from moving to the right or left, and as it arrives near the vertical position, to restrain it from continuing in the direction of the raising pulley. Don't forget to instruct your helpers in this latter point; more than one vertical has been successfully raised, only to continue unrestrained on its path to an inglorious end as it passes the upright position!

I've found that 1/8 inch (3 mm) diameter white woven nylon cord (sometimes called parachute shroud) is an economical, strong, long life material for guy stays. This is available at K-Mart stores in 50- and 100-foot (15 and 30 meter) lengths. I have some still in use after six years. The same cannot be said for polypropylene rope. Even 1/4 inch (6 mm) UV resistant material will fail in just two years.

radial systems

Installing radial systems is the dog work of building a low band array. It is also where the payoff — which too few Amateurs collect — is. There are two benefits to be gained with an extensive radial system: low losses and, more importantly, a low vertical radiation angle. But there's no free lunch: forget the loose talk you've heard on the bands about the benefit of water tables a foot below the surface, or being located over high conductivity earth. Pure water is a very good insulator, and most fresh water is too. And "high earth conductivity" is relative; it is *very* poor compared to the conductivity of copper. (For a perspective, see **table 2.**) Metal stakes in the ground at the base of your vertical give you good lightning protection, but *not* a good ground plane. Nor are there any rediscovered long-lost shortcuts; forty-eight radials raised a few feet above the ground won't provide any more efficiency than the same number on the ground. Undoubtedly, the best of all worlds would be an island surrounded by seawater, but for the near-field we'd *still* want an extensive copper radial system.

table 2. Conductivity comparisons.[1]

low conductivity earth	0.0005	mho/meter
high conductivity earth	0.03	mho/meter
sea water	5.00	mho/meter
copper	58,000,000.00	mho/meter

The best indicator of a good ground plane is how close the resistive component of the radiator's apparent self-impedance is to its theoretical resistance. The factors affecting theoretical radiation resistance are the electrical length and effective radius of the element, assuming a uniform cross-section monopole. Top hats, loading coils, and other means of shortening are also amenable to calculation, though the mathematics in some cases is more complicated.[2] For quarter-wave radiators this value is approximately 36 ohms.

In practice, there's another way to make this determination for any radiator without knowing the theoretical radiation resistance. It is the kind of analysis we usually wind up doing anyhow. Lay out radials, say ten at a time, distributed equally in all directions, taking measurements of the radiator's apparent self-impedance for each group of added radials. Plot these points on a graph as in **fig. 1** (open circuit any other elements of the array to avoid coupling). You will find that each lot of radials has less effect upon radiation

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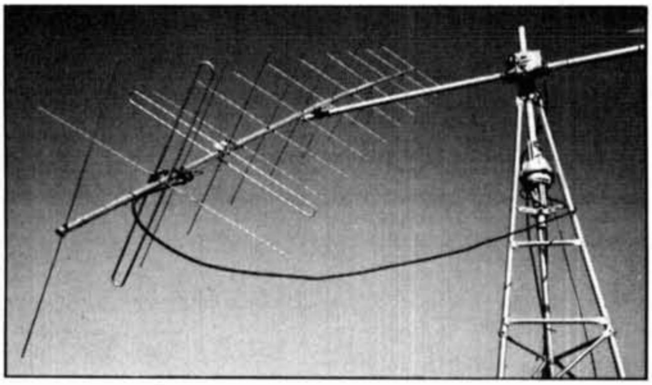
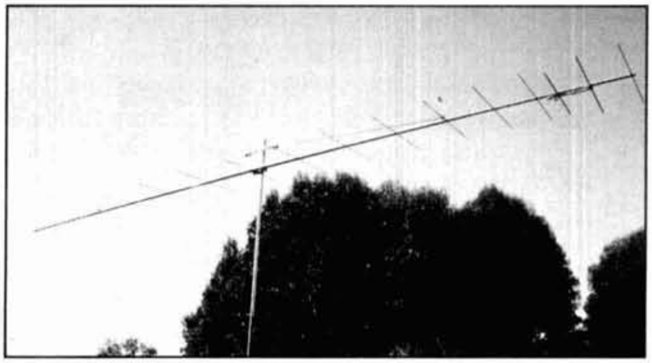
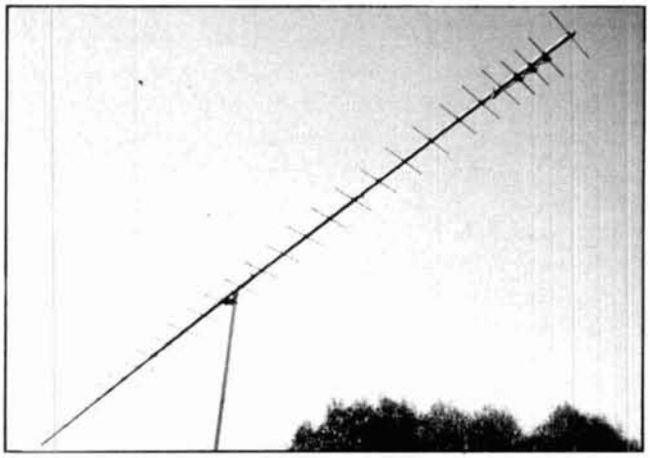


BANDWIDTH	144–148 MHz
GAIN	13 dBd
BEAMWIDTH	34°
FEED IMP	50 ohms unbal.
BALUN	(2) 4:1 coax
BOOM LENGTH	19 ft. 1 in. (tapered)
VSWR	1.5:1
WINDLOAD	1.85 sq. ft.
ELLIPTICITY	3 dB max.
CIRCULARITY SWITCHER	CS-3 included
WT. (lbs.)	11 lbs.



BANDWIDTH	143–146 MHZ
GAIN	(144 MHz) 14.8 dBdc
BEAMWIDTH	(V) 28°, (H) 33°
FEED IMP	50 ohms unbal.
BALUN	4:1 RG303, Teflon
BOOM LENGTH	28 ft. 1 in. (tapered)
VSWR	1.4:1
WINDLOAD	(H) 1.75 sq. ft. (V) 2.44 sq. ft.
WT. (lbs.)	10 lbs.
TURNING RADIUS	15 ft. 6 in.



432-30LBX

BANDWIDTH	430–440 MHz
GAIN	17.3 dBd
BEAMWIDTH	20°
FEED IMP	50 ohms unbal.
BALUN	included
BOOM LENGTH	21 ft. 9 in.
F/B	20 dB
F/S	35 dB
VSWR	1.5:1
WINDLOAD	1.43 sq. ft. (typical)
TURNING RADIUS	12 ft. 5 in.
WT. (lbs.)	9 lbs.

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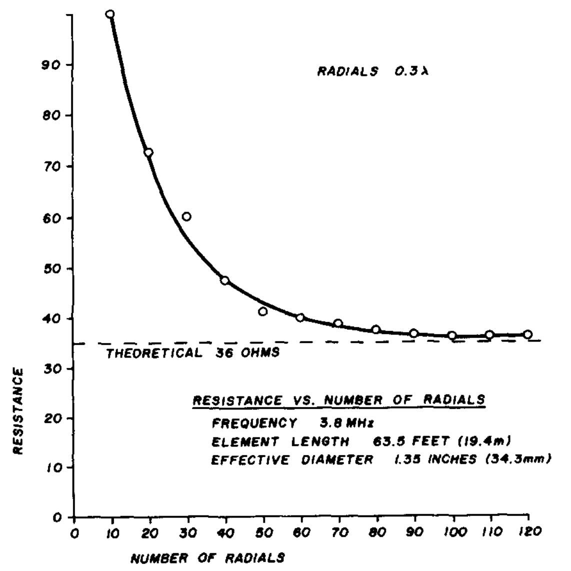


fig. 1. Input resistance of vertical antenna (includes all losses) versus number of radials.

resistance than the previous lot. Assuming radial lengths of a quarter-wave or more, after about 100 radials, the reduction in resistance with each added lot of radials is almost constant, but becomes vanishingly small (approximately 0.1 ohm). You'll notice that the curve on your graph has begun to flatten out; if you fit a French curve to this plot, you'll see that the plotted curve will nearly meet some horizontal line. In scientific terms, this is described as having become *asymptotic* with the theoretical resistance of the radiator; the horizontal line is a prediction of that theoretical value. (I am assuming negligible radiator element circuit losses. This is a fairly safe assumption for aluminum monopoles, but less safe if loading coils are present. More rigorously, the plot is becoming asymptotic with theoretical radiation resistance *plus* radiator circuit resistance.) Put another way, you've reached the point of diminishing returns. Although that point is self-definable, most experimenters would agree that it begins at the knee of that curve — i.e., at about *50* quarter-wave radials.

An aside to single vertical users accustomed to rating an antenna's merits according to VSWR readings: don't misinterpret an increase in VSWR as a negative indication when adding radials. Assuming VSWR is 1:1 with 50-ohm coax to a quarter-wave vertical, an appreciable ratio of output power (approximately 28 percent) is being used to heat the ground around the radiator. A higher VSWR after adding radials is desirable.

How should the radials be laid? This depends upon your personal aesthetics and also upon how the area occupied by the array is used. If you need to bury the radials (see "Build a Simple Wire Plow," page 107 — **Editor**), some form of protection against corrosion, such as PVC insulation or enamel coating, is necessary. Don't bury them too deeply; the closer radials are to the surface, the more effective they are. Some Amateurs have laid them flat on the surface and let grass cover them so well that limited traffic and even lawnmowers can be allowed.

What about wire size? I often hear people talk about laying No. 6 or No. 8 BS gauge radials. Unless you have to protect your system from farm animal traffic, this is calling for a hawser when thread will do. Consider: 1000 watts output to a single vertical with 25 radials (and assuming an apparent radiation resistance of 50 ohms). Each radial will be carrying all of 179 milliamperes, and *that* only near the base of the vertical.[3] Given a reasonable number of radials, a base current measured in amperes is divided into individual radial currents of milliamperes, and even this small current rapidly decreases as we move away from the base of the radiator. In the absence of concern about possible fragility, the wire size may be quite small.

Many articles in Amateur publications have suggested using steel fence wire or steel mesh as an economical substitute for copper. *Don't.* Unless the material has cost you nothing, and your labor is worth nothing, and you plan to abandon the antenna in less than a year, forget it. In just a matter of months, galvanizing — if present at all — is penetrated and corrosion proceeds. Steel, being magnetic, has a high permeability, making for a skin effect much thinner than copper when carrying RF current. Iron oxides are lossy semi-conductors. The thin skin effect, combined with a lossy surface, results in a wire which conducts *nearly zero* RF current long before it fails to conduct DC or has lost physical integrity — which takes only about three years after installation, and much less time if the system is buried. My first radial system consisted of a combination of aluminum, steel, and copper radials. It took a couple of years to solve the mystery of a slow but continually rising self-impedance of some of the elements in the array. In my efforts to overcome this rise, I compounded the mystery by adding more radials, which at first were — *more steel radials!*

array operation measurements

So you've constructed an array. Now you'd like to see how well it works. On-the-air tests are understandably at the top of your list. Unfortunately, this is not likely to be a good proof test of proper drive conditions, primarily because these arrays *want* to work and may show fair performance despite being poorly driven. This is almost always true for gain characteristics, and during some propagation conditions may even apply to F/B. So continue these tests, but give some thought to an old antenna man's advice, said to have been first enunciated during the period of Maunder's Minimum: "One swallowe prouveth not that summer is neare."*

A much more definitive test is a measurement of element currents in each of the array directions. Assuming you have designed the feed network for a 1:1 VSWR, then element base current amplitudes measured within ±5 percent of design values and an array VSWR *no greater* than 1.15:1 in any direction is almost complete proof that drive is in the proper range, including current phase angles. Measurement of element current amplitude *and* phase is, of course, the ultimate test for drive conditons. A wideband dual-trace CRT is needed for this test, and since this equipment is quite expensive, may be beyond the reach of most Amateurs unless it can be borrowed. On the chance you have access to this equipment, a method is described in the next section of this article.

Measurement of current amplitude, a must for any serious array builder, is quite easy to do. At the lower frequencies a high degree of absolute accuracy is not difficult to achieve, but good linearity is really all that is necessary. For example, if actual current is doubled (power multiplied by 4), does the reading double? For this purpose the meter readings might just as well go from 1 ampere to 2 amperes, or 400 mA to 800 mA; we are more interested in good linearity of readings than in absolute value because phased array design considerations are concerned only with element current amplitude ratios.

Fig. 2 shows a schematic of an RF ammeter (**photo 1**). The basic meter movement may be anything up to 1 milliampere. I use germanium diodes for the rectifier because of their low turn-on voltage. This simple design works well for absolute accuracy and linearity up to 14 MHz. Low capacitance of the pickup coil to RF line is important and is increasingly so as frequency is raised. For this reason we want a high permeability factor for the toroidal core (for least number of coil turns). A Faraday shield will provide even more isolation, but this additional protection is not necessary at lower frequencies.

Since this ammeter is easy to duplicate, you may find it useful to have one for each element of the array because the efficiency of data collection is considerably improved. Note the use of quick disconnects for element terminals and associated measurement devices.

*From 1645 to 1715 there were no observable sunspots, and no Northern Lights. (Imagine a 70-year period in which the 10-meter band never opens and the 20-meter band is only so-so during the day, and dead at night!) A British astronomer, E.W. Maunder, in 1895, was the first to call attention to this strange behavior of the sun.

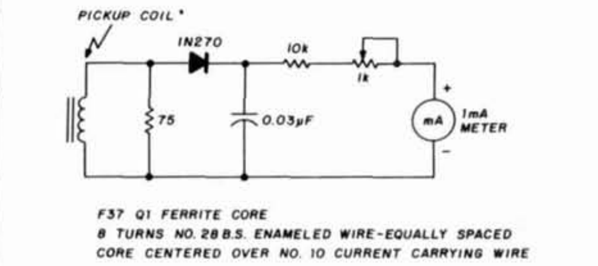
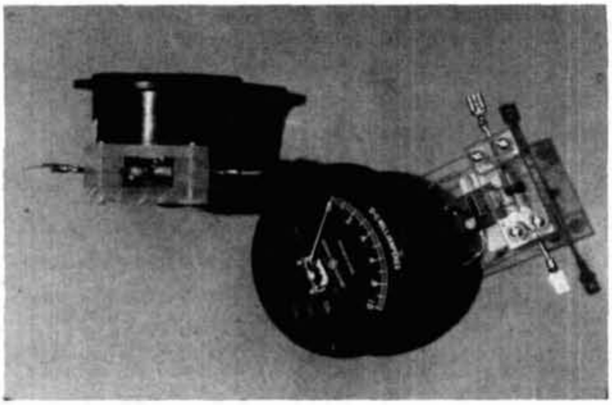


fig. 2. RF current probe circuit midscale reading corresponds to 1 ampere.



Solidly constructed RF ammeter uses quick connect/disconnect terminals.

dual-trace CRT measurements

Measurement of RF current phase angles involves an instantaneous comparison of sinusoidal currents at the bases of the elements. Since the elements are widely separated physically (and distance is proportional to phase), we must take special precautions to be sure we are really observing events in time coincidence. One way is to make these observations at another location of our own choosing in such a manner that all events have been equally delayed. Though we will see events at some time later than they occurred, they will be in time coincidence. Identical coax lines will meet this requirement nicely. Obviously the pickup coils for sampling base currents also must be alike, with the further proviso that the terminations of these lines must be alike, resistive, and match the characteristic impedance of the lines. (Most dual-trace CRTs provide 50-ohm inputs.) The line length chosen should be long enough to allow measurements of the most widely separated elements. I am sure you've anticipated my comment that the assurance of identical electrical length is not provided by a tape measure. Furthermore, to help ensure line identity for other characteristics, it would be a good idea to cut these

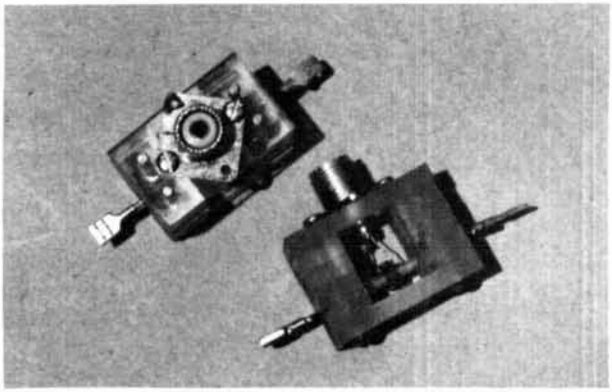
lines from a single piece of cable. (For an enlightening discussion on the variations that may be found in coaxial cable, see Bill Orr's "Ham Radio Techniques" in the January, 1984, issue.)

Photo 2 shows the construction of a pickup coil fixture. This is essentially the same as that used for an ammeter, but without the rectifier and filtering circuit. More attention must be paid to ensure that the pickup circuits have identical RF characteristics, however. We can test this by connecting both pickups in series as sensors in the same RF current circuit, preferably a resistive load. The amplitude and phase of the displayed current waveforms should be identical and should remain so when positions of pickups are interchanged. If reasonable care has been taken, the phase difference due to pickup coils should not exceed 2 or 3 degrees. Any small difference may be corrected for *a particular band* by connecting a mica capacitor (5-25 pF) across that pickup coil which *lags* in phase. My guess is that toroid core material variations are the probable cause of any slight differences. It is possible that substitution of another sample of the same core might also work; I did not investigate this.

In my experience with this measurement technique, I found it to be the most productive method for fine tuning a feed network to get the last bit of F/B performance improvement. Because both phase and amplitude changes are displayed, a much more rapid and intelligent analysis of cause and effect is possible. This comment applies with ever-increasing emphasis with the number of elements in the array. Lacking this capability, my advice is, "If it ain't broke, don't fix it!"; this can be as frustrating as attempting to adjust the color matrix board of a TV receiver without a crosshatch generator. The fact is that if self and mutual impedances are accurately read and used for the design and careful construction of the feed network, the array will be operating very close to, if not exactly at, optimum. The few adjustments determined with the dual-trace CRT are surprisingly miniscule "tweaks." Although the effect on F/B can be quite marked, for example, improving F/B from −20 dB to −30 dB, don't be carried away by these numbers: the effective frequency range over which this occurs is extremely narrow.

alternate methods of phase measurement

One would expect that considering its importance in antenna applications, measurement of phase angles at lower RF frequencies would have received more attention in the Amateur press than it has. A survey of Amateur publications did not yield much except one very interesting article directly applicable to phased array applications.[4] While the author's concept is ingenious and well chosen, it used a differential phase angle readout that was analog rather than digital. Considering the tremendous advances in semiconductor technology during the ten years since the article appeared, a digital readout should be possible. I hope that I may interest some enterprising experimenter to take up this challenge.



Pickup coils provide signals for dual trace scope.

network construction

Several readers have commented that although the no-compromise advantage of 4-terminal feed networks is obvious, and that matrix algebra for the modular design of the networks is a powerful tool, they had apprehensions about how to turn the mathematics into working hardware. Some, familiar with the Pi networks seen in linear amplifiers, were discouraged by visions of the need for the same size of components and the cost of construction. Still others thought the networks might be difficult to tune.

None of these concerns are justified. Construction is actually quite simple, and with an accurate noise bridge,[5] tuning is easy. Tuning with an impedance bridge is done in the same step-by-step manner as is the design, and one of the prime advantages of this method is that it allows tuning to be done at the design frequency. The impedance levels of these networks are low, being generally in the 35- to 125-ohm range. Since each network chain is designed to appear *resistive* at its input and deals with only a portion of the transmitter power, voltages are seldom above 300 volts, even when driven by kilowatt linears. For example, I use postage stamp size mica capacitors extensively (500 volt rating) and I've yet to have one fail. Where high impedances are encountered, for instance, with elements requiring very little direct drive because of drive coupled from other elements, the current is so low that high voltage is not developed.

Photo 3 illustrates the simplicity and small component sizes. This is the feed network for my 80-meter 4-square array.[6] It is built into a 3 × 6 × 8 inch (7.6 × 15.2 × 20.32 cm) box on PC board, with each network chain individually removable. This takes the

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The **KT-3 Keyer-Trainer** unit uses the teaching program used in the BT-1 trainer. In addition, the KT-3 features a full function Morse automatic keyer for keying any modern transceiver, or for sending practice. Speed range is 18-99 wpm for transmitting and 1-99 wpm for training.

KT-2 Keyer Trainer

The **KT-2 Keyer-Trainer** is a computerized keyer with all the features shown above, plus a Morse proficiency trainer. It is designed to increase your existing code as quickly as possible. The unit can be set for beginning practice speed, ending practice speed, and duration of practice. The microcomputer does all the rest by gradually increasing the speed during the practice time selected. You can even select between fast code (Farnsworth) or slow code methods. The characters are sent in 5 letter groups, or random word lengths. Two levels of difficulty can be selected; common Morse characters or all English Morse characters. A 24,000 character answer book is provided for the 10 separate starting positions. There is also random practice mode for which no answers are available.

CK-2 Contester™

The **CK-2 Contester™ Keyer** is the lowest cost automatic keyer available featuring an automatic serial number generator for contesting. The CK-2 keyer features a large 500 character message memory that can be soft-partitioned into as many as 10 sections. An exclusive AEA edit mode makes it possible to correct mistakes made while entering messages or to insert words into previously established messages. Two different speeds can be set for fast recall in addition to a stepped variable speed control. The CK-2 features an automatic message repeat mode with variable delay-before-repeat for automatic CQ transmissions or TVI testing.

MM-2 MorseMatic™

The **MM-2 Morsematic Keyer** represents the most sophisticated paddle keyer ever designed and features two powerful microcomputers. The Morsematic incorporates virtually all the features (except the preset and stepped variable speeds) of both the CK-2 and KT-2 shown above. In addition, the MM-2 offers an exclusive automatic beacon mode which is invaluable for meteor scatter, moonbounce scheduling, or beacon operation.

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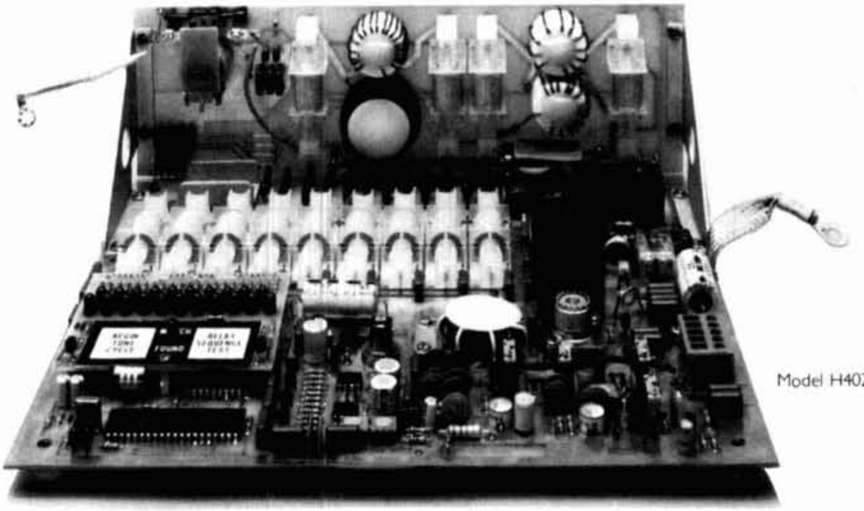
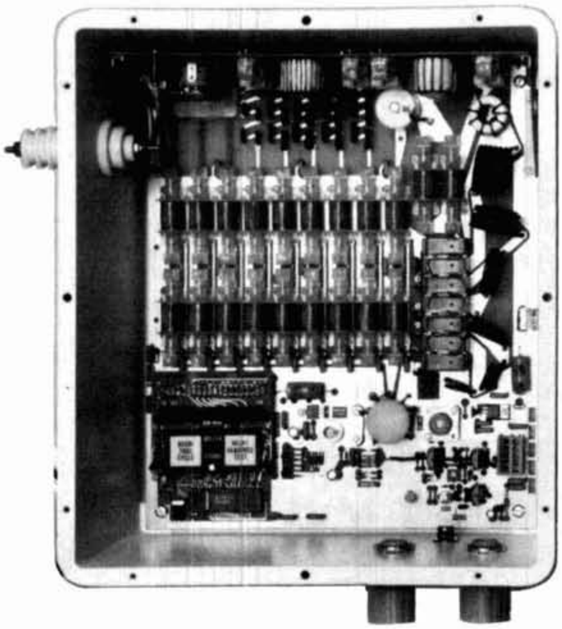
More Details? CHECK—OFF Page 148



Model H402CU



Model H-402/1000

place of other feed methods which require 130 feet (39 meters) or more of coax for this band. At today's prices for good quality 50-ohm coax, this alone should be the deciding factor, without even considering the superior technical merits of 4-terminal feed networks.

As can be seen from the photograph, small 100 pF air variable capacitors are used as trimmers. Mica capacitors, singly or paralleled, using their color coded values, are chosen to make the required network capacitance fall in the middle of the trimmer range. All inductors carrying significant current (and these tend to fall between 0.5 μH to 5 μH) are air core using No. 10 or No. 12 B.S. enamelled copper. I wind these on 1-inch (2.54 cm) diameter wooden dowels, letting them spring up to a slightly increased diameter. Inductances significantly above 5 μH are wound on powdered iron toroids using No. 18 B.S. wire. Using single layer charts for the air wound coils or toroid core manufacturer charts, all inductors are wound to be well above the inductance required. A grid dip meter, together with a known capacitance, is used to trim the inductors to slightly above the required values (5 to 10 percent). The network is constructed with these components and is completed with the exception that no network interconnections are made nor are any connections made to the *shack line* coax terminal.

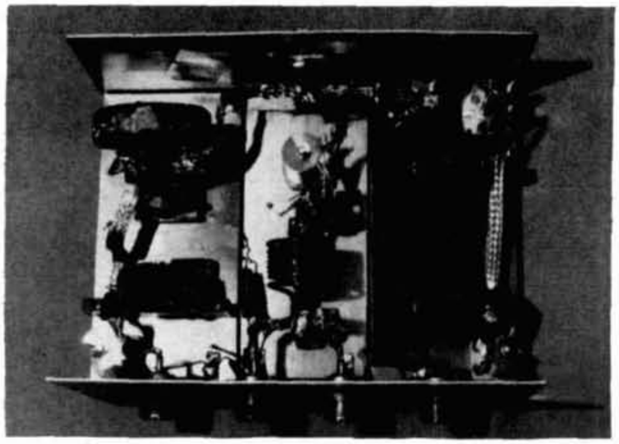
tune-up procedure

We have to choose which direction the impedance bridge will look into the network for tuning it. Each network chain was designed to transform a complex impedance to a pure resistance. Since it is much easier to duplicate resistances than complex impedances, this usually determines the choice. Assuming this case, consider a cascaded network consisting of a shunt L-match followed by a Pi circuit, which is the typical chain from the feeder of the -180 degree phased element of a 4-square array. For example, from Part 4[6] of this series, the input impedances as seen at the various points of a network chain are reproduced for element No. 4 of a 4-square array:

element No. 4 driving-point impedance	63.4 + j47.5
input impedance to 100 degree length feeder	22.73 − j11.37
input impedance to L-match	114.83 + j0
input impedance to Pi circuit	114.83 + j0

You will recall the reason for the Pi circuit was for phase matching, not impedance matching; therefore, its input impedance is the same as the impedance to the shunt L-match.

The impedance bridge unknown terminal is connected to the coax terminal, to which the element feeder would normally be connected. The resistor simulating the input resistance of the L-match (115 ohms is ok) is temporarily soldered to the input of the L-match at the shunt arm and ground (i.e., at the connection point normally going to the Pi circuit). Since we have chosen to measure conditions in the *reverse* direction through this network, we must consider what we want the bridge to "see" and set it accordingly. At first glance, it might seem reasonable to expect this to be equivalent to the impedance as seen at the input to the element feeder. Not so; this is not a bilateral case. Instead we should expect to see the *conjugate* of this impedance: i.e., 22.73 + j11.37. If the impedance bridge reads parallel circuit equivalents, these must be calculated and the bridge set accordingly. If the reactance is beyond the basic bridge range, an appropriate extender must be used. The tuning procedure is simplicity itself; without touching the bridge settings, adjust the L-match shunt trimmer for minimum detector output (being sure this minimum is within the trimmer range). If this is the normal impedance bridge null, the adjustment is complete. More likely, it is merely a minimum. Begin spreading out one of the outer turns of the inductor and readjust the trimmer. Since the null is sharp and deep, use care in spreading coil turns to be sure you have not passed through the null. (I use the tapered end of a pencil for this.) When the L-match is tuned, move the simulating resistor to the input of the Pi circuit (the point normally connected to the shack coax line terminal). Install an interconnection between the L-match and Pi circuit. With the bridge remaining connected and set as before, adjust the Pi circuit trimmers for minimum detector output and then reduce inductance by turn spreading. Since the Pi circuit has three interdependent adjustments, be sure to recheck the other two with each tuning change. The two trimmers should end up in approximately the same part of their range, assuming the fixed padders are similar. Since the tune-up of the Pi circuit is done with the bridge looking into the L-match, a separate procedure for integrating the two networks is unnecessary. Remove the resistor, but



Matching network for four square vertical array measures 3 × 6 × 8 inches (7.6 × 15.2 × 20.32 cm).

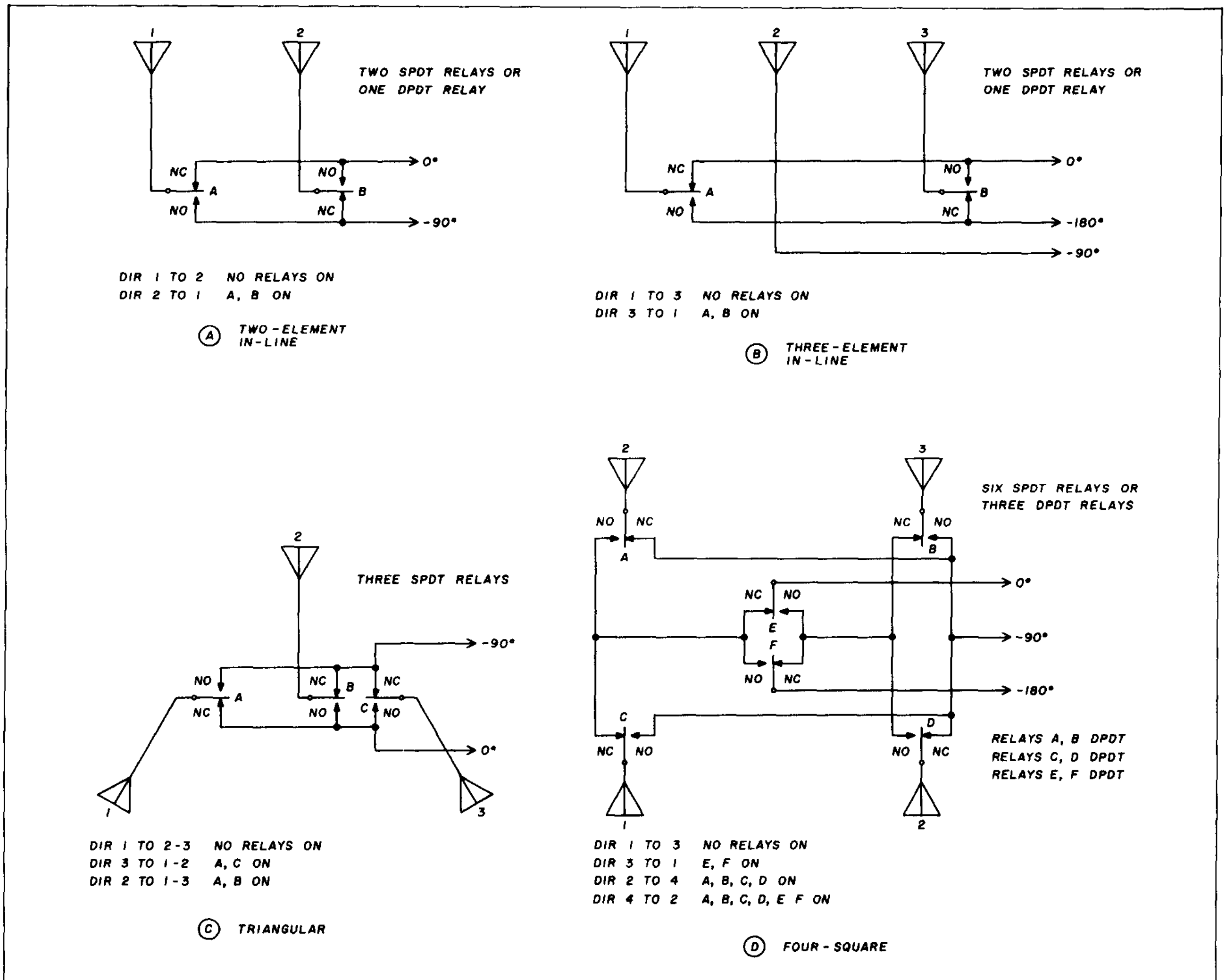


fig. 3. Relay interconnection diagram for four different vertical antenna arrays: (A) two-element in-line; (B) three-element in-line; (C) triangular configuration and (D) "4-square" configuration.

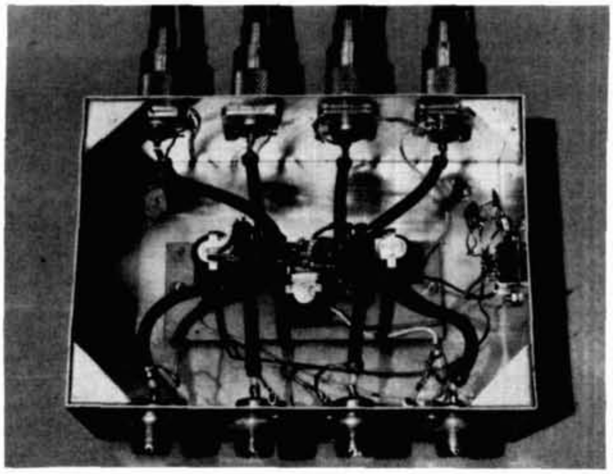
do not connect this chain to the shack line coax terminal until completing the adjustment of all chains.

In some circumstances it may be easier to simulate the calculated termination impedance of a network, in which case the bridge will look into this network in the same direction as the transmitter would. The impedance bridge is set to the pure resistance expected at the network input and it is connected to the shack line terminal. The simulated impedance (the same as calculated, not the *conjugate*) is connected to the coax terminal where the element feeder is normally connected. Assuming we are tuning the same network chain as above, a temporary connection of the shack line coax terminal is made to the input of the L-match (the same point at which the resistor was connected in the previous case). Except for these differences, the tuning procedure is the same. After tuning the L-match, the temporary bridge connection is transferred to the input of the Pi circuit, and an interconnection is made between the two networks in readiness for tuning the Pi circuit. After completion of tuning the Pi circuit, remove the shack line connection to it in preparation for tuning the next chain. Incidentally, there is nothing wrong with connecting the feeder coax into the chain to check out the entire network chain, making the appropriate changes to the bridge settings and/or the simulated network loads. However, do not connect an actual array element to this feeder in the expectation the element will present its array drive-point impedance, saving you the bother of simulating it. This simply won't work; part 4 of this series (October, 1983) explains why it will not.

directional switches

Relay interconnection diagrams for directionally switching four different vertical arrays is provided by **fig. 3**. When selecting relays for this application, remember that no one relay is switching *all* of your transmitter power; consequently ratings may be safely reduced. Since RF is being handled, ceramic insulation is advised, though I found no problem with linen bakelite at 80 meters. Always avoid "hot" switching relays. Even if they can stand it, your linear will not — and neither will the network, since high voltages will be present during switching.

Photo 4 shows a 4-square array relay construction that use three small telephone-type DPDT military surplus relays. At first I lost several relays each summer due to sympathetic discharges from lightning which would burn out the solenoids. This was cured by connecting a silicon high current diode in reversed direction across the coil in parallel with a 0.1 μF ceramic disc capacitor. I have since lost a few diodes to these discharges, but no more relays. Failed diodes are "shorts," so the 28 VDC supply to this system requires a protective series resistance to guard against this possiblity and to prevent damage to the power supply from the discharge.



3 × 5 × 7 inch (7.6 × 12.7 × 17.8 cm) box houses all relays for switching four square vertical array.

on rounding-off calculations

Calculator algorithms and computer operating system programs use guard digits as a means of retricting degradation of accuracy due to round-off in repetitive calculations. All values begin with and are calculated to one or two digits more than shown to the user. For example, if a calculator displays ten significant digits, it actually keeps values to eleven or twelve digits in its internal registers. Round-off errors thus tend to be restricted to these extra figures and seldom affect anything more than the least significant displayed digit. Since these extra digits rarely convey additional accuracy, they aren't displayed.

This concept also applies to calculations done by hand or with a slide rule. For example, using 3.14 for Pi reduces accuracy to only three significant figures *before* any calculations are done. A few computations immediately reduce that accuracy. Let's watch what happens with a simple calculation:

(Pi × 5)² − (Pi × 78)
= 1.57 if 3.14 is substituted for Pi.
If 3.1416 is used the result is 1.6965.
If 3.141593 then the result is 1.69591.

Note that the first approximation for Pi, accurate to three significant figures, has produced results accurate to only a *single* significant figure in just a few computations. What is happening is that every time this rounded off value for Pi is used, a small error is reintroduced, and in effect, the error is compounded.

Although many calculators round off to the nearest decimal, most small computers, and many large ones too, merely truncate values to some number of digits without adjustment to the nearest decimal, causing even more rapid divergence from accuracy if truncation is occurring after only a few digits.

The point of this discussion is to convince you to keep computations to several significant digits more than the accuracy you'd like to end up with. Except in determining rough approximations, constants such as 3.14 for Pi, or the number 984, expressing the speed of light in millions of feet per second, should always have two or more additional significant digits. This becomes particularly important when trigonometric functions involving angles approaching quadrant boundaries (for example, 0, 90, 180, or 270 degrees) are being used. Anyhow, in this day of ubiquitous calculators and computers, calculation to ten significant figures represents no personal mental effort.

The following constants, important to many calculations, are given to a level of precision more than sufficient for most applications:

Pi	3.141592654
e	2.718281828 Naperian logarithm base
c	299.792456 × 10⁶ velocity of light, meters/second 983.571049 × 10⁶ velocity of light, feet/second
cm/in	2.54 (exact) Metric to English unit conversion

Readers have inquired about the values given in these articles for inductances and capacitors in 4-terminal networks. Where, for instance, is a capacitor of value 734.8 pF to be obtained? Obviously no capacitor of that value will be listed in any catalogue; neither could we hope to find it to such accuracy by a measurement and selection process without also controlling temperature, humidity, aging, and so on. Measuring a capacitor or an inductance to just *three* places requires careful technique. I showed values to greater precision in an effort to prevent (mostly unsuccessfully) confusion caused by round-off errors if readers attempted to work backwards from my values for a capacitance or inductance to compute reactances, voltages and currents.

The author, beside his modest station, has proven that over 260 countries can be worked on 75 meters with legal power and a good antenna system.

concluding comments

I thoroughly enjoyed putting this series together, even though it required far more time and effort than I could possibly have imagined. I hope it proves useful and educational, though I'm not sure whether the author or his readers gained more! I tried to leaven the theoretical with the practical, well aware of the difficulties and pitfalls of doing so in such a technical subject.

I introduced the topic of matrix algebra as a tool of nearly limitless versatility that literally begs to be used. It not only reduces the tedium of network design calculations and simplifies transformation of one network to another, but also makes child's play out of the calculations of input/output conditions when networks are cascaded. It is particularly well suited to computer programmed calculations because the fundamental algorithms are unchanging; only the specific network parameter calculations differ. I did not begin to plumb the possibilities in these articles; there are ABCD parameters specific to lattices (bridge circuits), bridged Tee's, all types of transformers, real coax (with loss) and on and on. I sincerely hope this alone has found fertile imaginations in which to take root. It mystifies me that so powerful a tool has found so little welcome in our engineering educational institutions.

Antenna experimentation has always been of absorbing interest to Radio Amateurs, whether for DXing, for propagation studies, superior contesting, or to satisfy one's curiosity. Even though we have the ability, most of us don't have the time to devote to exploring the complexities of our station equipment. But anyone can innovate with a piece of wire, and would that it will always be so. However, antenna experimentation isn't magic; it's a technology like any other. Most of the fundamental principles were established two generations ago, though many of the pioneers, whom we find referenced and footnoted in articles and texts, are still with us.

To Bob Booth, WB6SXV, and Mason Logan, K4MT, for their encouragement, advice, and careful proofreading — which more than once kept me honest — much deserved words of appreciation. Finally, I want to thank you, my readers, for the many kind comments you sent my way via letters and on the air, and most of all — for your patient attention.

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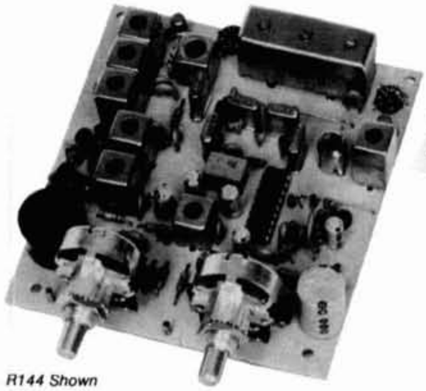

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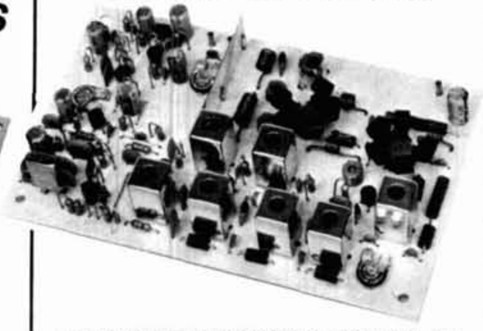

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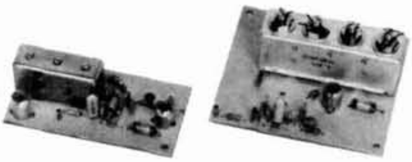

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Wired $69	144-146	28-30
	145-147	28-30
	144-144.4	27-27.4
	146-148	28-30
	144-148	50-54
	220-222	28-30
	220-224	144-148
	222-226	144-148
	220-224	50-54
	222-224	28-30
UHF MODELS	432-434	28-30
Kit with Case $59	435-437	28-30
Less Case $49	432-436	144-148
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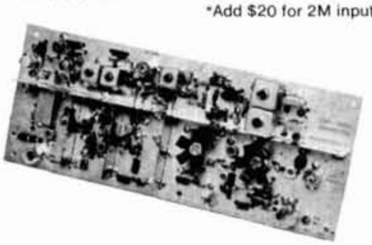
Kit $79	28-30	50-52
Wired $149	27-27.4	144-144.4
(Specify band)	28-30	220-222*
	50-54	220-224
	144-146	50-52
	50-54	144-148
	144-146	28-30
For UHF,	28-30	432-434
Model XV4	28-30	435-437
Kit $99	50-54	432-436
Wired $169	61.25	439.25
	144-148	432-436*

*Add $20 for 2M input



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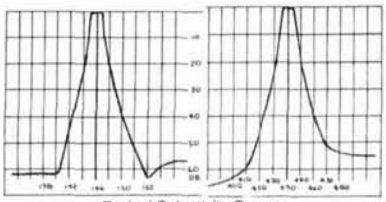

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ham radio TECHNIQUES

Bill Orr W6SAI

Fifty years ago this month a young junior high school lad walked into the New York office of the newly-formed Federal Communications Commission. The nameplate on the door in the old Federal Building still said "Federal Radio Commission." The Commission room was a typical 1930's government office with walls of varnished wood, dusty, oversize furniture and a heating system going full-blast.

It was close to zero outside and there was still some snow on the window ledges. After filling out an application form and enduring an interminable wait, I was instructed to sit at a table next to a window and to prepare myself for the code test for the Amateur examination.

I was a bundle of nerves and the room was stifling hot. When the Radio Inspector wasn't looking I quietly opened the window for a breath of fresh air.

The exam began. First I sent a minute or two of Morse on the hand key mounted on the desk. No problem. My pulse was still racing as the Inspector handed out earphones, paper, and pencil to me and a few other nervous wretches aspiring to become Radio Amateurs. We were cautioned to listen to the code for a short time; the inspector would tell us when to begin copying.

It seemed easy enough. Code speed was 10 WPM and I had practiced for hours, sending and receiving, at 12 and 15 WPM. I started to write down the code coming at me out of the headphones.

Suddenly there was a loud racket and a flurry of wings as two of New York City's infamous pigeons landed on the windowsill, only a few inches away from my left arm. I shut my mind to the distraction and grimly forged ahead, copying the torrent of code issuing from the spring-wound code machine at the front of the room.

But the pigeons would have none of this. One of them boldly stepped over the window ledge and onto my arm and started pulling at the threads in my sweater. I gestured furiously with my free arm, trying to scare the bird away. But no. The second bird observed the commotion, jumped over the window ledge, and started walking about on my desk, finally coming to rest upon the paper I was trying to write on.

I pushed back my chair and beat away at the birds, who responded immediately. One flew out the window, squawking loudly; the other deposited a large lump of foul-smelling debris on my exam paper. I heard snickers from the other examinees around me, but I frantically scribbled on, no longer aware of where I was, or what I was copying. It seemed an inglorious end to all of my months of hard work!

After what felt like *centuries* passed, the code mercifully stopped. The Inspector, who had observed my battle with the birds, took my paper with a grin, as the second bird strutted about on the windowsill. I closed the window with a sigh.

Now the Inspector was grading the code test; in just a few moments I would know the results. Luck was with me — I had passed! The Inspector congratulated me and predicted that I would become a good CW man, able to copy successfully through the toughest QRM.

Fifty years have passed since that eventful day, which was not only a turning point in my life, but an introduction to the world of electronics and radio communication as well. If I had failed the exam, would I have found the fortitude to take it again? Would fate have turned me toward a different profession?

On that cold spring day in 1934, two pigeons came very close to irrevocably altering my destiny. Today — a half century later — I still don't like pigeons.

new sources of RFI

The VCR is a popular item, to be sure, and more and more of them are appearing in American homes. But along with the VCR comes interference caused by the intrusion of HF and VHF signals into the recording circuits: complaints range from blanking out of the picture to herringbone pattern interference and an absence of color. In the majority of cases, the interference was traced to a nearby Amateur operating on the 80-meter band.

The problem is complex. Modern VCRs are built on plastic frames enclosed in unshielded plastic boxes, leaving them wide open to RFI intrusion (See Vaughn Martin's "EMI/RFI Shielding: New Techniques," Parts 1 and 2, *ham radio,* January and February, 1984). In addition, the black and white portion of the video signal is recorded onto the tape as an FM signal over a frequency range of 3.4 MHz to 4.4 MHz. 3.4 MHz is "sync-tip" and 4.4 MHz is "peak white." Thus the 80-meter band falls between black level and about fifty percent white.

According to Bill Bowen, K8YGT, of the JVC Company of America, the only sure cure for the problem is proper shielding of the video head drum and head amplifier, and the addition of a line filter to the VCR. Even with all these precautions, some of the newer all-plastic chassis VCRs are almost impossible to clean up!

As an example, Bill cites his work on cleaning up an RCA VCT400, a 1979 model made for RCA by Panasonic. After some effort, Bill obtained a shielding kit from RCA that, when installed, solved the problem. It is suggested, therefore, that unless you are an expert on the innards of a VCR, the prudent thing to do is to contact the supplier and find out if a filter kit is available.

Bill says that a quick way to get a "fix" on a VCR's resistance to RFI is to take a 2-meter HT into the store and transmit while the VCR is running. Although the frequency of the HT is far removed from the sensitive 80-meter area, when operated closely to the VCR it may produce RFI on the tape. This should be helpful in selecting a model that would be relatively "clean" of interference.

I should add that in any case, a good line filter on the VCR should help because RFI travels the power lines from ham transmitter to TV or VCR. If you have a stereo, TV, or VCR in your house, a line filter on your transmitter (and possibly on the entertainment equipment as well) is mandatory for peaceful coexistence with your family.

video disc players

The CED-type of video disc players (such as the RCA models) can be affected by even very low levels of RF in the 900-925 MHz region. In fact, one store that displayed a video disc player couldn't get it to play at all. The problem was finally solved by a technician who discovered that the "Sens-o-Matic" anti-shoplifting system was causing the interference. This device consists of an RF proximity alarm that sounds whenever merchandise tagged with a small series-tuned trap disturbs the RF field at a sensor, usually located near a store exit. In the case of the disc player, the 908 MHz carrier radiated by the sensor was invading the disc player through the stylus flyback circuit. Retuning the disc player circuit solved the problem.

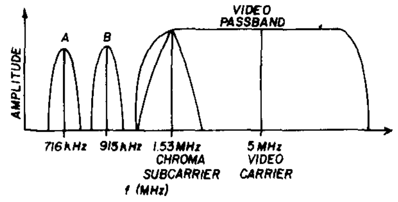

fig. 1. Frequency response of disc player covers range from audio carriers (A and B) at 716 and 915 MHz to video passband centered at 5 MHz. System is sensitive to 4 MHz as well as 910 MHz signals.

fig. 2. Cross-section (lengthwise) of video disc groove showing position of stylus and baseline. As the stylus moves up and down during playback, a varying capacitance is created between the gold layer at the back of the stylus and the platter. The capacitor tunes a 910 MHz circuit in the player.

how the disc player works

When a disc is cut, a combined video/audio signal on an FM subcarrier modulates a piezoelectric cutter, causing the depth of the grooves to vary with respect to the baseline (**fig. 1**). The audio carriers are centered about 716 kHz and 915 kHz, the video carrier is centered about 5 MHz, and the chroma subcarrier is at 1.53 MHz.

A lengthwise view of the platter groove is shown in **fig. 2**. During playback, as the stylus moves up and down, a varying capacitance is created between the gold layer at the back of the stylus and the player. This capacitance is one element of a 910 MHz series-tuned circuit that works somewhat on the principle of slope detection of an FM signal. The recovered signal is then split into its components (audio, video, chroma) for processing.

The sensitive portion of the machine is the flylead that connects the stylus to the circuit, which is a large portion of a wavelength long. Even though the whole circuit is enclosed in a two-compartment metal box and seems well shielded, the flyhead is very sensitive to RF in the 900 MHz region.

There will soon be a lot of RF activity — Amateur and otherwise — in the 900 MHz region. Cases of video disc RFI are already appearing in homes near military installations where 900 MHz radar is operating.

So far, there seems to be no easy solution to the problem. The basic circuit of the playback mechanism is shown in **fig. 3**. Any ideas from readers on this interesting and vexing problem would be appreciated.

light bulb RFI

What's next? A recent article in a broadcast industry newspaper pointed out that "the potential of RF lighting devices to cause interference to AM radio and certain other broadcast services has given rise to a regulatory debate at the FCC.

"Most broadcasters want the Commission to impose federal regulations on RF lighting devices, according to comments filed in response to an FCC Notice of Inquiry. But the FCC and most lighting producers would prefer to see the interference potential of these lighting devices controlled by a voluntary industry standard."

What are these lighting devices? I understand they are oversize bulbs that are not incandescent lamps, but are instead a variety of fluorescent lamp having a standard socket and a folded tube that is excited by a built-in VLF oscillator. In some versions of this RF-excited lamp, the oscillator runs continuously when the lamp is on; in others, the oscillator stops when the lamp is lit.

In either case, according to the article, "tests at the Commission show RF

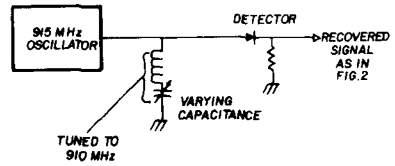

fig. 3. As the stylus moves up and down, a varying capacitance created between the stylus and the platter tunes a 910 MHz circuit, acting on the same principle as the slope detector of an FM signal. The recovered signal is then split into its component parts for processing (audio, video and chroma). Signals leaking into this circuit can upset the process and alter the video picture.

lighting emissions to be very broadband, with measurable emanations ranging from 10 kHz to 80 MHz.

"Referring to tests conducted by Harold Kassens of A.D. Ring and Associates, the NRBA found the interference potential of RF lighting 'alarming.' According to preliminary reports, AM radios were able to pick up objectionable radiation interference from as near as several meters from RF light bulbs.

"Mr. Kassens warns that if the development of this new technology is not regulated, it is the public which will suffer most when the uncontrolled use of the new product interferes with the reception of established broadcast services".

The article continues, "While broadcasters were skeptical about the lighting industry's willingness to establish an industry standard, General Electric, a leading manufacturer of RF lighting devices, expressed enthusiasm over voluntary limits." General Electric, moreover, presented proposed limits on radiation and measurement techniques for use in determining whether RF lighting devices meet the proposed limits.

It seems to me that Radio Amateurs would be vitally interested in this new RFI hazard. The Docket number on the FCC Notice of Inquiry is GEN 83-806; a copy can be obtained by calling the FCC at (202) 653-8247.

ham radio

easy antenna matching

Use a home computer and a noise bridge to solve for T-network values

Matching a transmission line to an unknown impedance can be done either by trial and error (probably most common method) or by measuring the actual impedance and designing a matching network. The latter method is faster and the availability of low cost noise bridges makes it much easier.

One of these noise bridges is the MFJ 202B. It comes with a very explicit manual and is easy to use except for one thing: the equations for converting from indicated values to actual impedances are a bit unwieldly. I took one look at those and decided that there was no way I'd do *that* more than once; instead, I wrote a program to do the calculations by computer. From there, it made sense to have the computer calculate the matching network, provide a printout of several measurements, and graphically summarize the data.

The program shown in **fig. 1** does all these things. It is written for the Radio Shack Color Computer™* but will run (except for the color graphics) as is on the TRS-80 Model 1™* and, with minor modifications, on any of the other popular machines. Its self-prompting feature makes it easy to use.

using the program

First, make the actual measurements. Write down, in order of increasing frequency, the frequency, indicated resistance, and indicated reactance. Treat capacitive reactance as a negative value.

Then load and RUN the program. The program will ask for the line impedance (used for SWR calculations) and then for frequency in MHz. Next you will be asked for the indicated values of resistance and reactance.

The screen will display the calculated impedance and SWR. (These values are also being stored internally for later use.) You will then have the opportunity to input more data, obtain a hard copy, calculate a matching network, or see a graphic display.

To input more data, merely repeat the process above. To calculate a matching network, answer "YES" when the question "MATCH?" appears on the screen. The display will now show the reactances to be used in the network of **fig. 2** and the necessary component values. You can influence the bandwidth and component values by specifying the value of Q to be used in the network. If the reactance for L1 is negative, a capacitor will have to be used.

To obtain a printout of the impedances as a function of frequency, answer "YES" to the "PRINT?" prompt. The printer first gives you the opportunity to name the antenna and then proceeds to tabulate.

To obtain a color graph of impedance versus frequency, answer "YES" to the "PLOT?" prompt. The screen will clear, axes will be drawn, and real and reactive impedances will be plotted. The resistance plot will consist of yellow blocks; the reactance plot, white. When the display is complete, the program will stop and wait for you to press any key. This allows you time to evaluate the plot. Pressing any key will resume program operation and erase the graph. At the completion of any of these operations, you will again be given the opportunity to input more data, calculate a match, and so forth.

To keep the program simple there is not a large

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*Radio Shack Color Computer and TRS-80 Model 1 are trademarks of the Tandy Corporation.

amount of error-trapping, so your data must be reasonable. For example, the program assumes the antenna impedance is *lower* than the line impedance — this is certainly true of most antennas I've needed to measure. The matching network calculation does include any antenna reactance; if there is no reactance at all, there is not much point in plotting the response: the plot will not work if there is no reactive data. If the data is not entered in order of increasing frequency, the printer output will not be in the proper order.

```
1 DIMF(20),R(20),X(20)
      :K=1
5 PI=3.1415926535
10 CLS
      :PRINT@224,"MFJ NOISE BRIDGE CALCULATOR"
      :PRINT"BY JAMES A. SANFORD"
      :PRINT
      :PRINT
      :PRINT
      :INPUT"LINE IMPEDANCE (OHMS)";ZL
15 FOR I = 1 TO 500
      :NEXTI
20 CLS
      :INPUT"FREQUENCY (MHZ)";F
      :INPUT"RESISTANCE (OHMS)";RD
      :INPUT"REACTANCE (PF, XC NEGATIVE)";XD
      :INPUT "EXPANDER";E$
      :PRINT
      :PRINT
      :PRINT
      :IF E$="YES"THENGOTO1000
30 XU=(888/F)-(160000/(F*(180+XD)))
      :RU=RD
39 S=SQR(RU^2+XU^2)/ZL
      :IFS<1THENS=1/S
40 PRINT"IMPEDANCE = ";RU;" + ";INT(100*XU)/100;"J OHMS";
      :PRINTTAB(10);"= ";INT(100*SQR(RU^2+XU^2))/100;" ANGLE ";INT(100*(ATN(XU/RU
))*(180/3.1415926535))/100
      :PRINT"SWR = ";S
45 S(K)=S
      :F(K)=F
      :R(K)=RU
      :X(K)=XU
      :K=K+1
47 INPUT"ANOTHER RUN";R$
      :IFR$="YES"THEN20ELSEINPUT"PRINT";R$
      :IFR$="YES"THEN2000ELSEINPUT"MATCH";R$
      :IFR$="YES"THEN3000ELSEINPUT"PLOT";R$
      :IFR$="YES"THEN4000ELSECLS
      :END
1000 XEQ=888*XD/(F*(XD+180))
      :XU=(40000*XEQ/((200-RD)^2+XEQ^2))
      :RU=200*(200*RD-RD^2-XEQ^2)/((200-RD)^2+XEQ^2)
      :GOTO39
2000 INPUT"ANTENNA";A$
      :PRINT#-2,TAB((80-(LEN(A$)))/2);A$
      :PRINT#-2,CHR$(10);CHR$(10),CHR$(10);"NUMBER","FREQUENCY","REAL","IMAGINARY
","SWR";CHR$(10)
2010 FORJ=1TOK-1
      :PRINT#-2,TAB(2);J,F(J),R(J),X(J),S(J)
      :NEXTJ
      :PRINT#-2,CHR$(10);CHR$(10);"FEEDLINE IMPEDANCE = ";ZL;" OHMS"
      :PRINT#-2,CHR$(&H0C)
      :GOTO47
3000 CLS
      :INPUT"CHOOSE Q FACTOR";Q
      :A=RU*(1+Q^2)
      :B=SQR(A/ZL-1)
      :X1=RU*Q
```

fig. 1. Antenna matching program is written for Radio Shack Color Computer™ but will run on TRS-80 Model 1™ or, with modification, on any other personal computer.

Some other comments regarding interpretation of the data are appropriate. First, the MFJ 202B is not intended to be a laboratory instrument. Even though the computer prints out answers to 9 digits, there is no point in believing anything past the first or second digit after the decimal point. This is simply because the input data is not that good.

Second is the issue of SWR. Much has been written about misconceptions of SWR; suffice to say that SWR is an *indication* of the impedance match. Some

```
      :X2=ZL*B
      :XC=A/(Q+B)
3010 PRINT"REACTANCES OF
      :"
      :PRINTTAB(5);"L1 = ";X1-XU;" OHMS"
      :PRINTTAB(5);"L2 = ";X2;" OHMS"
      :PRINTTAB(5);" C = ";XC;" OHMS"
3015 PRINT"VALUES OF
      :"
      :PRINTTAB(5);"L1 = ";
      :IF X1+XU>0THENPRINT (X1+XU)/(2*PI*F);"MICROHENRIES"ELSEPRINT1E6*1/(2*PI*F*
(XU+X1));"PICOFARADS"
3016 PRINTTAB(5);"L2 = ";X2/(2*PI*F);" MICROHENRIES"
3017 PRINTTAB(5);" C = ";1E6*1/(2*PI*F*XC);"PICOFARADS
3020 GOTO47
4000 CLS0
      :FOR I = 1 TO 417 STEP 32
      :PRINT @I,"! ";
      :NEXTI
      :PRINT@448,STRING$(31,"-")
      :L=64
      :FOR Q = 1 TO9
      :READ D$
      :PRINT@L,D$;
      :L=L+32
      :NEXT
      :DATA I,M,P,E,D,A,N,C,E
4010 PRINT@490,"FREQUENCY";
4020 BW=F(K-1)-F(1)
      :FOR I = 1 TO K-1
4021 IF RH<R(I) THEN RH = R(I)
4022 IF RL>R(I) THEN RL = R(I)
4023 NEXTI
4025 FOR I = 1 TO K-1
4026 IF X(I)>P THEN P = X(I)
      :
4027 IF X(I)<T THEN T =X(I)
4028 NEXTI
4030 PRINT@480,F(1);
      :PRINT@505,F(K-1);
      :PRINT@32,INT(RH);
      :PRINT@57,INT(P);
      :PRINT@416,INT(RL);
      :PRINT@443,INT(T);
4035 FORI=1TOK-1
      :W=2+(F(I)-F(1))*(61/BW)
      :Y=28-28*INT(R(I)-RL)/(RH-RL)
      :SET(W,Y,2)
      :Y=28-28*INT(X(I)-T)/(P-T)
      :SET(W,Y,5)
      :NEXTI
4037 PRINT@13,"R";
      :PRINT@17,"X";
      :SET(32,0,2)
      :SET(40,0,5)
4040 IFINKEY$=""THEN4040ELSECLS
      :GOTO47
5000 '************************** THIS PROGRAM CALCULATES RESULTS USING READINGS
FROM MFJ NOISE  BRIDGE, MATCHING NETWORKS, AND  SHOWS A GRAPH OF RESPONSE.
      <RUN> IT TO USE.
```

fig. 1. (continued)

- John Beun =

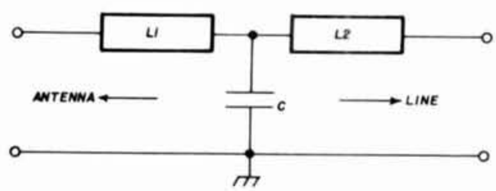

fig. 2. T-network used in this case to match antenna impedances lower than 50 ohms.

transmitters may not tolerate the reactive load even though the SWR is not excessive.

Third, temper results with reality. If a matching network calls for 10 Henries and 0.0001 picofarads, try a different value of Q, or change the effective line impedance with a broadband transformer.

Although I have talked about measuring antenna impedances, the MFJ bridge and these techniques can be used to measure other parameters. Linear amplifier input impedance can be measured and even the input impedance of a properly biased transistor stage can be determined. This could make matching easier. Realize that the MFJ bridge has limits on what it can measure, and that large voltage or RF will destroy it. So don't try to measure the plate impedance of a 2-kilowatt linear at 4 GHz!

how it works

Program operation is straightforward. Lines 1 through 10 initialize the program. Line 20 allows input of the measured information. If the noise bridge expanded range is not used, line 30 calculates the actual impedances. Otherwise, this is done by line 1000. These calculations are in accordance with the equations in the MFJ manual (see appendix). Line 39 calculates the magnitude of the SWR. Line 40 displays the result and line 45 updates the stored data. Line 47 gives you the opportunity to select what to do next. The printer output routine is at line 2000 and the matching network calculations at line 3000. The equations used are shown in the appendix.

The plotting routine begins at line 4000. For use in the TRS-80 Model I or III, simply change the scaling calculations and delete references to colors. To plot on other color computers, check the User's Manual that accompanies your machine.

conclusion

Impedance matching can be simplified by using a noise bridge to make actual measurements and a computer to do the brute force number-crunching. This program will help in that effort. Now, matching strange new antennas can be easier and a lot less frustrating.

references

1. *MFJ Noise Bridge Owner's Manual*, MFJ Enterprises, Box 494, Mississippi State, Mississippi 39762.
2. *Application Note No. 721: Impedance Matching Networks (Applied to RF Power Transistors)*, Motorola Corporation, 1974.
3. *Reference Data for Radio Engineers*, 6th Edition, Howard W. Sams Co., Indianapolis, Indiana, 1979.
4. J. J. DeFrance, *Communications Electronics Circuits*, Rinehart Press, 5643 Paradise Drive, Corte Madera, California 94925, 1972.

appendix

1. Calculating reactance without expander:

$$R = Rd$$

$$X = \frac{888}{f} - \frac{160{,}000}{f(180 + Cd)}$$

where f = frequency in MHz
Cd = reactance dial reading in pF
− for capacitance, + for inductance
X = reactance in ohms
R = resistance in ohms
Rd = indicated resistance

2. Calculating reactance with expander:

$$Xeq = \frac{(888)\ (Cd)}{f(Cd + 180)}$$

$$R = \frac{200\ [200\ Rd - Rd^2 - (Xeq)^2]}{(200 - Rd)^2 + (Xeq)^2}$$

$$X = \frac{40{,}000\ Xeq}{(200 - Rd)^2 + (Xeq)^2}$$

3. Three element matching network:

$$X_{L1} = R_A Q$$

$$X_{L2} = Z_{Line} \sqrt{\frac{R_A (1 + Q^2)}{Z_{Line}} - 1}$$

$$X_C = \frac{R_A(1 + Q^2)}{Q + \sqrt{\frac{R_A (1 + Q^2)}{Z_{Line}} - 1}}$$

where R_A = antenna resistance
Z_L = line impedance
Q = quality factor
X = reactance

For a copy of the program on tape, send $10.00 to James A. Sanford, 248 Worden Street, Portsmouth, Rhode Island 02840.

ham radio

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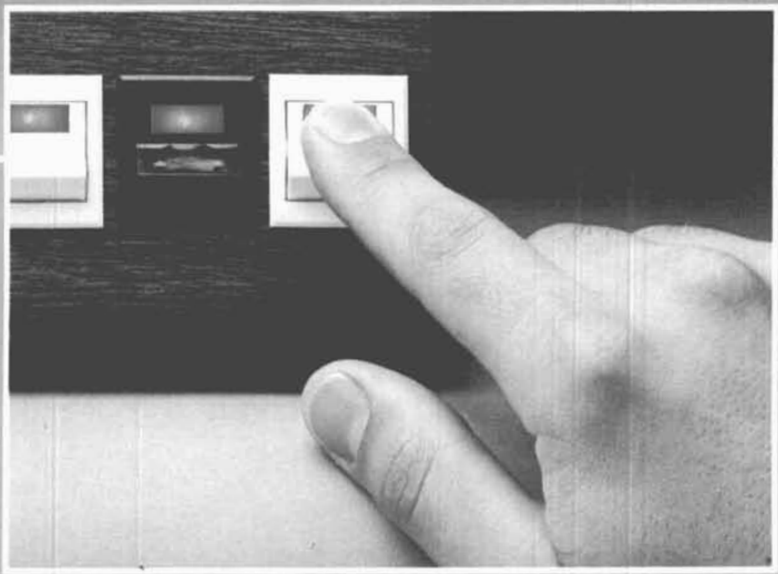

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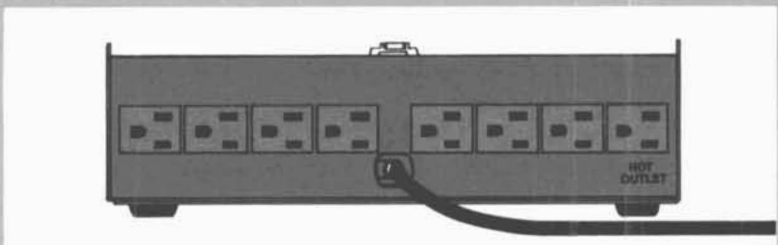

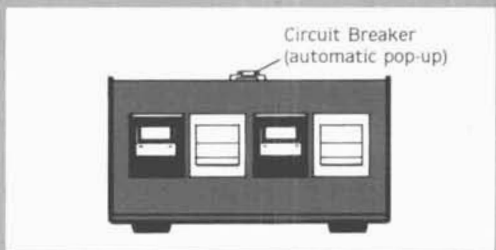

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The TR-7950/7930 features a large L.C.D. display that is easy to read in direct sunlight and is back lighted for comfortable night-time viewing. It displays TRANS/REC frequencies, memory channel, repeater offset (t.s.-.), sub-tone number (F-0, 1, 2, 3) tone, scan, and memory scan lock-out. It includes an LED S/RF bar meter, and LED indicators for reverse, center TUNING, PRIORITY and ON AIR. The 21 multi-function memory channels store frequency, repeater offset, and optional sub-tone channels. Memories 1 through 15 are for simplex or ±600 Hz offset. Memory pairs 16/17 and 18/19 are paired for non-standard repeater offset. Memories "A" and "B" set upper and lower scan limits, or are for simplex or ±600 kHz offset. In MEMORY mode, a circle of light appears around the memory selector knob. When the memory selector knob is rotated in either direction to channel 1, an audible "beep" sounds.

With 45 big watts, the TR-7950 is the most powerful 2 meter FM rig you can buy. The TR-7930 with a modest 25 watts is also available. A HI/LOW power switch allows power reduction to approx. 5 watts.

Other key features include: Programmable band-scan width, Center stop during band-scan, with indicator. Scan stops on busy channel and resume scan is automatic (time 5 sec. adjustable) or carrier operated. A scan delay of approx. 1.5 sec. is built-in. Scanning can also be accomplished with UP/DOWN microphone or "SC" key on front panel. Programmable priority alert can be set into any of 21 memory channels. With Alert switch "ON," a dual "beep" sounds when signal is present. The microprocessor is pre-programmed for simplex or ±600 kHz offset in accordance with the 2 meter band plan, with an "OS" key to allow manual changes in offset. The keyboard functions as a 16-key autopatch encoder during transmit. Frequency coverage is 142.000-148.995 MHz, and it has a repeater reverse switch and mobile mounting bracket. All these features are available in one compact, lightweight rig.

Yes, Kenwood is on top with the TR-7950! Its field proven reliability and matchless performance makes the TR-7950 the rig of tomorrow, today!!

TR-7950 optional accessories:

TU-79, three frequency tone unit, KPS-12 fixed-station power supply (7950), KPS-7A fixed-station power supply (7930), SP-40 mobile speaker, SP-50 mobile speaker, MC-55 mobile microphone with time-out timer, MC-46 16-key autopatch UP/DOWN mic, SW-100A/B power meters, PG-3A noise filter.

More information on the TR-7950/7930 is available from authorized dealers of Trio-Kenwood Communications, 1111 West Walnut Street, Compton, CA 90220.

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Optional FC-10 Frequency Controller
Connects to the TM-201A or TM-401A. Convenient control keys for frequency UP/DOWN, MHz shift, VFO A/B, and MR (memory recall or change memory channel). A green LCD display indicates transmit/receive frequencies, memory channel number, ALERT, and SCAN (with blinking MHz decimal).

TM-201A/TM-401A

TM-201A/TM-401A "comp-ACT"... tough act to follow.

The word "compact" best describes the TM-201A VHF (a big 25 watts!) or the TM-401A 70-cm (12 watts) mobiles. Measures 5.6Wx1.6Hx7.2D inches (the TM-201A and TM-401A are the most compact rigs available). Ideal in size, their performances are superlative. Each features a HI/LO power switch, dual digital VFO's built-in, 5 memories plus a "COM" channel with lithium battery back-up, memory scan, programmable band scan, priority alert scan, and GaAs FET RF (front end) amplifiers. They have a highly visible yellow LED digital display, a repeater offset switch, a reverse switch, and a "beeper" to confirm operation of various switches. For superior sound quality, the separate, external speaker, can be easily mounted to project the sound in the desired direction. A 16-key autopatch UP/DOWN mic. allows easy remote operation of major front panel functions. Thanks to KENWOOD, compact radios are now available for the popular VHF and UHF bands providing high performance and superior sound quality.

Other TM-201A/TM-401A Optional Accessories:
TU-3 Programmable two-frequency CTCSS encoder, KPS-7A fixed station power supply, MA-4000 dual-bander mobile antenna with duplexer, SW-100A/B SWR/power meter, MC-55 mobile microphone with time-out timer.

TW-4000A

TW-4000A FM "Dual-Bander"

KENWOOD'S TW-4000A FM "Dual-Bander" provides new versatility in VHF and UHF operations, uniquely combining 2-m and 70-cm FM functions in one compact package. It covers the 2-m band (142.000-148.995 MHz), including certain MARS and CAP frequencies, and the 70-cm band (440.000-449.995 MHz), all in a package only 6-3/8 W x 2-3/8 H x 8-9/16 D inches. RF output power measures 25 watts on either band. The TW-4000A features a large, easy-to-read LCD display, front panel illumination for night operations, 10 memories with OFFSET recall and lithium battery backup, programmable memory scan, band scan in selected 1-MHz segments, priority watch function, common channel scan, dual digital VFO's, repeater reverse switch, GaAs FET front ends, rugged die-cast chassis, "beeper" through speaker, a mobile mount, and a 16-key autopatch UP/DOWN mic.

The new optional VS-1 voice synthesizer has everyone talking! A voice announces the frequency, band, VFO A or B, repeater offset, and memory channel number when these functions are selected.

Other TW-4000A optional accessories:
VS-1 voice synthesizer, TU-4C programmable two-frequency CTCSS encoder, KPS-7A fixed station power supply, SP-40 compact mobile speaker, SP-50 compact mobile speaker, MA-4000 dual-band mobile antenna with duplexor, MC-55 mobile microphone with time-out timer, and a SW-100B SWR/power meter.

More information on the TM-201A/TM-401A and TW-4000A is available from authorized dealers of Trio-Kenwood Communications 1111 West Walnut Street Compton, California 90220.

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Other new features are the provision in Memory 9 for split memory offset operation, for those really unusual offset situations, and the capacity for hardware storage of a special PL tone for each memory channel (requires an optional encoder, available December, 1983). The new SANTEC Handhelds will also accept the keyboard input of all frequencies as either short, fast 4-digit numbers or the familiar 6-digit versions: your SANTEC Handheld is smart enough to know what you want, either way.

The handhelds with the most now have more for you. Don't you dare settle for anything less: get your hands on a SANTEC Handheld today!

Shown above is just one of the three new smarter handhelds from SANTEC: the **ST-142** VHF, the **ST-442** UHF and the **ST-222** VHF. Owners of earlier SANTEC models **ST-144, ST-440** and **ST-220,** please write for information on how your SANTEC Handhelds can be upgraded to the new state of the art in handheld transceivers.

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ICOM is proud to announce the latest in 440MHz handheld transceiver technology. The IC-04AT represents the best in a multifunction, multifeature handheld for 440 — 450 MHz.

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Compatible Accessories. The IC-04A(T) has the same styling, control features and functions of the IC-02A(T). The IC-04A(T) *utilizes the exisiting* accessory line available for the IC-2A and IC-2AT, plus new accessories such as long-life and high-power battery packs and a boom headset. Multiple battery packs allow the widest flexibility in charging: either from a wall charger, cigarette lighter plug, stand-up desk charger, or through the top of the radio. Twelve volts applied through the top of the radio not only provides operation of the radio at high power, but provides *charging of the battery packs at the* same time — a feature not commonly found in handheld units.

IC-02A(T)
2 Meter

Built to Last. The IC-04A(T) comes with a sealed case, providing resistance to moisture, dust, and other elements detrimental to the operation of the radio. An aluminum back provides a massive heatsink for the power module allowing the IC-04A(T) to run at a standard 3 or 5 watts (optional battery required). A battery lock is provided to ensure the battery will remain secure, and the unit will continue to operate even if mishandled. A custom LCD readout with S-meter is unique to the ham industry.

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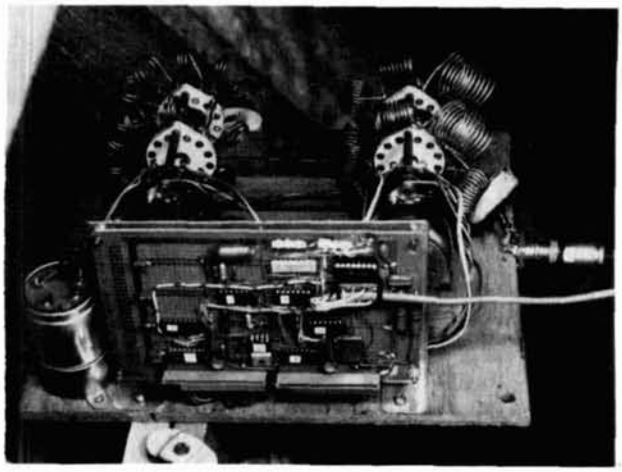


an end-fed multiband 8JK

A new approach to tuning and feeding for multiband operation

A wire that is 2-1/4 wavelengths long at the high-frequency end of the 10 meter band can be provided with adjustable series inductive loading to give a low feed impedance throughout the 10, 15, and 20 meter bands. Two such wires in an "end-fed W8JK" arrangement can form a multiband antenna whose dimensions and feed arrangements are well-suited to small backyards, and which combines useful gain with an SWR better than 1.4:1 across the whole of the three bands. Further possibilities exist for using the basic element and feed arrangement in other configurations.

design requirements

Several years of experimentation and experience convinced me that an HF band antenna for my location had to meet five requirements.

First, since I live in the suburbs, it had to be a fixed wire with unobtrusive supports, optimized to perform at a maximum height of about 30 feet.

Second, it had to be multiband so that I could follow my changing interests and also respond to varying propagation conditions. However, since rotatable arrays have already been ruled out by the first requirement, and I have no specialized geographical interests, there is no particular merit in having the same horizontal polar diagram on each band. Therefore, "long wire" arrangements were quite acceptable — particularly if they avoided the losses inherent in trapped dipoles.

Third, end feed was desired. My "shack" is inside the pitched roof of my house, quite near to the end of any practical long wire. Feeder cables running across the lawn to a center feed point are unsightly and subject to serious losses in humid weather. (I used to think that a 300 ohm tubular feed was ideal until I emptied a pint of water out of a length of such a feeder that was tied along a fence!)

Fourth, the feed should be a balanced two-wire arrangement. Early experiments with a single wire fed against ground and with Zepp feed had produced RFI to both household electronics and to my equipment in the shack.

Fifth, a little gain would be nice! Rotatable arrays get gain by narrowing the horizontal beamwidth, but in the case of a fixed wire antenna intended to provide coverage of all directions, this is impossible. The main option is to shape the vertical radiation pattern so as to concentrate energy into useful angles of elevation, ideally between 10 and 20 degrees above the horizontal — and minimize ohmic losses in the antenna

By **R.C. Marshall, G3SBA,** 30 Ox Lane, Harpenden, Hertfordshire AL5 4HE, United Kingdom

and in the surrounding ground. A second possibility is to use two or more antennas driven with different phases so as to provide steerable maxima and nulls. This is a choice that may be considered *after* the basic antenna is selected. Therefore, the choice was limited to arrangements that provide zero radiation both up and down — that is, the three families shown in **fig. 1**.

Study of the literature disclosed no clear evidence to support the choice of vertical polarization on the HF bands at the heights proposed, although, since the performance of horizontal antennas is more strongly affected by height, there might be a good case for a vertical antenna if the available height were much less. In a vertical antenna such as that shown in **fig. 1A**, the current is zero at the top and so the effective height is less than the actual height. If the radiator is trapped for multiband operation the top section may not be used, further reducing the effective height and with it the efficiency.

The so-called "Lazy H" array (**fig. 1B**) uses two dipoles stacked one above the other and fed in phase so as to provide maximum radiation horizontally and minimum radiation in the vertical direction. However, the effective height of the array is only the average height of the two elements, and the lower element would be inconveniently near ground level.

In contrast, the effective height of the "W8JK" array (**fig. 1C**) equals its actual height. The two dipoles are fed out of phase, and so straight-up-and-straight-down radiation is zero regardless of spacing, giving a potential for multiband operation with high efficiency. However, all the published multiband designs that I could find used center feed. So the question became, "how can two parallel long wires be end-fed out of phase?"

the horizontal loop

I spent a long time experimenting with the horizontal loop antenna of **fig. 2**. A 40-meter length of wire formed into a loop presents a low impedance when its length is any multiple of a full wavelength: in this case it is resonant at 7, 14, 21, and 28 MHz. Unfortunately, the resonances follow the simple harmonic relationship only when the wire forms a circular loop. For more complex shapes, the resulting concentrations of inductance and capacitance disturb the relative resonant frequencies so much that an ATU is still needed for multiband operation. Furthermore, while the currents in opposite sides of the loop flow in opposite directions (as is required for "W8JK" operation) it is not possible to find a shape where the whole length of the opposite sides are spaced by the 0.1 wavelength to 0.25 wavelength that is desirable. For example, in the rectangular loop of **fig. 2**, although the *long* sides are spaced correctly there are also current maxima in the *short* sides, which are spaced by 1.5 wavelength at

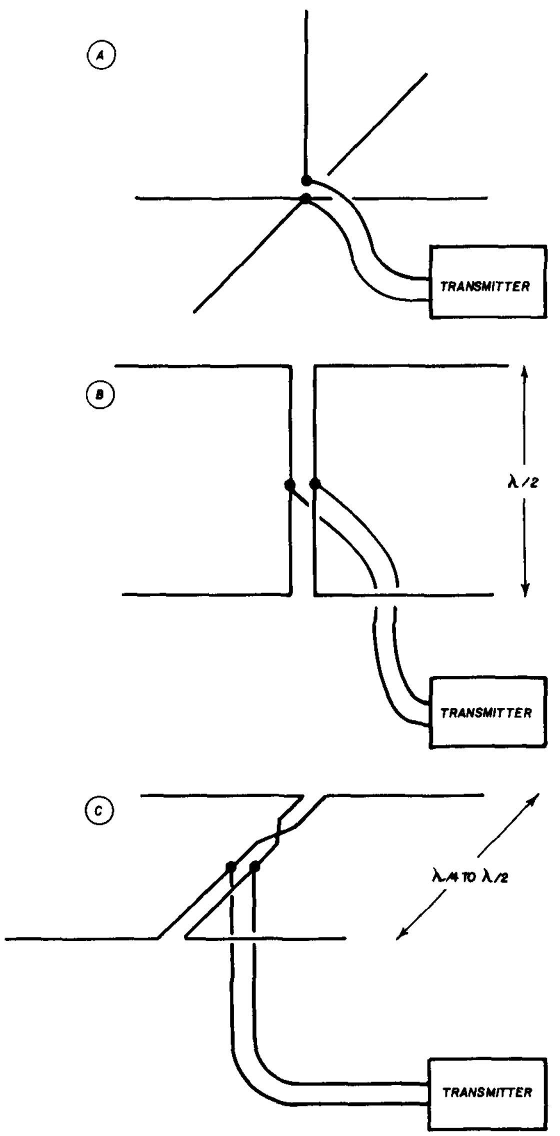


fig. 1. Basic antennas that don't radiate straight up or down: (A) vertical 1/4 or 5/8 wavelength with radials or groundplane; (B) horizontal dipoles ("lazy-H"), vertically stacked fed in phase; (C) horizontal dipoles (W8JK) horizontally stacked fed out of phase.

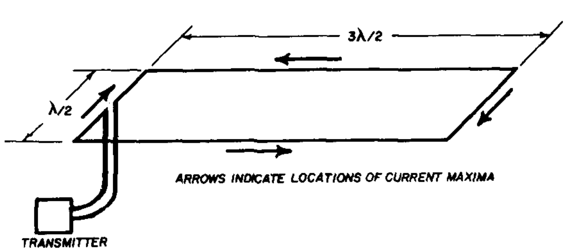


fig. 2. The 40-meter circumference horizontal loop antenna.

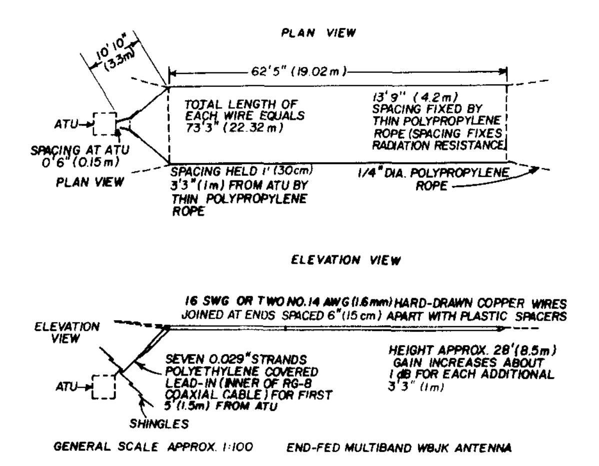


fig. 3. The end-fed multiband W8JK antenna.

30 MHz, and so provide strong horizontally-polarized end-fire radiation at directions 70 degrees above and below the horizontal plane, with a consequent loss of gain in useful directions.

the end-fed W8JK

At about this stage I read G6XN's book.[1] His words confirmed my faith in the W8JK type of antenna, gave me new insights about how to feed the end of an antenna, and provided useful cautions about the RF resistance of long wires. With confidence restored, I settled down to think about ways of eliminating the radiation from the short sides of the loop antenna, and came up with the arrangement of **fig. 3.** This retains both the basic horizontal radiation pattern of an end-fed long wire (2 wavelengths at 28 MHz: 1-1/2 wavelengths at 21 MHz and 1 wavelength at 14 MHz) and the gain of the W8JK, but has much reduced end-fire radiation. It will be seen that the far end of the loop has been removed altogether since it was not meeting its original objective of simplifying the tuning. The near-end "fan-out" from the ATU to the parallel wires has been shaped to minimize its end-fire radiation. The design of this section is based on study of the voltage distribution along either wire of the antenna, which is plotted in **fig. 4.** It can be seen that in every case the voltage is high, and hence the current is low, at a distance of about 19 to 21.5 meters from the open ends. It is in this region that the most rapid "fan out" of the feeder may be allowed without too much wasted high angle radiation.

antenna tuning unit

The length of each antenna wire is chosen so that at the highest design frequency (29.7 MHz), the antenna is resonant; that is the feed voltage is at a minimum. This occurs 22.32 meters from the open end; at this point the wires are terminated just inside the pitched roof of the house, at an antenna tuning unit that is in a dry location and easily accessible. In fact, at 29.7 MHz no tuning is required since the spacing of the parallel section of the antenna can be adjusted to obtain a radiation resistance of 50 ohms. At lower frequencies the effective length of the wires must be increased to obtain resonance; it can be seen from **fig. 4** that 1.5 meters must be added at 28 MHz, and about 2.4 meters and 4.3 meters, respectively, are required for 21 and 14 MHz operation. In practice this length can be added by the ATU in the form of adjustable series inductances. On the lower frequency bands radiation resistance decreases with smaller array size. On 14 MHz it was measured at about 25 ohms. However, the capacitance of the ATU and fan-out section can be chosen so that with the ATU inductance it forms a matching section that gives a low SWR on all three bands.

While a 2-gang roller inductor would be the ideal form of variable inductance to provide the balanced tuning network that is necessary, one was not available. Instead, "units" and "tens" steps of inductance were provided by two 2-gang ceramic wafer switches (driven by semi-rotary solenoids to be described shortly). As can be seen in the photograph (**fig. 5**) the coils

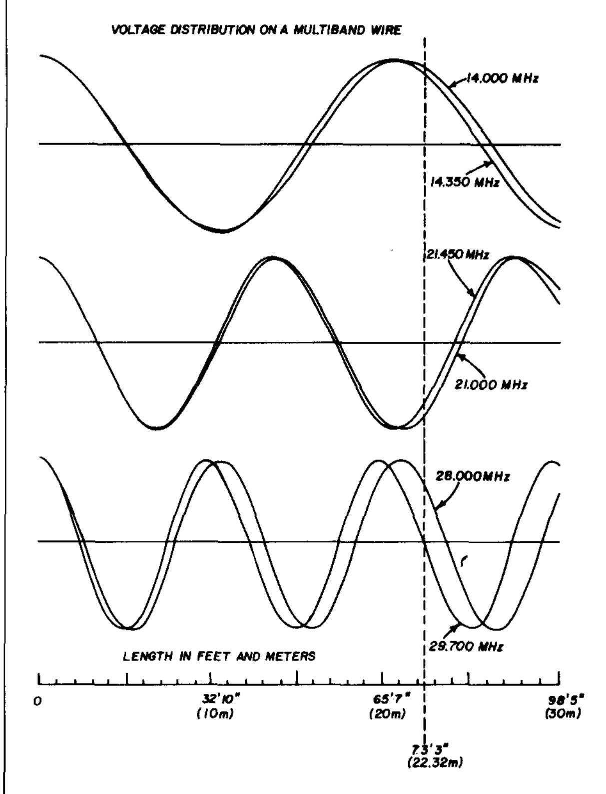


fig. 4. The voltage distribution along an end-fed long wire on the 20 meter, 15 meter, and 10 meter bands.

"Uncle Ben" Snyder, W2SOH the head man of

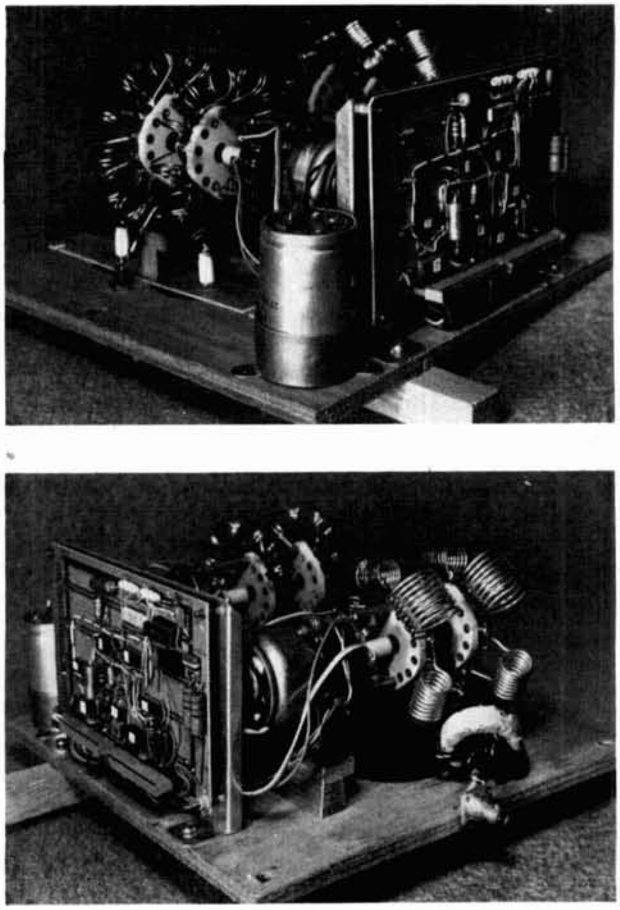


fig. 5. Side views of the remotely controlled antenna tuning unit.

are connected directly to the wafers, and the wafers spaced approximately 1.5 inches (40 mm) apart to optimize the stray capacitance. **Fig. 6** shows that an SWR of better than 1.4 can be obtained across almost all of the three bands by varying the inductance alone; no variable capacitor is necessary.

The RF circuits of the ATU are shown in **fig. 7**. Immediately next to the antenna connections are two lightning arrestor gaps, connected by a substantial conductor to a nearby copper water pipe. Next comes the "units" inductance providing up to 0.9 μH in nine switched steps. This is followed by the "tens" inductance, whose switch is wired so that unused inductor sections are short-circuited to avoid losses due to resonance with stray capacitance. The balun is of W1JR's original "supertoroid" design.[2] The criticisms of K4KJ do not apply to applications such as this where there is substantial capacitance to ground in the antenna itself.[3] The balun should be wound with 50 ohm cable to ensure that no reflection occurs at the connection to the main 50 ohm cable. This is the cable that leads from the ATU to the transmitter (which in my case, is also within the pitched roof some 33 feet or 10 meters away from the ATU).

The bandwidth of this antenna system is quite large on 10 meters, where little or no series inductance is used, and a single inductance setting may be used over a 200 kHz portion of the band. On 20 meters, however, it is necessary to change the inductance switch settings every 20 kHz or so. Control of the "tens" and "units" inductors is therefore provided by two thumbwheel switches at the transmitter. DC power and the multiplexed BCD thumbwheel settings are sent along an 8 conductor cable to the ATU and used to position the two inductor switches.

ATU control circuits

The solenoids that drive the ATU switches require considerable power for the short time that is needed

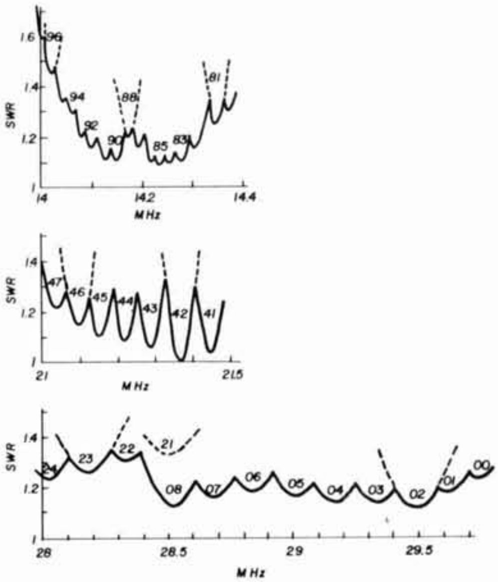


fig. 6. SWR plot achieved by the end-fed W8JK and series-inductance ATU. The numbers against each curve specify the 'tens' and 'units' inductance switch settings.

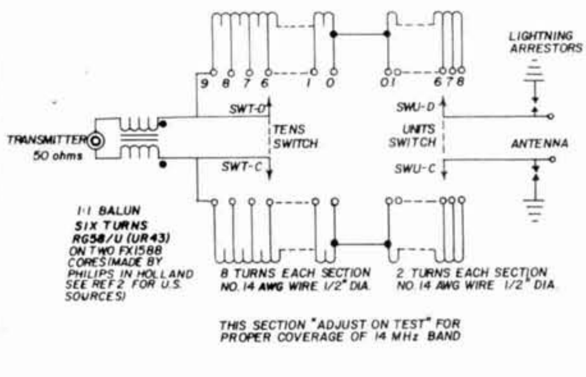
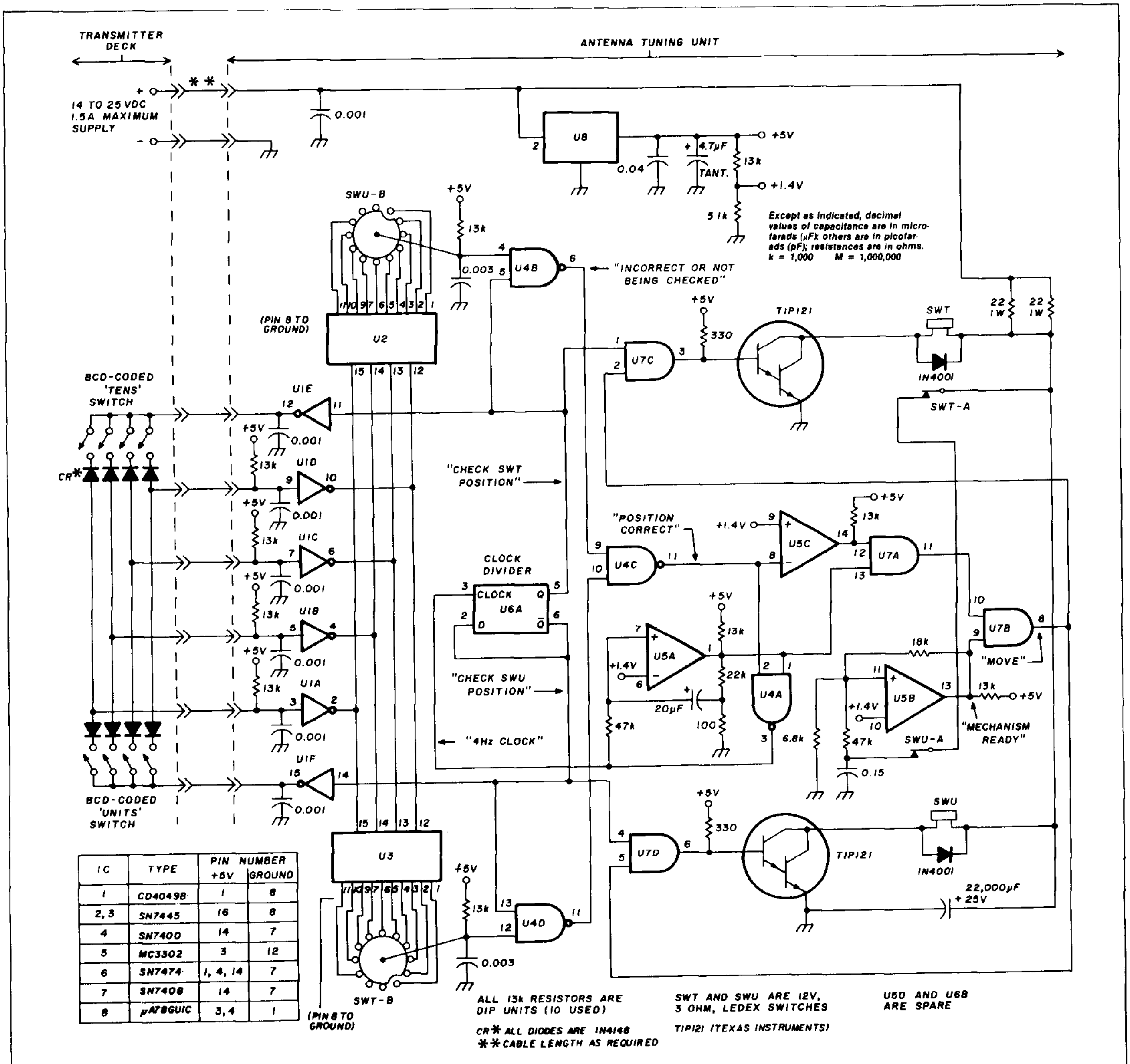


fig. 7. RF circuits of the series-inductance ATU.

to move the switch from one position to the next. The ones I used (SWT and SWU in **fig. 8**) need 4 amps at 12 volts, and so, to allow the use of thin telephone-type cable to the operating position, energy is stored at the ATU in a 22,000 microfarad capacitor. Circuit operation will be described with references to the "tens" switch SWT; operation of the "units" switch is similar but occurs on the other half-cycle of the clock waveform provided by divider U6A. When SWT is energized the solenoid pawl moves the switch ratchet to the next position and opens the interrupter contact SWT-A. In this circuit the interrupter contact tells the logic to turn off the power Darlington transistor that drives the solenoid; comparator U5B and its associated circuit then ensure that power cannot be re-applied until the pawl has returned to its rest position and the storage capacitor has been recharged to at least 14 volts.

The actual position of the "working" switch wafers SWT-C and SWT-D (**fig. 7**) is sensed by the all-but-one-connected wafer SWT-B (**fig. 8**) which is driven from the BCD — decimal converter U2. If the position is incorrect, then on the appropriate phase of the clock the output of U4C will be low. This stops the clock oscillator (U4A and U5A) and allows the solenoid to step repeatedly under the control of U5B until the correct position is reached. The clock oscillator then restarts, so that the position of the other sole-



IC	TYPE	PIN NUMBER +5V	PIN NUMBER GROUND
1	CD4049B	1	8
2, 3	SN7445	16	8
4	SN7400	14	7
5	MC3302	3	12
6	SN7474	1, 4, 14	7
7	SN7408	14	7
8	μA78GUIC	3, 4	1

fig. 8. Control circuits of the series-inductance ATU.

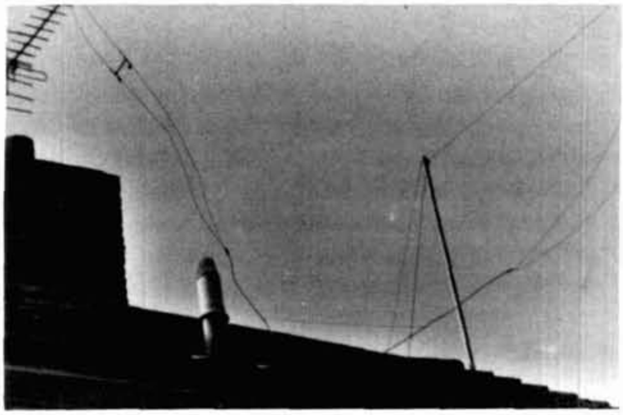


fig. 9. Feed-end of the antenna.

noid may be checked. To minimize interference that might be coupled into the antenna circuit, the clock oscillator is run at the lowest frequency that does not noticeably degrade the response of the circuit to changes of thumbwheel position — that is, 4 Hz. Consideration of the threshold levels resulting from the diode "or" circuit associated with the thumbwheel switches shows that a CMOS interface U1 must be used, even though the other circuits are all TTL. This is unfortunate, since the circuit is exposed to induced transients from lightning. It is recommended that a socket be used to mount the chip. The position-sensing switch wafers are not shielded from the high RF voltages on the working wafers; with 100 watts of RF it proved necessary to add the 3 nF capacitors to the rotors of SWT-B and SWU-B. Shielding is clearly desirable and would probably be essential with higher power.

choice of antenna conductor size

As previously mentioned, the radiation resistance at 14 MHz is only 25 ohms, and care is needed to ensure that resistive losses in the 44.64 meters of resonant radiating elements are not significant. The lowest frequency band represents the worst case, since measurement of this antenna has shown that the radiation resistance is roughly proportional to frequency, whereas the wire loss resistance due to skin effect only increases with the square root of frequency. With the two parallel No. 14 AWG (1.6 mm) conductors specified for each element (see **fig. 3**) the effective resistance is about 2.5 ohms giving less than 1 dB loss. The 1.5 meters of each element nearest the ATU are made from polyethylene-covered stranded conductors to provide good insulation and flexibility at the point of entry though the roof structure as shown in **fig. 9**.

conclusion

This antenna performs much like any other long wire; it would be difficult to make comparisons on the Amateur bands with sufficient accuracy to make any other claim. However, its losses are small and its directivity well defined, and therefore theory would suggest 3 to 5 dB gain relative to a dipole in the best directions. Its real advantages are the balanced end feed and multiband operation.

However, the principle of the tuning unit may be applied to many other antennas. What has been described is a way of using a single balanced variable to tune and match two long wire elements. It has been suggested to me that if these wires formed an Echelon array then one of the elements could be moved to provide steerable nulls. A "V" beam is possible, although the angle would have to be a compromise between the three bands. With the two elements co-linear, the design should display characteristics similar to the G5RV and offer the advantage of an alternative feed arrangement.

Finally, it may be noted that the antenna as described in **fig. 3** is also exactly resonant at 10 MHz, though its radiation resistance is very low and a different tuning arrangement is necessary.

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2. Joseph Reisert, W1JR, "Broadband Balun," *ham radio*, September, 1978, pages 12-15.
3. J.J. Nagle, K4KJ, "High Performance Broadband Balun," *ham radio*, February, 1980, pages 28-34.

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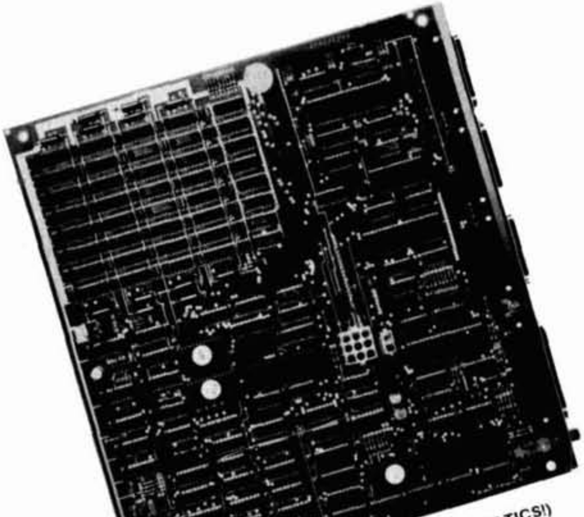

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the branch-line hybrid: part 2

At frequencies below 30 MHz, lumped constants offer less loss than coaxial cable to form compact hybrids.

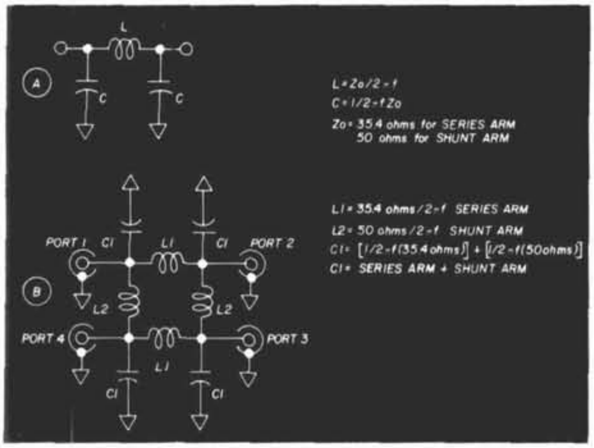

fig. 1. Lumped-constant branch-line coupler is formed with an artificial transmission line in series (A) and shunt (B) with each port.

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lumped-constant branch line

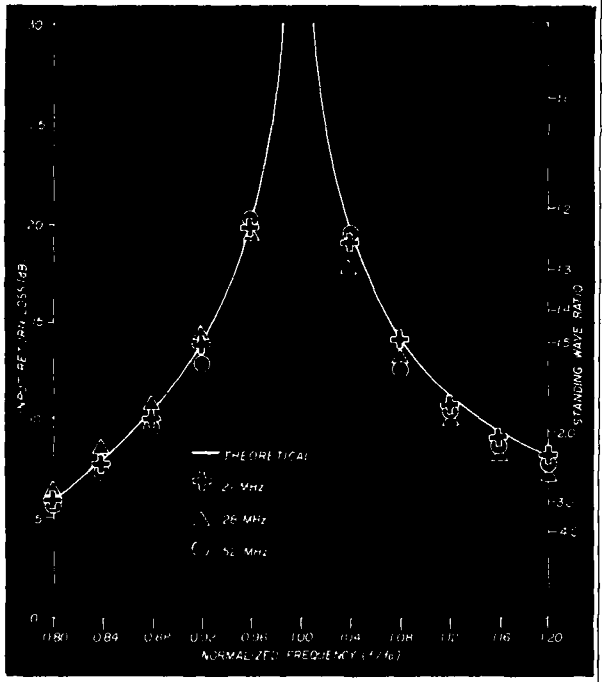
Below 100 MHz the coaxial cable form of a branch-line hybrid becomes excessively bulky. At these frequencies the branch-line hybrid can be formed using capacitors and inductors. An artificial transmission line may be formed using either the tee or π network. The π network is normally chosen because it functions as a lowpass filter. The inductance and capacitance values given in **fig. 1A** are calculated using the characteristic impedance of the transmission line. The single-section branch-line coupler (**fig. 1B**), is formed by two series and two shunt artificial transmission lines. Inductance L1 in the series line is calculated using the 35.4-ohm characteristic impedance calculated earlier. The 50-ohm shunt line is formed using L2. The capacitors, C, from each artificial line are added together to form a composite value, C1. The element values for a 3-dB 50 ohm branch-line hybrid are given in **table 1**. The theoretical and experimental response of the lumped-constant hybrid is shown in **fig. 2**. Note that the bandwidth is only slightly reduced from that in the transmission-line case. The curves are slightly skewed when using lumped constants.

The lumped-constant branch-line hybrid is adjusted by individually resonating the inductors with the shunt capacitances present at each port. Capacitors are well marked and can also be easily and accurately measured; therefore, only the inductors are trimmed. Values close to the calculated capacitance found in **table 1** are soldered in shunt with each port. Inductor L1 is then soldered from port 1 to port 2 to form a π network, as shown in **fig. 2A**. The coil is adjusted to resonance according to:

$$f = 1/\left(2\pi \sqrt{L1 \cdot C1/2}\right) \qquad (5)$$

By **Ernie Franke, WA2EWT**, 10484 138th Street, N., Largo, Florida, 33544.

fig. 2. Experimental results using a lumped-constant hybrid are very close to the theoretical values (solid line). *2A* shows input return loss vs. frequency; *2B* shows isolation vs. frequency; *2C* shows coupling versus frequency.



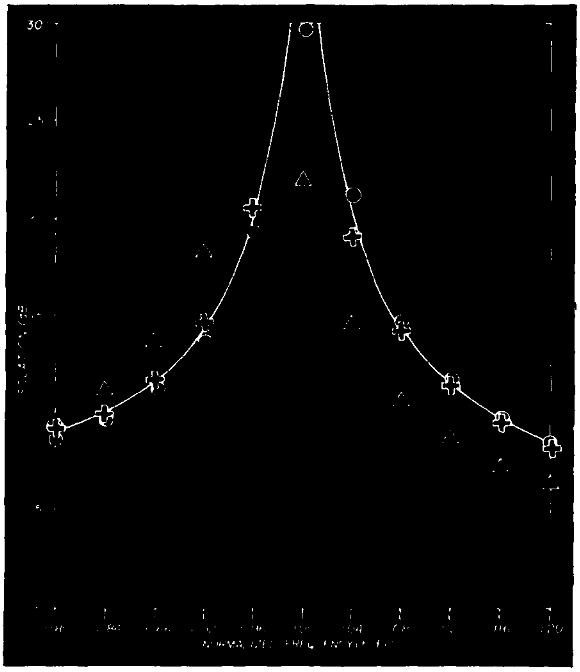


fig. 2B.

table 1. Lumped constant values for branch-line hybrids.

frequency (MHz)	L1 (nH)	L2 (nH)	C1 (pF)
3.75	1500.0	2122.0	2049.0
7.15	787.0	1113.0	1075.0
14.18	397.0	561.0	542.0
21.25	265.0	375.0	362.0
28.85	195.0	276.0	266.0
52.00	108.0	153.0	148.0
146.00	38.5	54.5	52.6
222.00	25.3	35.8	34.6

The *C1/2* term indicates that the *C1* capacitors are in series, with the center tap grounded and the inductor floating. For example, the series inductor in a 28-MHz hybrid should be adjusted to resonate at 31.2 MHz. Next, L1 is removed and L2 is placed between ports 2 and 3. A grid-dip meter is again used to resonate L2 with the series combination of the shunting capacitors. For the 28-MHz hybrid, the resonant frequency of the shunt arm is 26.2 MHz. After each coil is individually resonated, all are replaced, and the hybrid is ready for use. The experimental results shown in **fig. 2** were achieved by adjusting the hybrids in the above manner.

impedance transformation

Often it is required for a signal source to deliver two equal signals at loads other than 50 ohms. The input and output impedances of an RF transistor power amplifier, for example, are in the 1 to 10 ohm region. This impedance transformation may be incorporated directly into the branch-line hybrid. The series arm, as before, is made equal to the square root of the input impedance times one-half the output impedance. The

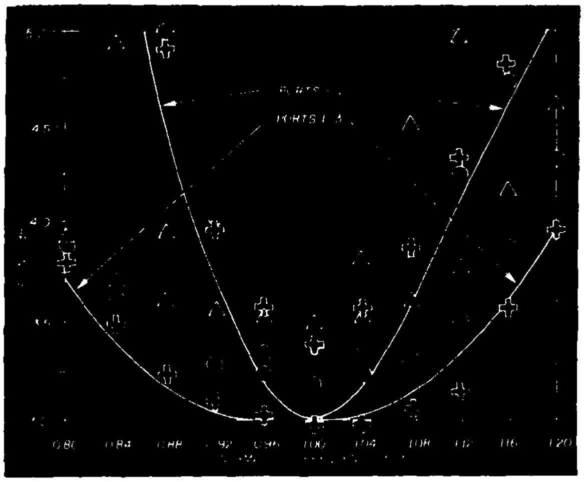


fig. 2C.

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one-half term occurs because the two output ports (2 and 3) are in parallel.

impedance ratio (ohms)	series arm (ohms)	shunt arm (ohms)
50/10 (5:1)	15.8	10.0
50/12.5 (4:1)	17.7	12.5
50/16.7 (3:1)	20.4	16.7
50/25 (2:1)	25.0	25.0
50/50 (1:1)	35.4	50.0

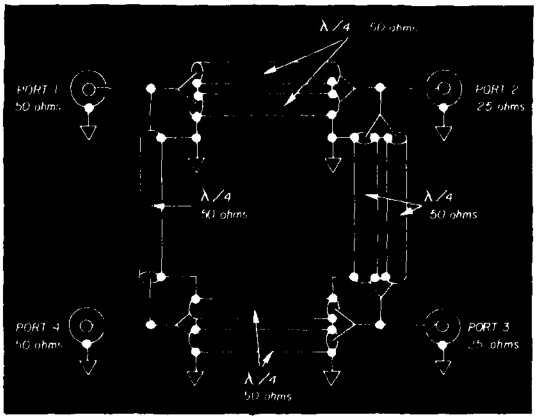
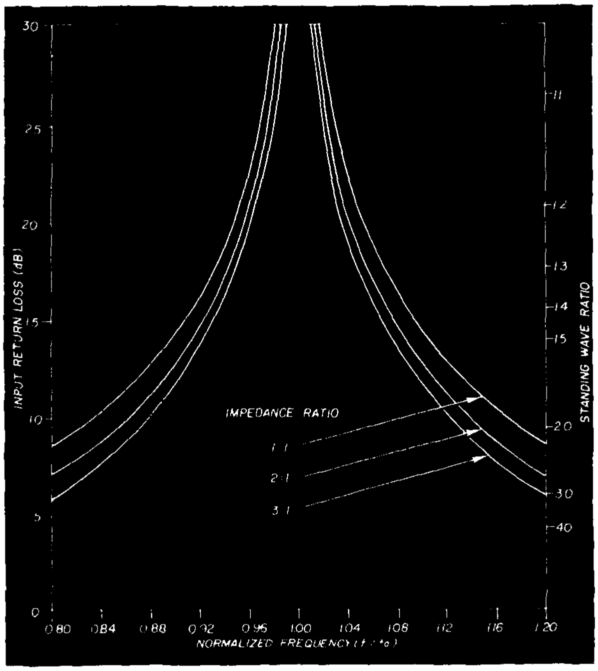


fig. 3. Common 50-ohm transmission line can be used to form a 2:1 impedance matching branch-line hybrid.

fig. 4. Theoretical response of transmission line branch-line hybrids used to transform 50 ohms to a lower value. *4A* shows input return loss versus frequency; *4B* shows isolation versus frequency; *4C* shows coupling versus frequency.



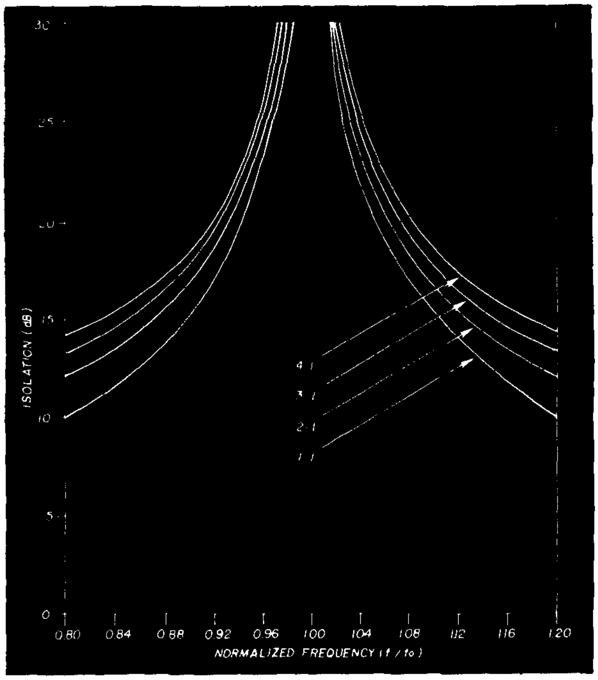


fig. 4B.

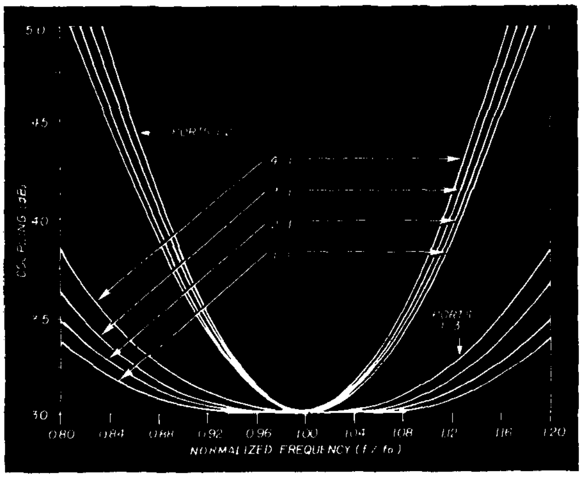
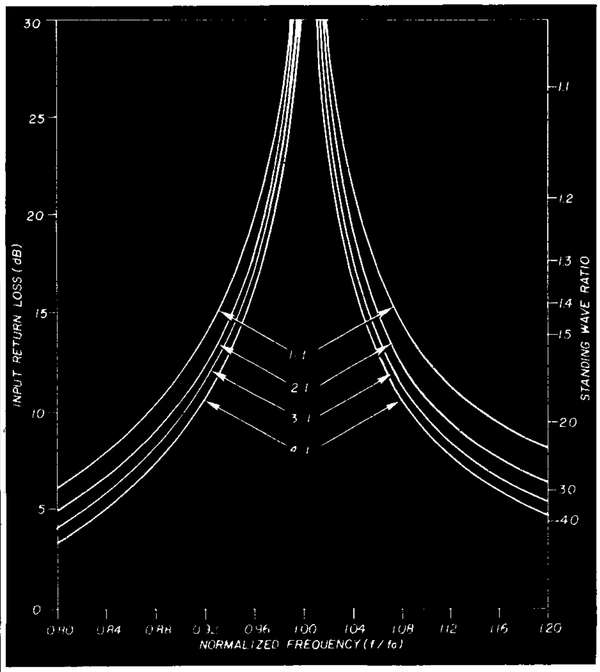


fig. 4C.

A convenient form of a 2:1 (50-ohm to 25-ohm) branch-line, impedance-matching hybrid is shown in **fig. 3**. The theoretical responses for several 50-ohm, input impedance matching branch-line hybrids are shown in **fig. 4** for various impedance transformation ratios. The response does not degrade significantly, even for an impedance matching ratio of 4:1.

Lumped constants can also be used to form artificial transmission lines for an impedance transforming branch-line hybrid. The theoretical response, (**fig. 5A**), fig. 5. Theoretical response of impedance-matching hybrids using lumped-constant components. *5A* shows input return loss versus frequency; *5B* shows isolation versus frequency; *5C* shows coupling versus frequency.



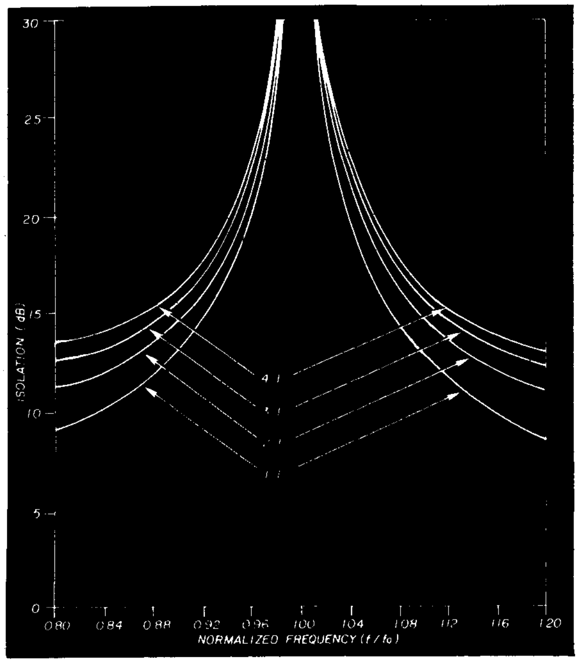


fig. 5B.

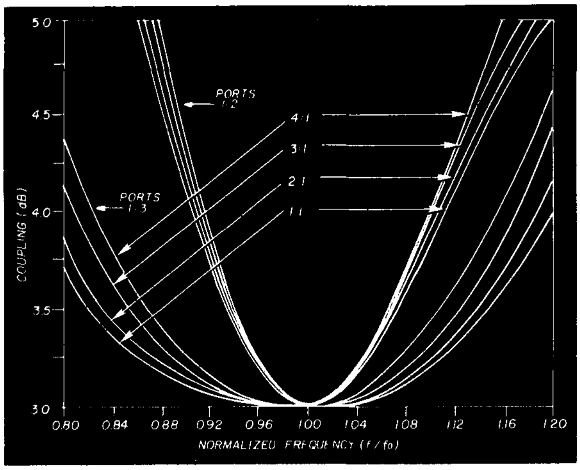


fig. 5C.

is only slightly degraded from that achieved using coaxial cable.

PIN-diode attenuator

The PIN-diode attenuator circuit,[3] **fig. 6**, is included to demonstrate that the input match remains constant despite large variations in the loads placed at ports 2 and 3. The resistance of a PIN diode decreases with forward bias. With zero bias current, the coupler behaves as a terminated hybrid with maximum attenuation from port 1 to port 4. As the diodes are forward biased, the resistance decreases. When each diode has a resistance of approximately 50 ohms, the attenuator has a loss of 10 dB, **fig. 7**; the diodes represent a mismatch. The reflected signals at ports 2 and 3 add in phase at the output, port 4, and out of phase to

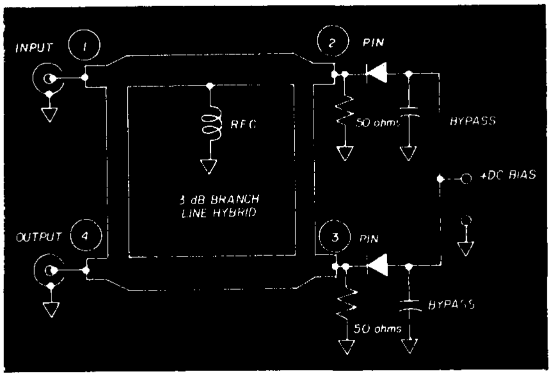


fig. 6. PIN diode attenuator with a constant input impedance of 50 ohms.

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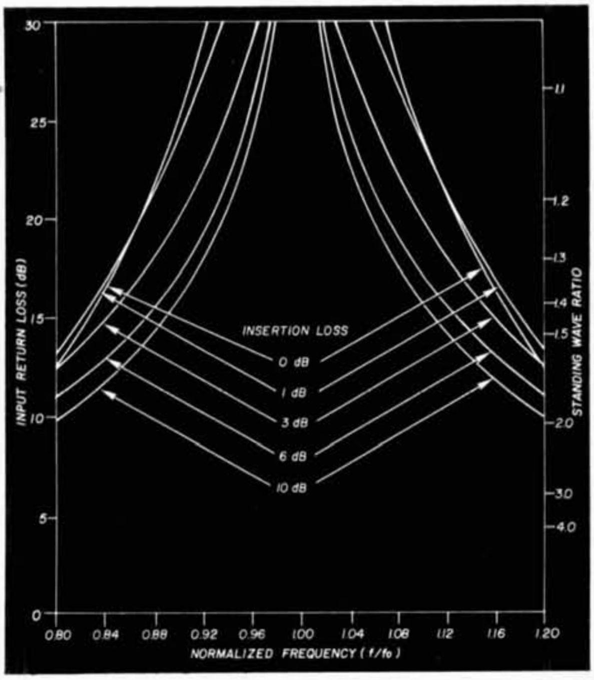
cancel at the input, port 1. As the bias is increased the loss of the attenuator decreases. When the PIN diodes' resistance is about 3 ohms, the loss decreases to 1 dB.

intermodulation performance

Even during a transmission the antenna operates as a receiving antenna for interference. Signals very close to the operating frequency, F_O, easily pass through



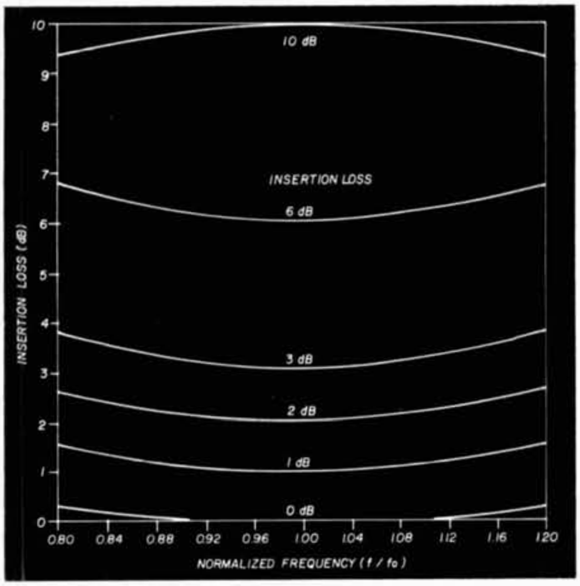
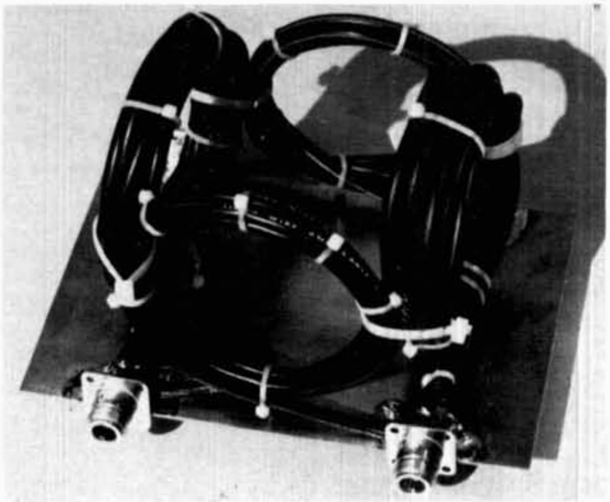
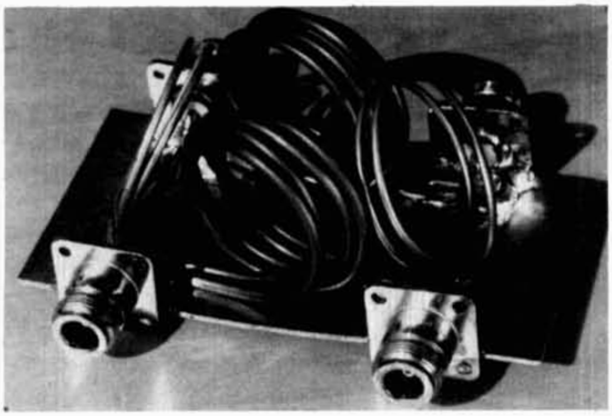


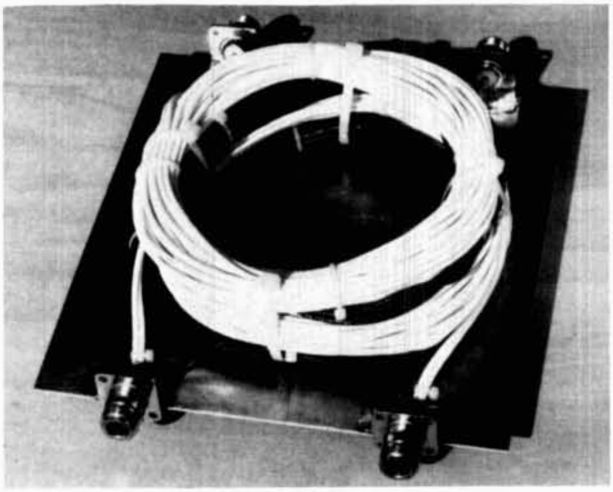
fig. 7. Input return loss remains greater than 15 dB (SWR $\leq$ 1.5) as the loss is varied between 0 and 10 dB.



At VHF frequencies, hybrids can be easily formed using several quarter-wave sections of 50 and 75-ohm coaxial cable.



For lower frequencies the semi-rigid cable must be coiled to contain the hybrid.



At low frequencies the loss in miniature coaxial cable increases the insertion loss.

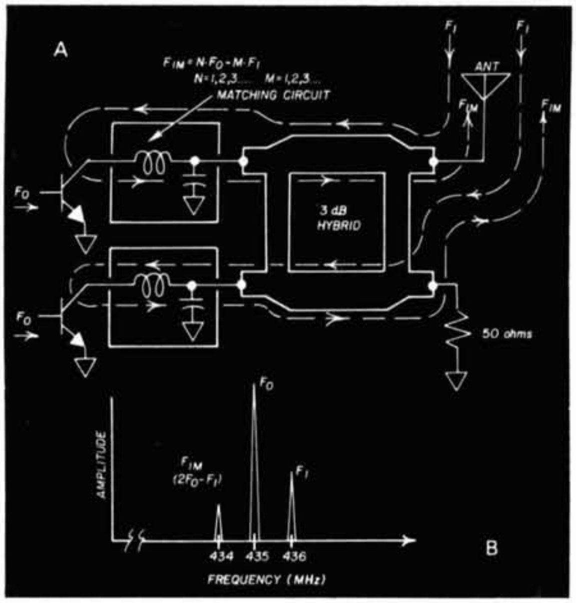


fig. 8. Intermodulation performance of a transmitter may be improved by adding a branch-line hybrid.

filters and arrive at the collectors of the final RF power transistors, **fig. 8(A)**. Because the final stage is operated Class C, mixing products are produced at these nonlinear transistor junctions. The most troublesome intermodulation product is produced by mixing the interfering signal, F_I, with the second harmonic of the operating frequency, **fig. 8(B)**. That is,

$$F_{IM} = 2F_O - F_I \qquad \textbf{(6)}$$

where F_{IM} is the intermodulation signal.

Because the collector ports of the branch-line hybrid[4] are offset by 90 degrees, the interfering signal must travel a quarter-wave longer from the antenna port to reach one collector compared with the other collector. The intermodulation product produced at the collector must also travel an additional quarter wave to reach the antenna port. Thus the intermodulation products from each collector will cancel at the antenna port because of the half-wave difference in round-trip paths.

references

1. James R. Fisk, W1HR, "Microstrip Transmission Line," *ham radio*, January, 1978, page 28.
2. Ernie Franke, WA2EWT, "The Hybrid Ring," *ham radio*, August, 1983, page 50.
3. Henry H. Cross, W1OOP, "Low-Noise Preamplifiers with Good Impedance Match," *ham radio*, November, 1982, page 36.
4. Ernie Franke, WA2EWT, "Capacitively Coupled Hybrids" *ham radio*, March, 1983, page 70.

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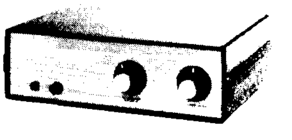

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More Details? CHECK—OFF Page 148

✓ 197

build a simple wire plow

Save time, effort with easy-to-build ground system installation aid

Any Amateur planning to erect a vertical antenna thinks long and hard about the labor involved in putting in the necessary number of radials. When I helped W7IR put in his radials, we used a small trencher, a tool used for installing the pipes for underground sprinkler systems. This worked fine, but it dug a trench much larger than was necessary for No. 14 wire, and replacing the soil after the wire was laid in was tedious work.

I had heard of the self-propelled wire plows used to install radials for broadcast stations, and I had seen one used in the installation of underground telephone lines. These tools simultaneously cut a slit in the ground and lay the wire. I wondered if it would be possible to make a smaller version of a wire plow that could be towed by a car or a garden tractor.

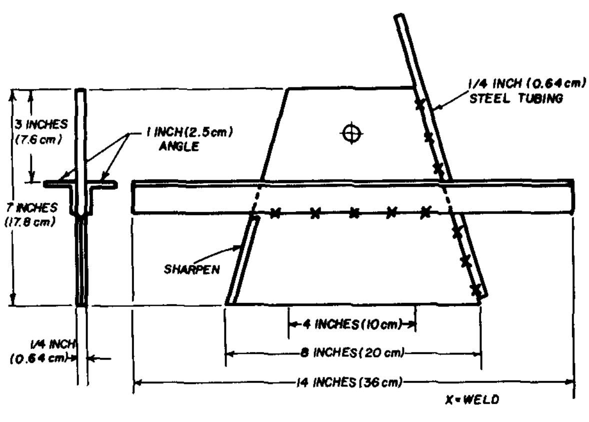

fig. 1. Construction details of wire plow blade.

My land was flat, reasonably unobstructed, and free of stones, at least to a depth of several inches. I convinced myself that the idea was practical. When I described my plans to friends at the local radio club, I got some skeptical comments, but my stubborn nature made me more determined than ever to go ahead. A little pencil-scratching produced a rough design, and the rest evolved as I went along.

Only the blade and some hardware had to be purchased. Everything else came from the scrap pile.

The blade, **figs. 1** and **2**, was cut from 1/4-inch (6.4 mm) sheet steel by a local blacksmith for $10. I drilled the holes for fastening it to the frame and sharpened the leading edge on a bench grinder. For the wire guide, I bought a length of 1/4-inch (6.4 mm) steel brake line from an auto supply store. A friend with a welding outfit tack-welded it to the trailing edge of the blade (**fig. 2**).

radials

I planned to put in 36 radials, spaced at 10 degree intervals. These would vary in length from 80 feet (24.4 m) to 120 feet (36.6 m), keeping them inside the property line. I found that I could buy 2000-foot spools of No. 14 bare copper wire (**fig. 3**) from an electrical supply house.

The first thing to do was calculate the points at the edges of the property where the radials would terminate; then, with a 100-foot (30.5 m) tape measure and a friend's help, drive stakes at these points. The radials would be laid from the stakes toward the center, where a concrete pad had been poured for mounting the antenna.

plowing begins

I will admit that it was with some trepidation that the actual wire plowing was begun. I had invested a lot of time and labor in building the plow. Would it work?

At the first stake, W7IR and I dug a small hole, just large enough for the blade to enter the soil to its full depth. We drove a wooden stake into the hole and fastened the end of the wire to it (**fig. 4**).

I connected the plow to the trailer hitch on my car

By **Harry R. Hyder, W7IV**, 1638 Inverness Drive, Tempe, Arizona 85282

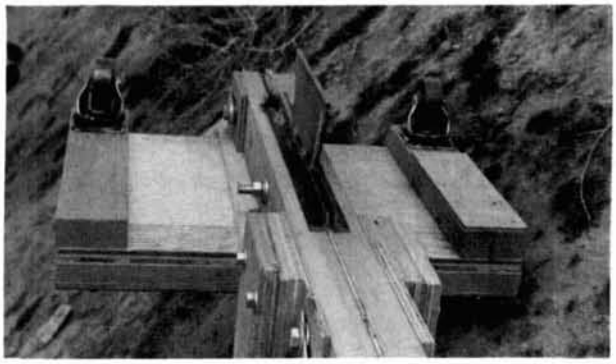

fig. 2. Bottom view shows blade, tack-welded to angle iron screwed into position. Wire guide tube is welded to trailing edge of blade (foreground).

with a tow cable. W7IR steered the plow (**fig. 5**). I shifted the car into its lowest gear and inched forward. After a few feet I stopped, jumped out, and ran back to see how it as going.

It was working perfectly!

We laid half of the radials that morning, and completed the job the following Saturday. It took less time to install all the radials than it took to build the plow.

Only one minor problem emerged: during construction of my house, the builders had buried some chunks of concrete, and these had to be removed before the plow could proceed.

There was no reason to fill in the narrow slits left by the plow. Natural erosion took care of this, and after a few months they were barely visible.

securing the radials

In attaching the radials to the large sheet of copper on top of the concrete pad, I discovered that the copper sheet made a wonderful heatsink. My largest soldering iron — at the end of 200 feet of extension cable — could not solder the radials to the copper. A propane torch worked fine.

Another problem developed after the radials had been installed, but before the antenna was erected. The local telephone company, with their king-size wire plow, took a shortcut across the back of my property while laying a cable. While there was an eight-foot (2.5 m) easement running along the rear property line, specifically for utilities, they ignored this and cut several of my radials. (My radials did not extend into the easement.)

Afer working my way up through the telephone company bureaucracy, I was finally able to extract a promise that their cable would be relocated to its proper position; they did so a few months later. I chose to splice the severed radials myself.

Whether you can use a plow like mine depends on your circumstances. If your property is rocky and full of trees and brush, forget it. If it is clear with only light cover, the wire plow will work fine. It's a lot easier than using a pick and shovel!

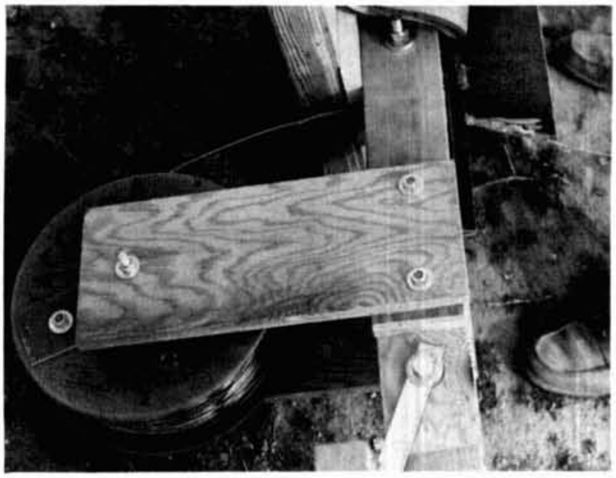

fig. 3. Wire is fed from mounted spool through guide tube into trench.

fig. 4. Wire plow in position over starting hole. Handle guides plow; 100-pound sandbag provides necessary weight.

fig. 5. W7IR, shown here, guided plow while author drove 4 × 4 in low gear; plow can also be pulled by garden tractor or conventional auto.

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VHF/UHF WORLD

Joe Reisert W1JR

In my February column,[1] I broached the subject of antenna performance but space did not permit a full treatment at that time; therefore, — and because this month's issue is dedicated specifically to antennas — I'll discuss several ways to determine antenna performance and offer some tips on how to obtain peak performance from the antennas you are now using.

performance parameters

When it comes to measuring antenna performance, most Amateurs measure only VSWR, and in the case of a rotary beam, front-to-back ratio. Consequently, commercial antenna manufacturers usually try to make sure that these parameters are good. All other specifications of a commercial antenna (or someone else's design you are duplicating) have to be accepted more or less on faith! This is unfortunate; you're at the mercy of the designer and may not be obtaining the performance you think you are.

Gain is surely one of the most important antenna parameters. However, other antenna parameters such as beamwidth, front-to-back ratio, side lobe level, VSWR, feed system, wind load and structural strength are likewise important and may be indirectly linked to gain. With this in mind, I will try to give you some guidelines to evaluate antenna performance as well as various measurements you can perform with a minimum of test equipment. Finally some rules of thumb and graphs will be presented that can help you approximate the gain and performance of your antenna or antenna system *even without test equipment*!

Gain. There is probably no other antenna parameter that is more widely discussed and confused by Amateurs than gain. *Gain is the property of an antenna which enables it to direct or radiate power in a desired direction as well as to receive signals from that same direction.* Note that when transmitting, an antenna doesn't really amplify or change the signal as in a power amplifier but does affect the direction of radiation similar to using a passive voice megaphone. Likewise, when receiving the antenna discriminates against noise and signals from undesired directions by not focusing on them. However, gain is a relative quantity that cannot be defined in terms of physical quantities such as watts or volts. Hence, gain must be referenced to something such as a dipole or an isotropic radiator (a theoretical antenna that radiates power equally well in every direction).

Herein lies the problem. *An isotropic radiator does not exist* (more on this later), but dipoles do! A lossless dipole has a theoretical gain of approximately 2.15 dB over an isotropic radiator, but a dipole is an extremely poor reference because it radiates power in many directions other than the desired one. This is why reflections from local objects, reflections from the ground, height above ground, and many other factors enter into the measurement of gain over a dipole.[2]

However, all is not lost! Over the years, VHF/UHF antenna manufacturers have developed acceptable gain standards that are accurate if properly used. The most common reference used by VHF/UHF Amateurs is the "EIA (Electronic Industries Association) Standard Antenna"[3] originally designed by Richard F.H. Yang.[4] It consists of two $\lambda/2$ dipoles which are spaced $\lambda/2$ apart and located $\lambda/4$ above a square groundplane with one-wavelength sides. It is easily duplicated and often used at antenna gain measurement parties (more on this subject later) on 432 and 1296 MHz and has a gain of 7.7 $\pm$0.15 dBd (dB over a lossless dipole) or 9.85 dBi (dB over an isotropic radiator). This antenna is often confused with the "NBS Standard Gain Antenna,"[5] which is considerably larger and has a gain of 9.31 $\pm$0.2 dBd. On the microwave frequencies accurate pyramidal standard gain horns[6] specified in dBi are usually used because they can be accurately designed and tailored to the desired reference gain. *It really doesn't matter whether we reference gain to a dipole or an isotropic radiator as long as we indicate what the reference is!*

Beamwidth. This is probably the most important parameter because it tells you how wide an area you are transmitting to and receiving from. It should be intuitive that in order to increase gain, the beamwidth of the antenna must become narrower. Wide beamwidth implies low gain and narrow beamwidth suggests high gain.

You cannot have high gain with wide beamwidth! It will be shown later in this column that the beamwidth parameter of an antenna can be used to mathematically determine gain.

Front-to-back ratio. This is a frequently quoted but somewhat elusive parameter. Yes, high front-to-back ratio does imply a high gain, but this is not necessarily the only important parameter for high gain. In fact, small (2 to 5 elements) Yagi antennas optimized for gain frequently have higher gain when the front-to-back ratio is only 10 to 15 dB.[7] Likewise, once the front-to-back ratio exceeds 20 dB, further increases will have little or no effect on gain or noise temperature since the rear signal is already so far down from the front one. It must also be remembered that the front-to-back ratio is measured over a small angle to the rear of the antenna and can be difficult to measure accurately due to its narrow angular width and reflections from other objects in your local area. High front-to-back ratio will, however, cut down QRM from strong local stations directly off the rear of an antenna.

Side Lobes. It wasn't that many years ago that side lobes on common Yagi type antennas were only 10 dB down from the main lobe. A typical "E" plane (azimuth) pattern on a widely used 144, 432, and 1296 MHz Yagi antenna is shown in **fig. 1.**[8,9,10] Unfortunately, the presence of side lobes on an antenna pattern is almost a fact of life. The higher the gain of an antenna, the more likely you are to have a greater number of lobes. *What is really important is how far down these lobes are with respect to the main beam, because they represent additional signal and noise pickup as well as lower gain.*

Fortunately the NBS Yagi designs[7] (an NBS 4.2λ Yagi's E plane pattern is shown in **fig. 2**) and other more modern techniques,[11] sometimes involving computers,[12] have improved design parameters, especially on Yagi antennas. Suffice it to say that it is desirable for serious work to have side lobes down at least 13 to 15 dB from the main forward lobe. What isn't always considered is that there may be numerous side lobes and therefore *it is desirable to have all side lobes — not just the first one — down as far as possible, especially for EME operation.*

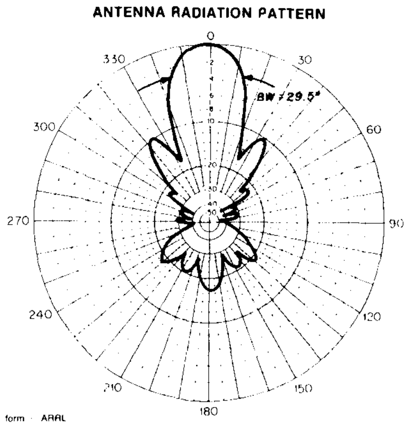

fig. 1. "E" plane plot of W2NLY/W6QKI 13-element 144 MHz Yagi. (See text and references 8, 9, and 10.) Note that beamwidth in "E" plane is approximately 29.5 degrees, and that the first side lobes are down only −10 dB. "H" plane beamwidth is the same (plotted on ARRL antenna radiation pattern paper.)

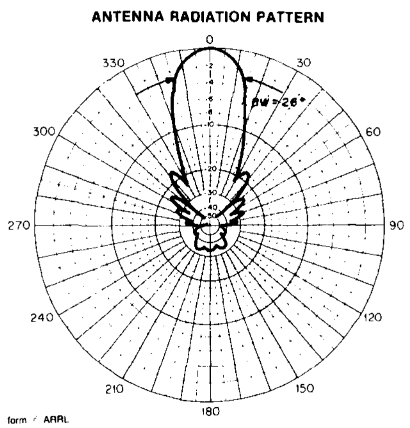

fig. 2. "E" plane plot of NBS 4.2λ 15-element Yagi adapted from reference 7. Note that the beamwidth is 26 degrees and "H" plane, not shown, is 29 degrees. First side lobes are down approximately −18 dB. (Plotted on ARRL antenna radiation pattern paper.)

VSWR. Antenna experts may tell you that you don't have to have a good VSWR to achieve full performance. However, VHF/UHFers have some slightly different problems than HFers do mainly because of mismatch losses. Let me be more specific. In the typical VHF/UHF station, 1-2 dB transmission line losses are quite common. If your antenna VSWR is 3:1, there will be an additional mismatch loss of 0.5 to 0.8 dB.[13] Therefore, your actual transmission line loss will be 1.5 to 2.8 respectively! Good VSWR is particularly desired when two or more antennas are stacked and fed with an in-phase power divider. Furthermore, a mismatch can frequently cause the noise figure of a low-noise preamplifier to increase since the preamplifier is no longer "seeing" the optimum source impedance it was designed for. Fortunately this parameter is seldom a problem nowadays, since low VSWR (1.2:1 typically) is quite common on most VHF/UHF antennas in use.

Feed System. Most VHF/UHFers agree that for best performance, an antenna should have a balanced feed system. Gamma and similar unbalanced matching systems can cause problems such as radiation from the feedline or assymmetry in the antenna pattern — two things we don't want! In the last few years, I have been doing some testing on various feed systems for Yagi antennas. Over all, I feel that the optimum feed system is a "T" match with a built in λ/2 coaxial type balun. Feed systems and baluns are covered in detail elsewhere[14] so I will not spend any more time on them in this column.

Wind Load. The modern VHF/UHFer is starting to challenge the HFers when it comes to antenna size. As a result, more attention has to be paid to wind survivability. Suffice it to say that *the optimum antenna should have the least number of elements necessary to attain the electrical specifications,* especially when stacking is employed. Don't forget that the wind load will increase rapidly when a large diameter stacking frame is used. In this respect, it may be prudent when selecting Yagi antennas to use the fewest number of long Yagis rather than a larger number of smaller models. Only by calculating the overall wind load on the array[15] can you be sure that your tower and rotator will adequately support the antenna.

Structural Strength. It wasn't too long ago that VHF/UHF Yagi antennas were almost always constructed with heavy-wall tubing. Nowadays it is becoming more popular to use various lengths of thin-wall tubing. As a result, more attention must be paid to tubing diameter, wall thickness, tubing overlap, and the hardware used to connect sections of tubing. Often overlooked is the fact that a 25-30 percent smaller width square tubing may have the same strength as its round cousin. Square tubing is usually much easier for the homebrewer to drill. Trusses are strongly recommended on long antennas especially where wind and ice are prevelant. Never skimp when choosing adequate size bolts and nuts with lockwashers. Stainless steel hardware, despite its initial higher cost, is highly recommended because it will not rust out at the least desirable moment!

Preventive Maintenance. One area in which I think we are all lax is in preventive maintenance. Time should be scheduled at least once a year for checking all bolts and nuts for tightness as well as cleaning corroded joints. All connectors should be checked for moisture or corrosion as well as coax shield integrity. I've had good luck keeping water out of connectors by using "Coax Seal."® One problem I've noticed over the years is "center pin creep," particularly on "N" and "LC" connectors, especially when extreme temperature variations are encountered. After connectors are in place for a while, and definitely where some pulling or twisting is present such as on a cable going around a rotator, the center pins may push forward or pull back. At the least opportune time the pin may disengage or break the connector pin to which it is mated.

There are two reasons why I've covered so much background material in this month's column. The first is that I wanted you to be aware of all the areas that should be considered in the selection of a VHF/UHF antenna, whether it be homebrew or purchased. The second reason is that certain parameters can be used to determine other parameters. Furthermore, in some cases you may be able to substitute tests or just evaluate a data sheet parameter to determine other performance data on an antenna *but only if these parameters are well understood*! Read on.

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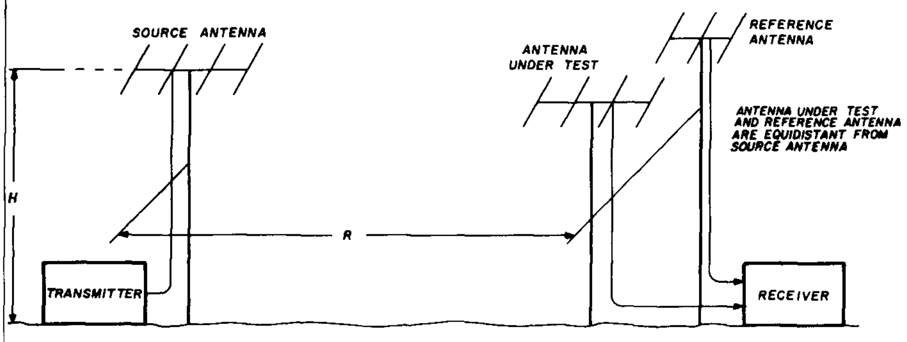

fig. 3. Typical VHF/UHF antenna test range. (See text for explanation of R and H test equipment.)

making measurements

Antenna Gain. This is probably the parameter you are most interested in testing. Gain can be measured on an antenna range. (A typical antenna range is shown in **fig. 3.**) A low-power transmitter is set up at one end and the antenna under test at the other end of the range. The transmitter is usually low power (1 watt maximum) with 1 kHz amplitude modulation. Typical circuitry has been published [16] for 144 MHz, and other frequencies through 432 MHz can be generated using the circuitry in my column in the March, 1984, issue of *ham radio* [17]. Note that the distance between the transmitter and receiver, "R," should be at least $2D^2/\lambda$ where D is the largest aperture dimension of the antenna and λ is the free space wavelength in the same units as D. I find that this yields only a 1.0 dB accuracy and hence I recommend $10D^2/\lambda$, which should yield 0.2 dB or better accuracy. "H" is the height of the source antenna and is described in detail in reference 2.

Basically what takes place is that the antenna under test is compared to the gain of a reference standard or antenna with a known gain, as discussed earlier in this article. Then the difference in gain between the two antennas is added to or subtracted from the reference as required to obtain the true measured gain. Many factors must be taken into consideration, but they are all well documented elsewhere.[2,18]

I want to point out that many VHF/UHFers have become quite competent at measuring gain and their results have been quite instrumental in making antenna designers "more honest" when it comes to gain specifications. We are very fortunate here in the USA in that antenna measuring parties are becoming quite common. They are usually held at various conferences such as the Central States VHF Conference, the West Coast VHF Conference, the Eastern VHF/UHF Conference, and more recently, at the Dayton Hamvention (did I miss anyone?), *weather permitting* of course. Therefore, if you want to measure the gain of your favorite antenna, attend one of these gatherings and see for yourself how the tests are conducted, as well as how your antenna stacks up against the competition!

So, you say, how do I measure antenna gain without assembling all this test gear? I'm glad you asked. There is a way you can obtain reasonable performance evaluation using your own equipment. You'll note that earlier I mentioned the importance of knowing the half-power (−3 dB) beamwidth of your antenna because it is the most important parameter in terms of actual antenna gain. Measuring the beamwidth of an antenna is not a difficult task if you have a rotator with reasonable relative accuracy in the azimuthal plane.

It almost takes longer to explain the test procedure used to measure beamwidth than it takes to do the actual test. The idea is to first peak your antenna on a test signal such as a local Amateur *not on an obstructed path,* preferably near the frequency of interest (±QRM!). Note this reference level on your receiver "S" meter. Then rotate the antenna until the signal drops by 3 dB or about one half an "S" unit. This should be done as carefully as possible to maintain accuracy. Carefully note the direction. Now rotate the antenna toward the other direction, through the peak, and note the half-power point on the other side of boresight (boresight as in "straight ahead," and in this case, maximum response). Subtract the readings to obtain the true half-power beamwidth of the antenna under test. Then check how far down the first side lobes are and note this value for future reference.

The easiest way to insure "S" meter calibration accuracy of the half-power point is to place a 3 dB attenuator pad (as described below) in your IF line. (Note that attenuator accuracy is usually easier to obtain at lower frequencies). However, you can put the attenuator at the antenna input to your receiver if you have an accurate pad for the frequency of interest. For more accurate results, it is better to use three separate 3 dB pads, one ahead of, and one behind the reference pad as shown in **fig. 4**. This insures that the 3 dB reference is relatively unaffected by any impedance mismatches on the line.

An improvement in accuracy can usually be obtained by reversing the procedure as follows: first place the reference 3 dB attenuator in the line per **fig. 4** and peak your antenna on the signal of interest, noting the reading on your "S" meter. Next remove this attenuator. The signal will increase, hopefully by 3 dB, but the reading is not important. Next rotate the antenna to either side of boresight until the meter returns to the original value before the attenuator was removed. The rotator directions indicated are the −3 dB points.

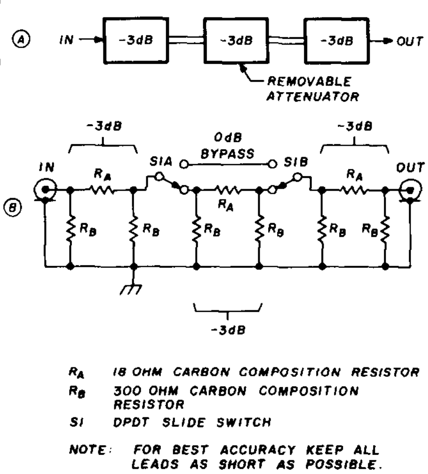

fig. 4. Recommended calibration attenuator: (A) with coaxial attenuator pads, and (B) with homebrew switchable attenuator.

If this test is too difficult or too time-consuming to perform, you may want to try a less accurate but faster method. Basically you modify the above procedure this way: first peak the antenna on the test signal and then rotate the antenna in either direction for the first null. Note the direction of the null and rotate back through boresight for the corresponding null on the other side of the pattern. Subtract the rotator readings. The antenna 3 dB beamwidth is approximately 47.5 percent of the difference between nulls.[19] For example, if the first nulls are 60 degrees apart, the approximate 3 dB beamwidth is 28.5 degrees.

Finally we're ready to apply your test results to see what the gain of your antenna really is! Many years ago John Kraus, W8JK, pointed out that the gain of an antenna could be roughly approximated if the "E" and "H" beamwidths of an antenna were known.[20] He also noted that the method was accurate only if the antenna beamwidth is narrow (less than 27 degrees), the side lobes are low (greater than 30 dB down), and the feed system is highly efficient. The equation he derived is:

$$G = \frac{41253}{\theta_E \times \theta_H} \qquad (1)$$

where G is the directivity gain as a numeric (Gain in dB = 10 $\log_{10}G$) over an isotropic antenna and Θ_E and Θ_H are the antenna −3 dB beamwidth in degrees in the horizontal and vertical plane.

Over the years this equation has been widely accepted by the professional antenna community where −20 to −30 dB side lobes are quite common. This formula also seems to be usable over a much greater range of beamwidths than originally intended with surprising accuracy if the side lobes are low. I have noticed that if you use the following equations, you can also account for side lobes and thus improve accuracy even further.

$$G = \frac{38400}{\theta_E \times \theta_H} \quad \text{for } -25 \text{ dB side lobes} \qquad (2)$$

$$G = \frac{35000}{\theta_E \times \theta_H} \quad \text{for } -20 \text{ dB side lobes} \qquad (3)$$

$$G = \frac{32600}{\theta_E \times \theta_H} \quad \text{for } -15 \text{ dB side lobes} \qquad (4)$$

$$G = \frac{30000}{\theta_E \times \theta_H} \quad \text{for } -10 \text{ dB side lobes} \qquad (5)$$

To save you some time and math I have drawn a graph (**fig. 5**) which includes not only the answers to **eq. 1** directly in dBi, but also includes the answers to **eq. 5** for −10 dB side lobes. You can easily interpolate for intermediate side lobe levels or just use the appropriate equation above.

Let's take a few examples to see how this system works. In **fig. 1**, we see that the beamwidth of this once-popular Yagi antenna is approximately 29.5 degrees and the side lobes are down approximately −10 dB. Now locate 29.5 degrees on the graph in **fig. 5**. If we were to ignore the side lobes (as the original authors did in reference 8), and use the upper line, the gain would be 16.8 dBi or 14.65 dBd. However, if you account for the side lobes per **fig. 5**, and therefore use the

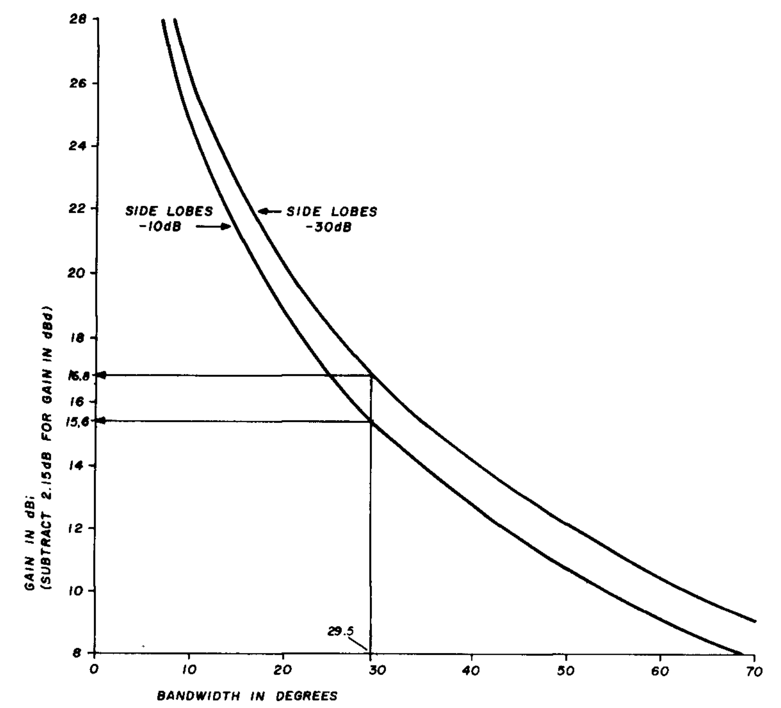

fig. 5. Beamwidth versus gain for antennas with square aperture and −30 dB side lobes or −10 dB side lobes. (See text for example shown.)

lower line on the graph, the gain is only 15.4 dBi or 13.25 dBd, a gain figure that was often measured on this Yagi on a good antenna range.

Next let's look at the NBS 4.2 λ Yagi in **fig. 2** which has a 26 degree beamwidth and −18 dB sidelobes. Using the upper line on the graph for no side lobes we see a gain of 18 dBi or 15.85 dBd but using **eq. 4** for 15 dB side lobes we obtain 16.83 dBd or 14.58 dBi. So you say NBS claims 16.35 dBi or 14.2 dBd? Well, I've left out one small factor. Some antennas do not have the same beamwidth in both planes. The error, however, is usually slight for antennas with rectangular apertures such as the Yagi. The "H" plane beamwidth for the NBS 4.2 λ Yagi is actually 29 degrees. If we go back and recalculate these numbers using **eq. 4** we obtain a gain of 16.35 dBi or 14.2 dBd. Not bad accuracy for just using simple equations!

As you've probably surmised, you needn't go through all this testing if you have accurate antenna data. In this respect, the commercial antenna manufacturers and Amateur designers usually include beamwidth data since it is easy to measure accurately. Now you can check the gain figures claimed and see how honest they are! (Always make sure that you use the correct data since some sources quote *half-beamwidth*. In this case, just double the number and proceed as shown above. And remember, is the gain quoted in the optimistic *dBi* figure or the lower *dBd*?

Other Testing. The front-to-back ratio can be tested using the methods above but may be influenced by local reflections and the accuracy of your rotator. If it is over 15 to 20 dB down from the main lobe, it is probably acceptable. VSWR, on the other hand, should always be tested before the antenna is raised to its final resting point as mentioned in the next section. Use a good VSWR indicator, not the "Monimatch" type. I recommend that you buy or borrow a Bird model 43 or equivalent with the appropriate power slug. If VSWR is not 1.2:1 or better, try to adjust the match until the optimum is attained. If it's above 1.5:1, you probably have trouble and better find the problem and fix it before placing the antenna in its final location!

Caveat Emptor. Sometimes commercial manufacturers make errors. This can sometimes be irritating even when the problem is simple and easily detected, such as in the case of a missing part. It's the undetected errors that cause real inconvenience — such as a wrong element length, for example, or a hole drilled in the wrong place in the boom. It is very easy to assemble directors on a Yagi improperly when the elements do not taper in a linear fashion. Nowadays most antenna manufacturers include mechanical drawings with element lengths and spacings clearly marked. *After final antenna assembly check carefully to see that all dimensions agree exactly!* If they don't, try to locate the source of the problem. If it is not obvious, contact the manufacturer and *get the problem resolved before you put the antenna on a tower.*

Let me share with you some problems I've encountered over the years so that you'll be alerted to things that can and do happen. One manufacturer copied another's design, forgot to correct the element lengths for a different element attachment method, and therefore had very high side lobes. Another drilled a boom improperly and thereby placed one director several inches off the proper location, causing high VSWR and poorer pattern. Another apparently had a mechanical resonance in the boom. The forward boom section would vibrate at certain wind speeds and eventually fall off because of metal fatigue. This was easily corrected by placing some weight inside the boom to dampen the effect.

One manufacturer uses end caps on certain elements. Neglecting to use these or having them fall off after mounting causes VSWR to increase. Some manufacturers use connectors that are screwed in place; during assembly, check these to make sure they are properly tightened. Another recent problem was a connector plate that was reversed during manufacturing and hence caused the antenna phase to be reversed by 180 degrees. This is not a problem with a single antenna, but a null on boresight can occur when the new antenna is stacked with a properly built model.

Most of these problems could have been caught prior to installation if the assembler paid attention to details, especially by cross-checking with the mechanical diagrams enclosed with the antenna. A VSWR check with the antenna mounted a wavelength or more above ground could also have pointed out other problems. Still other anomalies could have been noticed by testing the beamwidth, side lobes, and other parameters, using tests just described.

summary

In the past this information on determining antenna performance has been scattered throughout many different articles, with the gain methods mentioned, seldom used by Amateurs, buried in the math or appendicies at the end, with little explanation. I hope that this column has provided some practical guidance and that you will use it to compare one antenna's performance against another's. I'll refer to this information in future columns; good luck in selecting or evaluating your antenna!

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Important VHF/UHF Events in May, 1984:

May 2: ARRL 432 MHz Sprint Contest
May 4: 0730 UTC, predicted peak of Eta Aquarids Meteor shower
May 4,5,6: Tenth Annual Eastern VHF/UHF Conference, Sheraton Tara, Nashua, NH. (Contact K1LOG for further information.)
May 5,6: West Coast VHF Conference, Paso Robles, CA. (Contact K6HXW, Box 493, Arroyo Grande, CA 93420.)
May 10: ARRL 1296 MHz Sprint Contest
May 12,13: EME Perigee weekend
May 19: ARRL 6-meter Sprint Contest

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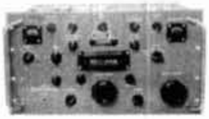

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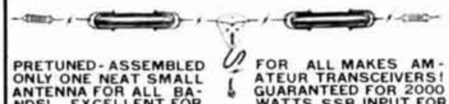

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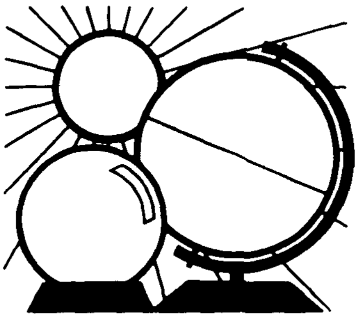

DX FORECASTER

Garth Stonehocker, KØRYW

sporadic-E propagation

In summer the overhead sun fills the lower ionosphere with ions which support short skip propagation, even multiple short skips. The geomagnetic field clusters these ions into cloud-like patches known as sporadic-E (E_s). To make best use of E_s DX openings, which are enhanced from late May until mid-September, a short review is in order.

E_s is a thin layer of intense ionization about 60 miles (100 km) above the earth. It gives rise to strong, mirror-like signal reflections over short-skip distances of 600 to 1200 miles (1000 to 2000 km). Signals remain strong for about a half-hour up to a couple of hours after the onset of the first strong signals, on the average; they're generally stronger than long-skip. Station location also determines how strongly the sunspot/geomagnetic disturbances affect sporadic-E propagation, with mid-latitudes the least affected and equatorial and polar paths the most. The highest *frequency* propagated by E_s occurs at local noon, since it follows the sun across the sky. However, the highest *probabilty of occurrence* is near sunrise and again around sunset. These two characteristics of E_s affect short-skip openings differently. Openings on the higher-frequency bands occur near local noontime; the lower bands tend to have openings near sunrise and sunset.

Because E_s is related to the summer sun, the best locations for these E_s openings are in the Northern Hemisphere from June through September and in the Southern Hemisphere during their summer, December through March. The best E_s is on either side of the geomagnetic equator; it's especially good where the geomagnetic equator is furthest from the geographic equator and during geomagnetic disturbances. These special areas are Southeast Asia in the Northern Hemisphere and South America in the Southern Hemisphere, with the former the better of the two.

To look for E_s openings on the higher-frequency bands, monitor beacons on 6 and 10 meters and CB channel 19. Also monitor unused TV channels 2 through 5 for 6- and 2-meter openings. The lower bands don't need beacon monitoring because E_s openings (sunrise and sunset) are available most nights.

last-minute forecast

A slight solar flux increase, with the possibility of a few flares about May 18th, should enhance DX on the higher-frequency bands (10-30 meters) the third week of the month. During the first and last weeks, look to the lower frequency bands (40-160 meters) for the best DX. Long periods in which the geomagnetic field will be disturbed are expected around the 1-9, 13, 23-26, and 31st.

An annual eclipse of the sun begins on May 30 at 1354 UTC near Hawaii, but stretching from the equator to Canada. It then crosses the Americas to Europe, stretching from northwest Africa to Norway, where it ends at 1935 UTC. Maximum duration is 62 seconds as it swings through the path. You might try some DX propagation experiments and compare your results to propagation or DX the day before and after.

The lunar perigee and full moon, of interest to moonbounce DXers, occurs on the 12th and 15th of this month. An Aquarid meteor shower of interest to meteor-scatter and meteor-burst DXers peaks between May 4th and 6th, with rates of 10 and 25 per hour for the northern and southern hemispheres, respectively.

band-by-band summary

Six meters will provide occasional openings to South Africa and South America around local noontime by short-skip E_s.

Ten and fifteen meters will have many short-skip E_s openings, and long skip during high solar flux to most areas of the world during daylight. Some trans-equatorial openings associated with disturbed ionospheric conditions may occur in the evening hours.

Twenty, thirty, and forty meters will have DX from most areas of the world during the daytime and into the evening hours almost every day, either long-skip to 2500 miles (4000 km) or short-skip E_s to 1250 miles (2000 km) per hop. The length of daylight is now approaching maximum, providing many hours of good DXing.

Thirty, forty, eighty, and one-sixty meters are all good for nighttime DX. On many nights 30 and 40 meters will be the only usable bands because of thunderstorm QRN, but signal strength via short-skip E_s may overcome the static when E_s is available. Although E_s is scarce in May, it should occur often the following two months.

GMT	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000	

MAY

WESTERN USA

PDT	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	
ASIA FAR EAST	20	20	20	20	20	20	20	20	20	20	_20_	_20_	_20_	20*	15	15	15	15	20	20	20	20	20	20	N
EUROPE	15	15	20	20	20	20	20	20	20	20	20	20	20	_20_	_20_	_20_	_20_	20	20	20	20	15	15	15	NE
S. AFRICA	15	15	10	10	10	10	10	10	15*	15	15	15	_20*_	_20_	_20_	_20_	_20_	20	20	20	20	20	15	15	E
S. AMERICA	10	15	15	15	15	15	20	20	20	20	20	20	20	20	_15_	_15_	15	15	10	10	10	10	10	10	SE
ANTARCTICA	15	20*	20	20	20	20	20	20	20	_30_	_30_	_30_	_30_	_30_	30	30	30	20	20	20	20	20	20	20*	S
NEW ZEALAND	10	10	10	15	15	15	15	20	20	20	_20_	_20_	_20_	20	15	15	15	10	10	10	10	10	10	10	SW
OCEANIA AUSTRALIA	10	10	15	15	15	15	20	20	20	_20_	_20_	_20_	20	20	20	15	15	15	10	10	10	10	10	10	W
JAPAN	20*	20	20	20	20	20	20	20	_30_	_30_	_30_	_20_	_20_	20	20	20	20	15	15	15	15	15	15	15	NW

MID USA

MDT	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	
ASIA FAR EAST	20	20*	15	15	15	15	20*	20	20	20	_20_	_20_	_20_	_20_	_20_	_20_	_20_	_20_	20	20	20	20	20	20	N
EUROPE	15	20*	20	20	20	20	20	20	20	20	20	20	_30*_	_30_	_30_	_30_	20	20	20	20	20	20*	15	15	NE
S. AFRICA	15	15*	10	10	10	10	10	10	10	15	15	15	_15_	_20_	_20_	_20_	20	20	20	20	20	20	15	15	E
S. AMERICA	15	15	10	10	10	10	10	10	10	15	15	15	_15_	_20_	_20_	_20_	20	20	20	20	20	20	20*	15	SE
ANTARCTICA	20	20	20	20	20	20	20	20	20	_30_	_30_	_30_	_30_	_30_	_30_	30	30	30	30	20	20	20	20	20	S
NEW ZEALAND	10	10	15	15	15	15	15	20	20	_20_	_20_	_20_	_20_	_20_	15	15	15	10	10	10	10	10	10	10	SW
OCEANIA AUSTRALIA	10	15*	15	15	15	15	20	20	20	_20_	_20_	_20_	_20_	_20_	_20_	15	15	15	10	10	10	10	10	10	W
JAPAN	20*	20	20	20	20	20	20	20	_30_	_30_	_30_	_20_	_20_	_20_	20	20	20	15	15	15	15	15	15	15	NW
CDT	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	

EASTERN USA

EDT	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	
ASIA FAR EAST	20	20	15	15	15	15	15	20	20	20	20	_20_	_20_	_20_	_20_	_20_	_20_	_20_	20	20	20	20	20	20	N
EUROPE	20	20	20	20	20	20	20	20	20	20	20	20	_30_	_30_	_30_	_30_	_30_	20	20	20	20	20	20	20	NE
S. AFRICA	15	15	10	10	10	10	10	10	10	15*	15	15	_15_	_20_	_20_	_20_	20	20	20	20	20	20	15	15	E
CARIBBEAN S. AMERICA	15	15	10	10	10	10	10	10	10	15	15	_15_	_15_	_20_	_20_	_20_	20	20	20	20	20	20	15	15	SE
ANTARCTICA	20	20	20	20	20	20	20	20	20	_30_	_30_	_30_	_30_	_30_	_30_	30	30	30	30	20	20	20	20	20	S
NEW ZEALAND	10	10	15	15	15	15	15	20	_20_	_20_	_20_	_20_	_20_	_20_	15	15	15	10	10	10	10	10	10	10	SW
OCEANIA AUSTRALIA	10	15*	15	15	15	15	20	20	_20_	_20_	_20_	_20_	_20_	_20_	_20_	15	15	15	10	10	10	10	10	10	W
JAPAN	20*	20	20	20	20	20	20	_20_	_20_	_20_	_20_	_20_	_20_	_20_	_20_	20	20	15	15	15	15	15	15	20*	NW

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides the MUF during 'normal' hours.
*Look at next **higher** band for possible openings.

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The filters are automatically selected according to the mode selection (CW, USB, LSB, etc.) and according to the narrow/wide switch. One limitation of this is that the narrow CW filter cannot be used in the LSB mode. Most RTTY operation with this rig will be done in the LSB mode, and having a narrower filter would reduce the effects of QRN and QRM.

The original circuit (**fig. 1A**) uses a diode switching approach to select the appropriate filter. Connector No. 27 (may be labeled No. 29 in the instruction manual) comes from the narrow/wide switch on the front panel. Either of the control lines SSW or CWW go high in the wide position, depending on the mode (SSB or CW respectively). Similarly, SSN or CWN go high in the narrow position, according to the mode selected. These control lines connect through resistors (and sometimes diodes) to the appropriate IF filter. A modified circuit (**fig. 1B**) is shown which allows for the use of the narrow CW filter in the SSB mode. In the LSB mode, in particular, this filter ends up being centered around an audio frequency of about 2 kHz, which is ideal for RTTY interfaces using audio tones in that area. The IF shift control can be used to adjust this frequency, if necessary.

In normal transceiver operation, switching from CW or SSB often results in the narrow position selected in the SSB mode. If no narrow SSB filter is installed, the IF section is simply left open and no signals can be heard. The suggested but untested circuit shown in **fig. 1C** will enable the wide filter in SSB mode regardless of the narrow/wide switch position.

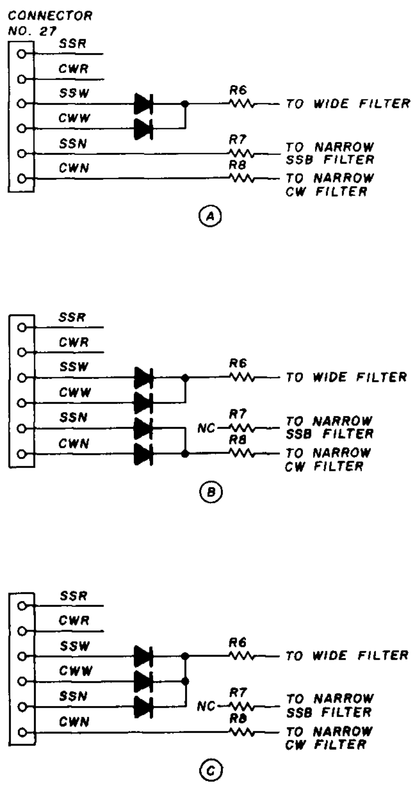


fig. 1. (A)Original circuit selects the appropriate narrow filter depending on whether the transceiver is in SSB or CW mode. (B)Modified circuit allows for narrow CW filter to be used in both CW and SSB modes. (C)Suggested circuit for enabling the wide filter in SSB/narrow mode.

To locate the appropriate area inside the transceiver, follow the instructions for installing the optional filters. R7 and R8 are located towards the rear of the IF filters. The ends of R7 and R8 nearest the rear of the transceiver go to connector No. 27. (Be careful in unsoldering the resistors because the printed circuit board traces are delicate.)

Robert A. Witte, KBØCY

short circuits

PL tone generator

In the April, 1984 article, "A Programmable PL Tone Generator," the component labeled "C7" in the upper left-hand corner (immediately below "U7") of the parts placement diagram (**fig. 5**, page 56) should be labeled "C17."

RF synthesizers

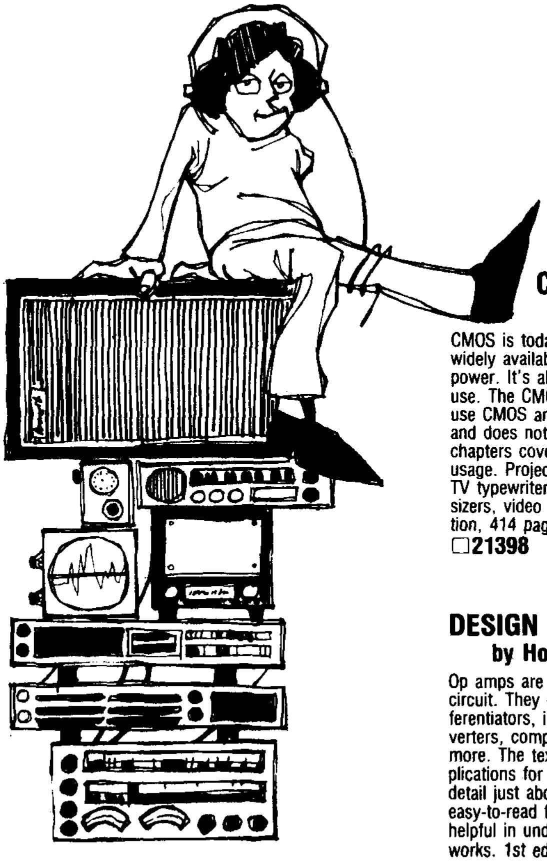
In the three-part series "RF Synthesizers for HF Communications," (August, September, October, 1983), three corrections are required. First, the labeling of the vertical axis in the phase noise plots in **figs. 15** and **20** of **Part 2** (September) and **fig. 13** of **Part 3** (October) should read "P_n dBc (IN 1 HZ BANDWIDTH)."

A second error appears in the last paragraph of the September article (page 50) and under "Using Bode Plot" on page 26 of the October issue. The open-loop unity gain frequency ($f_{\beta O}$) is not exactly equal to the closed loop 3 dB frequency (f_β). While it is a reasonable approximation, the two are more accurately related by:

$$f_{\beta O}/f_b = \frac{\sqrt{2\xi^2 + \sqrt{(2\xi^2)^2 + 1}}}{\sqrt{2\xi^2 + 1 + \sqrt{(2\xi^2 + 1)^2 + 1}}}$$

This difference is caused by the fact that at open-loop unity gain, the phase lag is not exactly 90 degrees. The closer this lag approaches 180 degrees (i.e., damping *decreasing*), the larger the difference between the open-loop unity gain frequency and closed-loop 3 dB frequency. (This ratio is approximately 0.755 at $\xi = 0.707$, 0.829 at $\xi = 1$, and 0.943 at $\xi = 2$.)

Finally, in **fig. 9** of **Part 3** (October) a 0.01 μF capacitor should be connected between pins 2 and 6 of the NE5534 op-amp (as described in the text).



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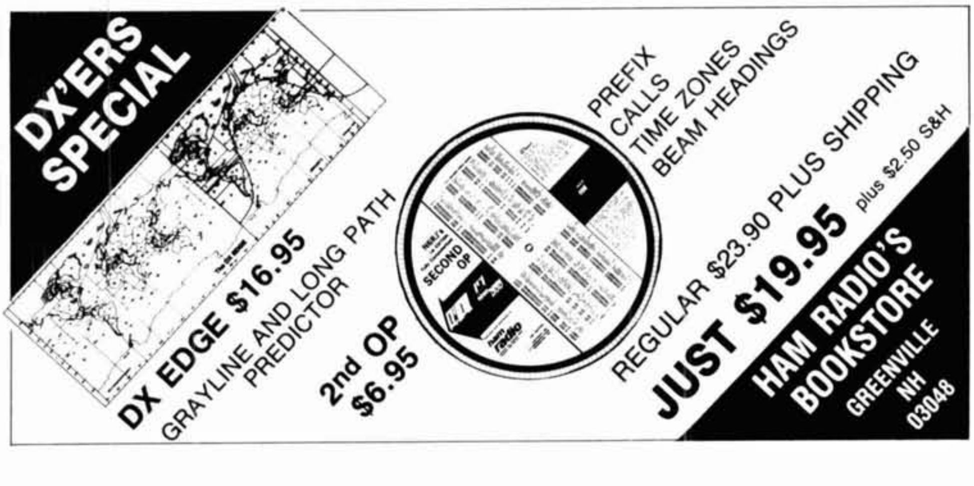

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Use GDO, noise or RF bridge
to determine resonance

matching dipole antennas

This article describes how to use a grid dip oscillator (GDO), RF bridge, or noise bridge to measure an antenna's resonant frequency and its resistance at resonance. While the article specifically addresses dipole antennas, the procedure described is applicable to any antenna, and is meant for those Amateurs who wish to feed antennas directly without the need for a transmatch or other matching device.

cutting to formula

The starting point for finding a dipole's resonant length is:

$$L = \frac{468}{f} \tag{1}$$

where L = length in feet
f = frequency in MHz

This length allows for "end effects." Specific height above ground, length-to-diameter ratio and proximity to other objects (particularly conductors) also influence the resonant length.

As an example, a recently erected 10- and 15-meter dipole cut to formula had to be adjusted by removing six inches from one dipole and adding even more to the other. These are appreciable changes in 33- and 22-foot dipole lengths — about 2 percent. These length changes also represent about a 2 percent frequency variation: 280 kHz on 20 meters and 420 kHz on 15 meters. These changes are about as large as the bands are wide! Even though the resonant frequency of the antenna is "off," this information is still useful in determining correct length by working with "percentages." For example, if you find that the resonant frequency of the antenna *at its operating height* is 2 percent low, correct by reducing the overall length of the antenna by approximately 2 percent. Because this change is still relatively small, the 2 percent reduction can be made to one side only.

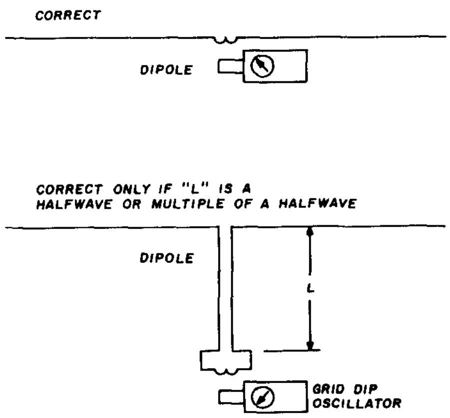

fig. 1. "Grid dipping" for the resonant frequency. Eliminating the feedline removes false resonances that can be more pronounced than the real one.

eliminating feedline ambiguities

If possible, it's best to make measurements at the antenna terminals directly (**fig. 1**). If you try to measure the resonant frequency of the antenna from the transmitter end of the cable, you'll see a combination of effects related to the antenna, feedline, and matching devices between the antenna and yourself.

However, if your feedline is a multiple of an electrical half-wave at your antenna's resonant (and desired operating) frequency, the feedline will reflect the antenna's characteristics at its input end (at the transmitter) (**fig. 1**). This way the antenna can be checked at its final height. To do this, determine the approximate feedline length using **eq. 2**:

$$L_{\lambda/2} = \frac{492 \bullet V_F}{f} \tag{2}$$

where $L_{\lambda/2}$ is electrical half wavelength in feet
V_F is velocity factor (between 0 and 1)
f is frequency in MHz

Because the velocity factor of cables can vary from manufacturer to manufacturer, and even within the

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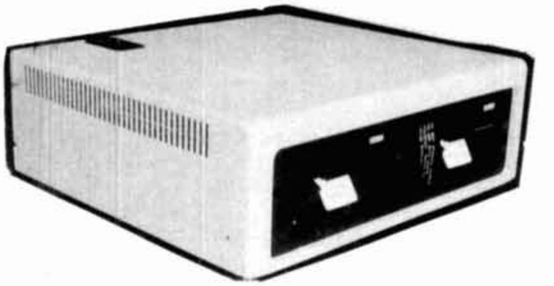

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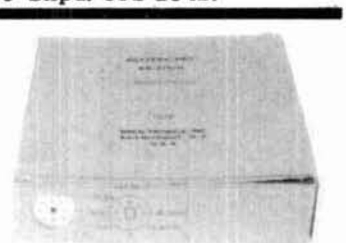

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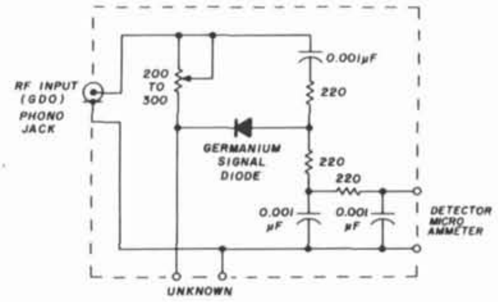

quantity	description
1	enclosure RS-270-235
4	binding posts RS-274-661
1	phone jack RS-274-1575
1	potentiometer, 200 to 300 ohms carbon composition (typically, Allen Bradley type AB; Claristat, type 53; or Ohmite, type J)
3	resistors, 1/4 watt, 220 ohm 5 percent RS-271-1313
3	capacitors, disc 0.001 µF RS-272-126
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fig. 2. RF bridge circuit.

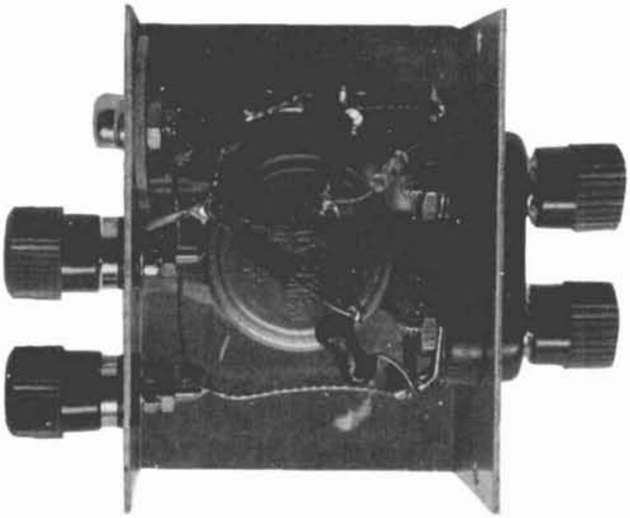

fig. 3. Interior view of the RF bridge shows the parts arrangement. The layout is not critical. Be sure to use non-inductive, carbon composition resistors. Terminals may be substituted to suit your test equipment.

same manufacturer's run of cable, more accurate approaches — such as a GDO, noise or RF bridge — should be used to determine the exact half wavelength of cable. The input end of a cable is resonant when it is shorted at a half or multiples of a half wavelength or when it is open-circuited at a quarter wavelength or at multiples of an *odd* quarter wavelength. These facts make a simple measurement possible.

To find an electrical half wavelength using a GDO, cut the cable a little longer and short its far end. Connect a small coupling coil (a single shorted turn might be sufficient) and bring the GDO up close. Use the smallest coupling coil possible to minimize error. Trim the far end as needed. (A more accurate frequency indication can be achieved by listening to the GDO on an accurately calibrated receiver.) If you want a quarter wave cable length rather than a half wave, repeat the procedure with half the length of cable, but do not short the far end.

When using a noise or RF bridge, the technique for determining a half wavelength of cable requires setting the bridge for zero resistance (and reactance if your bridge is equipped to measure reactance), cutting and shorting the cable as above and connecting the bridge to the input end of the cable. Resonance is indicated by a reduction in received noise in the case of the noise bridge or a minimum reading on an RF bridge's null detector. Trim the cable until the resistance at the input end goes to zero (or as close to zero as is practical to obtain). A quarter wavelength is determined in the same manner, but the far end of the cable is open-circuited.

The RF bridge and GDO combination can be used for outdoor antenna work because these devices are usually quite portable. Noise bridges themselves are easily portable, but the combination of bridge and receiver presents a real challenge to mobilty. On the other hand, noise bridges are simpler to set up and handle than the RF bridge and GDO combination. If you plan to do more complex antenna and/or RF circuit work, noise bridges will provide accurate reactance and resistance measurements over a very wide range of frequencies.

building an RF bridge

The bridge shown in **fig. 2** uses an outboarded 100 microampere meter for sharp and deep nulls. Parts placement is not critical, but a metal enclosure should be used to minimize "hand-capacity" variations. All parts are available from Radio Shack except the balance potentiometer, which should be a linear carbon composition type: typically, Allen Bradley, Type AB; Claristat, Type 53; or Ohmite, Type J.* Its value should be about 200 ohms. Most of the measurements will be in the order of 50 ohms. A low value potentiometer will assure that the scale is expanded enough to read easily (see **fig. 3**).

The bridge is calibrated using an ohmmeter. (1 percent resistors would provide greater precision — **Ed**). Mount a paper scale (see **fig. 4** and **5**) behind the pointer, marking each 10-ohm point between 10 and 100 ohms and each 50-ohm point above 100 ohms. Calibration may be done with the circuit wired up since

*Most electronic supply houses carry these types of potentiometers but have minimum order amounts of at least $20.00. Group ordering is a possibility; the potentiometers are in the $4 to $5 price range. Most large cities have one or two suppliers that will sell to Amateurs over the counter. One such is Linear Electronics in Waltham, Massachusetts.

fig. 4. Panel view of the RF bridge shows the calibration of the variable (balance) resistor. This is done using an ohmmeter – no trick to it all! Make sure the variable resistor value increases in a clockwise direction.

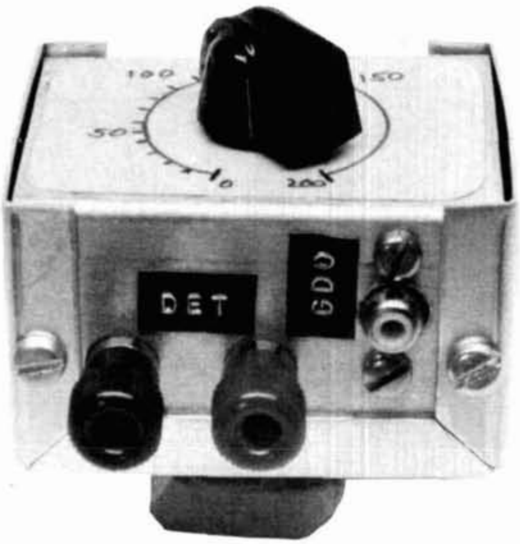

fig. 5. Top view of the RF bridge shows the jack for connecting the grip dip oscillator and the detector terminals.

the potentiometer is isolated by capacitors. Make sure the correct potentiometer ends are connected such that the scale increases in a clockwise direction.

The GDO is coupled to the bridge using a small coil and a short length of twisted hook-up wire. A two-turn loop slightly larger than the coil in the GDO is usually adequate. Tight coupling initially may make the dip easier to find, but afterward use as little coupling as practical to assure minimum interaction between the GDO and the circuit being measured.

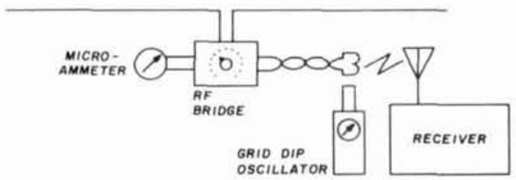

fig. 6. Measurement set-up for a simple RF bridge. The receiver is not necessary but may be used to increase the frequency measurement accuracy.

using the bridge

Connect the bridge, null indicator (microammeter) and GDO as shown in **fig. 6**. The dipole should be connected as directly to the bridge as possible. Turn the GDO on and adjust the coupling for about a half-scale reading on the null detector. Set the resistance knob to about 50 ohms. Vary the GDO frequency until the detector microammeter, *not* the meter on the GDO, goes through a minimum (dip). Set the frequency for the lowest dip and then adjust the resistance knob to further increase the dip. Loosen the GDO coupling until the dip is barely perceptible and again set the frequency and resistance for the best possible dip. Now read the GDO frequency and bridge resistance. These are the antenna's resonant frequency and its resistance at that frequency, respectively. If corrections in length (shorter to increase and longer to decrease the frequency) are necessary, proceed as previously discussed and then recheck the frequency as just described. **Fig. 7** illustrates the use of a noise bridge and a receiver to determine antenna resonant conditions.

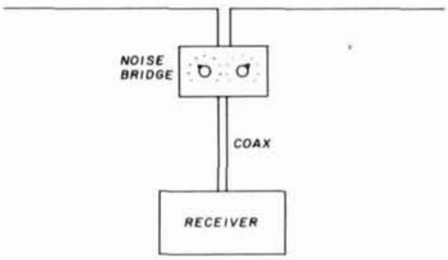

fig. 7. Measurement set-up for a noise bridge. The receiver senses less noise at the antenna resonance because it is being absorbed (transmitted) by the antenna when the bridge is properly balanced.

conclusion

The material in this article should be particularly useful to those wishing to take their first steps toward antenna experimenation. More importantly, it may stimulate deeper interest in antennas and other tuned RF devices. The kind assistance of Domenic Mallozzi, N1DM, Robert Doherty, K1VV, and Clyde Shappee, KA1CRV, are gratefully acknowledged.

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The EXL-5000 digital communications terminal from Amateur-Wholesale Electronics features a built-in high-resolution, long-persistence green monitor for sharp, clear images with no jiggle or jitter even under fluorescent lighting. Also featured are an external plug-in keyboard and a versatile built-in power supply for 117/234 AC or 13.8 VDC. Operation is greatly simplified by front-panel pushbutton controls.

The EXL-5000 includes capability for operating in AMTOR modes A, B, and L. A high-speed demodulator allows Baudot and ASCII operation from 12 to 300 bauds with AFSK and 12 to 600 bauds at TTL level, in increments of 0.1 baud. The demodulator will work with high or low tones. For transmitting, AFSK or FSK keying can be used. Morse sending and receiving speed is adjustable from 5 to 100 WPM in 1-WPM steps, with receive autotracking and variable transmitting weight.

A 1280-character display memory is split into two pages of 40 characters by 16 lines. Seven independently programmable 72-character channels and eight independently programmable 24-character channels allow storage of messages for permanent use. The memories can be preloaded and easily reprogrammed. Errors are easily corrected. The programmable memories are backed up by an internal battery so that they are never lost.

Other features of the EXL-5000 include full cursor control, function display, split-screen operation, automatic send/receive switching, automatic carriage return and line feed, automatic letters-code insertion, word-mode and line-mode operation, word wrap-around, simultaneous send-receive capability, selective calling, automatic timer-controlled transmission, RY and "quick-brown-fox" test signals, automatic ID, random-character generator for code practice, a printer interface, provision for an external monitor, a built-in audio monitor, a bar-graph LED tuning meter, noise-reduction receiving circuit, and time clock.

Further information about the EXL-5000 may be obtained from Amateur-Wholesale Electronics, Inc., 8817 S.W. 129th Terrace, Miami, Florida 33176.

Circle #301 on Reader Service Card.

IC-R71A

ICOM has introduced the new IC-R71A 100 kHz to 30 MHz professional-grade general coverage receiver, offering the same performance of the IC-R70 as well as several new features at the price of $799. This easy-to-use, versatile receiver features keyboard frequency entry, 32 programmable memories, SSB/AM/RTTY/CW/FM (optional), scanning, selectable AGC and noise blanker, passband tuning, and three tuning rates: 10 Hz/50 Hz/1 kHz. Two optional CW filters FL32 (500 Hz) and FL63 (250 Hz), are available, as well as an optional FL44A high-grade crystal filter (455 kHz).

The IC-R71A makes it possible for anyone, even without previous shortwave receiver experience, to listen to worldwide communications. Utilizing ICOM's DFM (Direct Feed Mixer), a 100 dB dynamic range, deep IF notch filter and adjustable AGC and noise blanker, the IC-R71A provides clear reception even in the presence of strong interference or high noise levels. A quartz-locked synthesized tuning system provides stable operation.

The pushbutton keyboard provides instant selection of frequencies which is accomplished by pushing the digit keys in sequence of frequency. Memory channels can be called up by pressing the VFO/M switch, then keying in the memory channel digit/s.

Options include FM, synthesized voice frequency readout, a wireless remote controller, a DC adapter for 12V operation, a mounting bracket, two CW filters and a high-grade crystal filter-455 kHz.

For further details, contact ICOM, 2112 116th Avenue, N.E., Bellevue, Washington 98004.

Circle #302 on Reader Service Card.

improved autopatch

A new simplex autopatch from CES will work on any Amateur or commercial simplex radio. CES engineers have redesigned the VOX enhancement circuitry and mobile presence detectors in the Model 510SA Smart Patch. The improvements allow the advanced microcomputer in the Smart Patch to keep the user from missing words or information. After trial testing at over 400 customer locations, it was concluded that the Smart Patch is now easier to install and

is the only simplex patch that gives the mobile unit complete and immediate full break-in capability without loss of information. The immediate control feature allows operation in the Amateur service because Smart Patch cannot transmit on top of another mobile. Transmission can be terminated by simply keying the transmitter. Installation consists of connecting RX audio, TX audio, PTT and power.

For further information about the Smart Patch, contact Communications Electronics Specialties, Inc., P.O. Box 2930, Winter Park, Florida 32790.

Circle #303 on Reader Service Card.

feather-weight headset

Telex has introduced an ultra-light headset for hand-held land-mobile transceivers. The ProCom 352-IC weighs 2.6 ounces when worn *with* the headband, but only one ounce without, and can be clipped directly onto eye or sunglass frames for convenience. Priced at $129.95, the headset plugs directly into ICOM or Ten-Tec hand-held transceivers.

A soft ear tip channels incoming messages directly into the operator's ear so that communications are essentially private. The noise cancelling electret microphone is designed for very close talking and transmits the operator's voice clearly even in high-noise environments. The electret microphone is also immune to electromagnetic or RFI so it can be operated effectively near power lines, large transformers, generators, broadcast towers, and other equipment that often interferes with radio communications.

For more information, contact Telex Communications, Inc., 9600 Aldrich Avenue, South, Minneapolis, Minnesota 55420.

Clean up the radio/computer clutter.

For less than $250 you can make your investment in yourself pay off!

Chances are you have spent a couple thousand dollars on setting up a computer system that gets a lot of your work done. But sometimes it gets to be work to work at it.

I know that when I have to move two program manuals and a pencil holder to boot up the disk drive, it is work. When there is an unlabeled floppy (that I am going to identify some day) on top of the monitor and the business checkbook is on top of the printer . . . and I will remember (I hope) before the next "report" comes through . . . that is work.

MICRO-OFFICE
WORK CENTER

I found the annoyance of my own "computer clutter" was even worse than the extra work the disorder created. And that is when I started looking for some practical furniture for my computer set up. Since I had already spent a lot of money on the system itself, I was really dismayed when I found out how much it would cost to get a decent-looking desk or even a data table for my equipment. $400 . . . $500 . . . even more for a sleasy unit that looked like junk! In fact, it was junk! And it took a long time for me to find something that was really worth the money . . . and more.

A lot of my working day is spent with my computer, and I will bet a lot of your time is too. So I figure a "home" for my system—a housing that is good looking as well as efficient to work at—will pay off two ways:

1. Less work: an efficient and orderly layout will save me time and energy.
2. Personal satisfaction: good quality furnishings look better; they just plain feel better to work at too.

So imagine how good I felt to find the "Micro-Office" Work Center! These are fine pieces of computer system furniture that make my office-at-home as pleasant a place to work as it ought to be. And the biggest and best surprise is the low, low price for such good quality.

Here is what you get—all for only $249.50 plus shipping.

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- Strong, sturdy and steady. All-steel welded frame construction is concealed by top-quality wood grain surfaces with finished trim. Adjustable floor levelers included. The work center is really a piece of fine furniture.
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1S2200	15.00	1S2208/9	1.00	8B1087/48R869558	65.00	8D3020	65.00
A2X116M Aertech	50.00	BB105B	1.00	BB105G	1.00	BD4/4JFBD4 G.E.	15.00
BL161 Bomac	5.00	CMD514AB C.M.	POR	D4060 Alpha	POR	D4159 Alpha	POR
D4233B Alpha	POR	D4900 Alpha	POR	D4959 Alpha	POR	D4987M Alpha	POR
D5047C Alpha	POR	D5147D Alpa	POR	D5503 Alpha	POR	D5506 Alpha	POR
DGB6158-98 Alpha	POR	DMD6022 Alpha	POR	DMD6460A Alpha	POR	DP20054 Crown	POR
GC1691-89 GHZ	31.35	GC1602-89 GHZ	31.35	GC1607-40 GHZ	31.35	GC2531-88 GHZ	37.40
GC2542-46 GHZ	37.40	GC3208-40 GHZ	37.40	GC17044 GHZ	50.00	HP33644A-HO1	125.00
HP5082-0112	14.20	HP5082-0241	75.60	HP5082-0253	105.00	HP5082-0320	58.00
HP5082-0375	POR	HP5082-0386	POR	HP5082-0401	POR	HP5082-0438	POR
HP5082-1028	POR	HP5082-1332	POR	HP5082-2254	POR	HP5082-2302	10.70
HP5082-2303	5.20	HP5082-2696	POR	HP5082-2711	23.15	HP5082-2727	POR
HP5082-2800	1.00	HP5082-2805	4.45	HP5082-2835	1.00	HP5082-2884	POR
HP5082-3039	6.70	HP5082-3040	36.00	HP5082-3080	2.00	HP5082-3188	1.00
HP5082-3379	1.50	HP5082-6459	POR	HP5082-6462	POR	HP5082-6888	POR
HP5082-8016	POR	HP5082-8323	POR	K3A Kemtron	7.00	MA450A	POR
MA475	POR	MA40008	POR	MA41487	POR	MA41765	POR
MA41766	POR	MA43004	48.00	MA43589	POR	MA43622	POR
MA43636	POR	MA45104	27.00	MA47044	POR	MA47051	25.50
MA47100	3.05	MA47202	30.80	MA47771	POR	MA47838*	POR
MA47852	POR	MA49106	37.95	MA49558	POR	MA86731	125.00

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Electronic Specialty Co./Raven Electronics FSN 5985-556-9683 $49.00
Part # 25N28 Part # SU-01
26Vdc Type N Connector, DC to 1 GHz.

Amphenol
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115Vac Type BNC DC to 3 GHz.

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FSN 5985-543-1225

$39.99

FXR
Part # 300-11173
120Vac Type BNC Same
FSN 5985-543-1850

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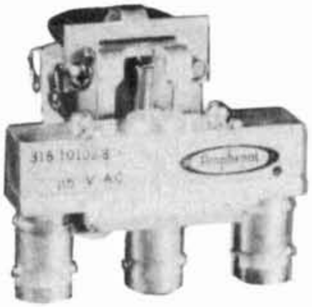

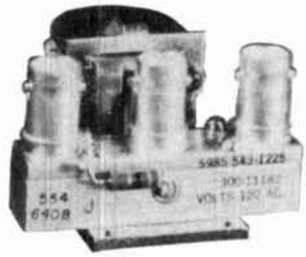

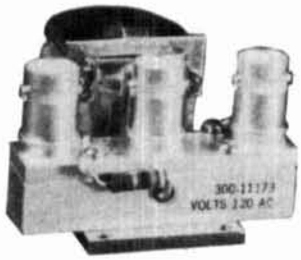

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$7.99 or 2 For $13.99 or 10 For $50.00

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P&B Model ECT1DB72 PRICE EACH $5.00	5vdc turn on	120vac contact at 7amps or 20amps on a 10"x 10"x .124 aluminum. Heatsink with silicon grease.
Digisig, Inc. Model ECS-215 PRICE EACH $7.50	5vdc turn on	240vac contact 14amps or 40amps on a 10"x 10"x .124 aluminum. Heatsink with silicon grease.
Grigsby/Barton Model GB7400 PRICE EACH $7.50	5vdc turn on	240vac contact at 15amps or 40amps on a 10"x 10"x .124 aluminum. Heatsink with silicon grease.

NOTE: *** Items may be substituted with other brands or equivalent model numbers. ***

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TYPE	PRICE	TYPE	PRICE	TYPE	PRICE
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2E26	7.95	4600A	500.00	7843	107.00
2K28	200.00	4624	310.00	7854	130.00
3-500Z	102.00	4657	84.00	ML7855KAL	125.00
3-1000Z/8164	400.00	4662	100.00	7984	14.95
3B28/866A	9.50	4665	500.00	8072	84.00
3CX400U7/8961	255.00	4687	P.O.R.	8106	5.00
3CX1000A7/8283	526.00	5675	42.00	8117A	225.00
3CX3000F1/8239	567.00	5721	250.00	8121	110.00
3CW30000H7	1700.00	5768	125.00	8122	110.00
3X2500A3	473.00	5819	119.00	8134	470.00
3X3000F1	567.00	5836	232.50	8156	12.00
4-65A/8165	69.00	5837	232.50	8233	60.00
4-125A/4D21	79.00	5861	140.00	8236	35.00
4-250A/5D22	98.00	5867A	185.00	8295/PL172	500.00
4-400A/8438	98.00	5868/AX9902	270.00	8458	35.00
4-400B/7527	110.00	5876/A	42.00	8462	130.00
4-400C/6775	110.00	5881/6L6	8.00	8505A	95.00
4-1000A/8166	444.00	5893	60.00	8533W	136.00
4CX250B/7203	54.00	5894/A	54.00	8560/A	75.00
4CX250FG/8621	75.00	5894B/8737	54.00	8560AS	100.00
4CX250K/8245	125.00	5946	395.00	8608	38.00
4CX250R/7580W	90.00	6083/AZ9909	95.00	8624	100.00
4CX300A/8167	170.00	6146/6146A	8.50	8637	70.00
4CX350A/8321	110.00	6146B/8298	10.50	8643	83.00
4CX350F/8322	115.00	6146W/7212	17.95	8647	168.00
4CX350FJ/8904	140.00	6156	110.00	8683	95.00
4CX600J/8809	835.00	6159	13.85	8877	465.00
4CX1000A/8168	242.50*	6159B	23.50	8908	13.00
4CX1000A/8168	485.00	6161	325.00	8950	13.00
4CX1500B/8660	555.00	6280	42.50	8930	137.00
4CX5000A/8170	1100.00	6291	180.00	6L6 Metal	25.00
4CX10000D/8171	1255.00	6293	24.00	6L6GC	5.03
4CX15000A/8281	1500.00	6326	P.O.R.	6CA7/EL34	5.38
4CW800F	710.00	6360/A	5.75	6CL6	3.50
4D32	240.00	6399	540.00	6DJ8	2.50
4E27A/5-125B	240.00	6550A	10.00	6DQ5	6.58
4PR60A	200.00	6883B/8032A/8552	10.00	6GF5	5.85
4PR60B	345.00	6897	160.00	6GJ5A	6.20
4PR65A/8187	175.00	6907	79.00	6GK6	6.00
4PR1000A/8189	590.00	6922/6DJ8	5.00	6HB5	6.00
4X150A/7034	60.00	6939	22.00	6HF5	8.73
4X150D/7609	95.00	7094	250.00	6JG6A	6.28
4X250B	45.00	7117	38.50	6JM6	6.00
4X250F	45.00	7203	P.O.R.	6JN6	6.00
4X500A	412.00	7211	100.00	6JS6C	7.25
5CX1500A	660.00	7213	300.00*	6KN6	5.05
KT88	27.50	7214	300.00*	6KD6	8.25
416B	45.00	7271	135.00	6LF6	7.00
416C	62.50	7289/2C39	34.00	6LQ6 G.E.	7.00
572B/T160L	49.95	7325	P.O.R.	6LQ6/6MJ6 Sylvania	9.00
592/3-200A3	211.00	7360	13.50	6ME6	8.90
807	8.50	7377	85.00	12AT7	3.50
811A	15.00	7408	2.50	12AX7	3.00
812A	29.00	7609	95.00	12BY7	5.00
813	50.00	7735	36.00	12JB6A	6.50

NOTE * = USED TUBE

NOTE P.O.R. = PRICE ON REQUEST

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606B	Same as above but has frequency control feature to allow operation with HP 8708A Synchronizer.	$1100.00
608C	10MHz to 480MHz,0-1uV-1V into 50 ohms,AM,CW,or pulse modulation, calibrated attenuator.	$ 500.00
608D/ TS510	10MHz to 420MHz, 0.1uV-0.5V into 50 ohms,+-0.5% accuracy, built-in crystal calibrator, AM-CW or pulse output.	$ 375.00
608E	Improved version of popular 608C.Up to 1V output.Improved stability,low residual FM.	$1450.00
608F	10MHz to 455MHz in 5 bands +-1% frequency accuracy with built-in crystal calibrator.Can be used with HP 8708A Synchronizer. Output continuously adjustable from .1uV to .5V into 50 ohms.	$1100.00
612A	450-1230MHz ,o.1uV-0.5V into 50 ohms,calibrated output.	$ 750.00
614A	900-2100MHz with many features including calibrated output and all modulation characteristics.	$ 500.00
616A/ TS403	Direct reading and direct control from 1.8 to 4.2GHz. The H.P.616A features +-1.5dB calibrated output accuracy from -3127dBm to -dBm.The output is directly calibrated in micro-volts and dBm with continuous monitoring. Simple operation frequency diad accuracy is +-1% and stability exceeds 0.005%-/ C change in ambient temperature. Calibrated attenuator is within +-1.5dB over entire output band. 50 ohm impedance unit has internal pulse modulation with rep rate variable from 40 Hz to 4KHz,variable pulsewidth(1 to 10usec)and variable pulse delay(3 to 300usec).External modulating inputs increas versatility.	$ 375.00
616B	Same as above but later model.	$ 600.00
618B	3.8 to 7.6GHz range,with calibrated output and selection of pulse-FM or square wave modulation.	$ 600.00
618C	Same as above but later model.	$2200.00
620A	7 to 11GHz range,with calibrated output and selection of pulse-FM or square wave modulation.	$ 750.00
620B	Same as above but later model.	$2200.00
626A	10 to 15GHz,10mw output power with calibrated output and pulse-square wave or FM modulation.	$4200.00
8708A	Synchronizer used with 606B,608F.The synchronizer is a phase-lock frequency stabilizer which provides crystal-oscillator frequency stability to 430MHz in the 608F signal generator.Phase locking eliminates microphonics and drift resulting in excellent frequency stability.The 8708A includes a vernier which can tune the reference oscillator over a range of +-0.25% permitting frequency settability to 2 parts in 10 to the seventh.Provides a very stable signal that satisfies many critical applications. (With HP 606B or 608F) / (Without)	$ 350.00 / $ 450.00
EMC-10	ELECTROMETRICS EMC-10 RFI/EMI RECEIVER Low frequency analyzer covering 20Hz to 50KHz frequency range.Extendable to 500 KHz in wideband mode.	$2500.00
NF-105F	Empire Devices Field Intensity Meter. Has NF-105/TA,NF-105/TX,NF-105/T1,NF-105/T2,NF-105/T3. Covers 14KHz to 1000MHz.	$2100.00

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DEFECTIVE MATERIALS: All claims for defective materials must be made within 30 DAYS after receipt of the parcel. All claims must include the defective material (for testing purposes), a copy of our invoice, and a return authorization number which must be obtained prior to shipping the merchandise back to us. This can be obtained by calling (602) 242-8916 or sending us a postcard. Due to Manufacturer warranties we are unable to replace or issue credit on items which have been soldered to or have been altered in any way. All return items must be packed properly or it will void all warranties. We do not assume responsibility for shipping and handling charges incurred.

DELIVERY: Orders are usually shipped the same day they are placed or the next business day, unless we are out of stock on an item. The customer will be notified by post card if we are going to backorder the item. Our normal shipping method is UPS or U.S. Mail depending on size or the weight of the package. Test Equipment is shipped only by air and is freight collect, unless prior arrangements have been made and approved.

FOREIGN ORDERS: All foreign orders must be prepaid with a Cashier's Check, or Money Order made out in U.S. FUNDS ONLY. We are sorry but C.O.D. is not available to foreign countries and letters of credit are unacceptable as a form of payment. Further information is available on request.

HOURS: Monday thru Friday 8:30 a.m. to 5:00 p.m. Saturdays 8:30 a.m. to 4:00 p.m.

INSURANCE: Please include 25¢ for each additional $100.00 over $100.00, UPS ONLY. All insured packages are shipped thru UPS only. If you wish to have it shipped through the post office there is a $5.00 fee which is additional to the shipping, handling and insurance.

OPEN ACCOUNTS: We regret that we do not issue open accounts.

ORDER FORMS: New order forms are included with each order for your convenience. Additional order forms are available on request.

PARTS: We reserve the right to substitute or replace any item with a part of equal or comparable specification.

POSTAGE: Minimum shipping and handling in the U.S., Canada, and Mexico is $3.00 for ground shipments, all other countries is $5.50. Air rates are available at the time of your order. All foreign orders please include 25% of the ordered amount for shipping and handling. C.O.D.'s are shipped AIR ONLY.

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PRICES: Prices are subject to change without notice.

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RESTOCK CHARGES: If parts are returned to MHZ ELECTRONICS, INC. due to customer error, the customer will be held responsible for all fees incurred and will be charged a 15% RESTOCK CHARGE with the remainder in CREDIT ONLY. The following must accompany any return; A copy of our invoice, return authorization number which must be obtained prior to shipping the merchandise back. Returns must be done within 10 DAYS of receipt of parcel. Return authorization numbers can be obtained by calling (602) 242-8916 or notifying us by post card. Return authorizations will not be given out on our 800 number.

SALES TAX: ARIZONA residents must add 6% sales tax, unless a signed ARIZONA resale tax card is currently on file with us. All orders placed by persons outside of ARIZONA, but delivered to persons in ARIZONA are subject to the 6% sales tax.

SHORTAGE OR DAMAGE: All claims for shortages or damages must be made within 5 DAYS of receipt of parcel. Claims must include a copy of our invoice, along with a return authorization number which can be obtained by contacting us at (602) 242-8916 or sending a post card. Authorizations cannot be on our 800 number. All items must be properly packed. If items are not properly packed make sure to contact the carrier so that they can come out and inspect the package before it is returned to us. Customers which do not notify us within this time period will be held responsible for the entire order as we will consider the order complete.

OUR 800 NUMBER IS STRICTLY FOR ORDERS ONLY (800) 528-0180. INFORMATION CALLS ARE TAKEN ON (602) 242-8916 or (602) 242-3037.

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HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

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DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

Coming Events

ACTIVITIES

"Places to go..."

COLORADO: Rocky Mountain VHF Society's annual Spring Hamfest, Sunday, May 20, 9 AM to 3 PM, rain or shine, Boulder National Guard Armory, 4750 North Broadway, Boulder. Admission $3 per family, no seller's charge. Sellers please bring own tables. Tech demonstrations and seminars on packet radio, fast-scan ham TV, microwaves, satellite communications, etc. Food and drink available. Talk in on 146.16/.76 and 146.52. For more information: Richard Ferguson, KAØDXM, 1150 Albion Rd., Boulder, CO 80303. (303) 499-2871.

GEORGIA: The Atlanta Hamfestival 1984, sponsored by the Atlanta Radio Club, June 16 and 17, at the Atlanta Civic Center. 70,000 square feet of air-conditioned exhibitor space and over 800 outdoor flea market spaces will be available. Flea Market $12.50 per space in advance; $15.00 at the gate for both days. Hamfest registration $5.00 in advance, $6.00 at the door. To be pre-registered for the Flea Market or Hamfest, we must receive your application and check by June 8. Pre-registration applications received after June 8 will be returned. Hours 8 AM to 5 PM on Saturday. 8 AM to 2:30 PM on Sunday. Talk in on 3.97 MHz, 146.22/82 and 146.94 simplex. For pre-registration or other information write Atlanta Radio Club, PO Box 77171, Atlanta, GA 30357.

IDAHO: Kootenai Amateur Radio Society presents Hamfest '84 at the North Idaho Fairgrounds, Ceur D'Alene, June 9, 8 AM to 4 PM. Swap tables available at no charge. RV's are welcome but no hookups available at the site. Come early for our Friday program including pot luck and dancing afterwards. For further information write Avon Anderson, WB7WBZ.

ILLINOIS: The Six Meter Club of Chicago will hold its 27th annual Hamfest, Sunday, June 10, Santa Fe park, 91st and Wolf Road, Willow Springs. Gates open 6 AM. Advance registration $2.00, $3.00 at gate. Large swapper's row, picnicking, displays in the pavillion, plenty of parking, refreshments, AFMARS meeting and more. For advance tickets: Val Hellwig, K9ZWV, 3420 South 60th Court, Cicero, IL 60650 (or any club member). Talk in K9ONA 146.52 or K9ONA/R 37-97.

INDIANA: The Wabash Valley Amateur Radio Association's 38th annual Hamfest, Sunday, June 3, Vigo County Fairgrounds, Terre Haute. For more information SASE to WVARA, PO Box 81, Terre Haute, IN 47808.

INDIANA: The 16th annual Wabash County Hamfest, May 20, 4-H Fairgrounds, Wabash. 6 AM to 4 PM. Contact Don Spangler, W9HNO, 235 Southwood Drive, Wabash, IN 46992. (219) 563-5564.

INDIANA: The Annual Evansville TARS Hamfest, May 20, all indoors at the Vanderburgh County 4-H Fairgrounds. Open 6 AM CDT. Admission $3.00. Indoor tables $7.50. Outdoor flea market $3.00. Talk in on 147.75/.15 and 146.19/.79. For table reservations and information contact Mike Anderson, KA9LQM, PO Box 3284, Evansville, IN 47732.

MARYLAND: The Maryland FM Association's annual Hamfest, Sunday, May 27, Howard County Fairgrounds, West Friendship, 30 miles west of Baltimore. 8 AM to 4 PM. Donation $3.00. Tailgating $3.00. Inside tables $6.00 each in advance, $10.00 at the door if available. Talk in on 146.16/76 and 146.52. For table reservations or information: MFMA Hamfest Committee, c/o John Elgin, WA3MNN, 8216 Styers Ct., Laurel, MD 20707. (301) 621-2352.

MICHIGAN: The Chelsea Swap and Shop, Sunday, June 3, 8 AM to 2 PM, Chelsea Fairgrounds, Chelsea. Setups 5 AM. Donation $2.50 advance and $3.00 at the gate. Children under 12 and non-ham spouses admitted free. Talk in on 146.52 simplex and 147.855 Chelsea Repeater. For information: William Altenberndt, 3132 Timberline, Jackson, MI 49201.

MINNESOTA: The North Area Repeater Association will sponsor the state's largest Swapfest and Exposition for Amateur Radio operators, Saturday, June 2, Minnesota State Fairgrounds, St. Paul. Admission $4.00. Exhibits, booths, giant outdoor flea market. Free overnight parking for self-contained campers on June 1. Call wide area repeaters 25/85 or 16/76 for directions. For information write Amateur Fair, PO Box 857, Hopkins, MN 55343. (612) 420-6000.

NEW ENGLAND: The Hosstraders Spring Tailgate Swapfest, Saturday, May 12, sunrise to sunset at Deerfield, NH, Fairgrounds. Admission $2 includes tailgaters and commercial. Friday night camping for self-contained rigs at nominal fee. None admitted before 4 PM Friday. No reserved spaces. Profits benefit Boston Burns Unit of Shriners' Hospital. Last year's donation over $4700.00. For map to northeast's biggest Ham Flea Market SASE to Norm, WA1IVB, RFD Box 57, West Baldwin, ME 04091 or Joe, K1RQG, Star Route Box 56, Bucksport, ME 04416 or Bob, W1GWU, Walton Road, Seabrook, NH 03874.

NEW HAMPSHIRE: The 10th annual Eastern VHF/UHF Conference, May 4-6, Sheraton Tara, Exit 1, US 3, Nashua. Friday night hospitality room. Tech talks by well-known VHFers. Pre-registration $14.50 to Rick Commo, K1LOG, 3 Pryor Rd., Natick, MA 01760 before April 29. Registration at door $20.00. Saturday night banquet is $15.00 payable before April 29. For information: Lewis D. Collins, W1GXT, 10 Marshall Terrace, Wayland, MA 01778. (617) 358-2854 before 10 PM.

NEW JERSEY: The Jersey Shore Chaverim is sponsoring the third annual Ham & Computerfest, June 10, 9 AM to 4 PM, Jewish Community Center, 100 Grant Avenue, Deal. 7300 sq. ft. of indoor space. Admission $3 per person (children under 12 and XYL's free). Refreshments available. Indoor table $8 and tailgating $3.50 per space. For reserved space SASE with advance payment to Jersey Shore Hamfest, PO Box 192, West Long Branch, NJ 07764 by June 1. Talk in on 147.045 + .6, 145.110 + .6 and 146.52 simplex. Deal, NJ is less than 50 miles from NYC and 70 miles from Philadelphia. For information call Arnold, W2GDS (201) 222-3009.

NEW JERSEY: TCRA Hamfest Tri County Radio Association, rain or shine, Sunday, May 13, Passaic Valley Community Center off Valley Road, Stirling, NJ. 9 AM to 4 PM. Indoors, refreshments, rest rooms, free parking. Tables $6, registration $2.50. Table reservations call or write Dick Franklin, W2EUF (201) 232-5955 or 270-3193, PO Box 182, Westfield, NJ 07090.

NEW YORK: "ROME HAM FAMILY DAY", Sunday, June 3, Beck's Grove in Rome. Presented by the Rome Radio Club, Inc. this event features something for everyone. Games, contests and the largest Flea Market in the area. Good food and beverages available throughout the day. Educational and scientific displays and presentations climaxed by a fine dinner and our "Ham of the Year" award. For further information: Rome Radio Club, PO Box 721, Rome, NY 13440.

NEW YORK: The 25th annual Southern Tier Amateur Radio Club's Hamfest, Saturday, May 5, Treadway Inn, Owego. Flea market opens at 8 AM. Vendor displays and sales. Tech and non-tech talks. Refreshments available. Dinner is at 6:30 PM by advance tickets only. Talk in on 22/82, 16/76, or 146.52 simplex. For further information SASE to KF2X, C. England, RD #1, Box 144, Vestal, NY 13850.

OHIO: The Sandusky County and Ottawa County Combined Hamfest, May 20, Ottawa County Fairgrounds, state Rt. 163, 3 miles east of Oak Harbor. Advance tickets $2.50, $3.00 at gate. Free trunk space and parking. Tables available. For information: John Dickey, 545 N. Jackson St., Fremont, OH 43420. Talk in on 147.675/075 or 52 simplex.

OHIO: The Champaign-Logan Amateur Radio Club's annual Hamfest, Sunday, June 10, Logan County Fairgrounds, Bellefontaine. Gates open 8 AM. Tickets $2.00 advance, $2.50 at the door. Tables $3.00. Plenty of free parking. Call in 147.60/00. Mobile check 146.52 simplex. For ticket info: Steve Kidder, N8ETD, Box 265, Russells Point, OH 43348 or (513) 843-6099.

OKLAHOMA: The Broken Arrow ARC and the Tulsa ARC will sponsor the Greencountry Hamfest, May 18, 19, and 20, Western Hills Lodge, 6 miles east of Wagoner at Sequoyah State Park. Pre-registration $2.50 or $3.00 at the door. There will be programs for the whole family. For information: Broken Arrow ARC, PO Box 552, Broken Arrow, OK 74012.

OHIO: Medina County Hamfest, sponsored by the Medina Two Meter Group, May 13, Medina County Community Center Building, Lafayette Rd., State Rt. 42 S.W. 8 AM to 4 PM. Vendor setup 7 AM. Refreshments and free parking. Tickets $2.50 advance, $3.00 at door. Tables $5.00. Some elec. hookups available. Talk in on 147.63/03, K8TV/R. For tables and tickets write PO Box 452, Medina, OH 44258. (216) 725-5021 or (216) 723-5010.

OKLAHOMA: The Great Plains ARC's third annual Northwest Oklahoma Eyeball & Swapmeet, Sunday, May 20, starting at 9 AM in Mooreland. Covered dish dinner at noon. Local airport. Dealer and swap tables free. Talk in on 147.72/12 and 146.52 simplex. Campsites available. For further information call (405) 994-5394 or write KB5XI, Gordon Richmond, Rt. 1, Box 12, Mooreland, OK 73852.

PENNSYLVANIA: The Murgas ARC (K3YTL) will sponsor the annual Wilkes-Barre Hamfest, Sunday, June 3, 109th Armory, Market St., Kingston (across the river from Wilkes-Barre). General admission 8 AM. Setup at 6 AM. Admission $3.00. XYL's and children under 16 free. Tailgating $2.00 per space indoor/outdoor rain or shine. Talk in on 146.01/61 and .52 simplex. For further information: Hamfest Committee, PO Box 1094, Wilkes-Barre, PA 18703.

PENNSYLVANIA: The tenth annual Warminster Amateur Radio Club's Hamfest, Sunday, May 20, Middletown Grange Fairgrounds, Penns Park Road, Wrightstown, rain or shine. Gates open 7 AM (Vendors at 6 AM). Donation $3.00. Pre-registration $2.00. XYL's and children free. Tailgaters $2.00 add. per 10' space. Food and drink available. Talk in on 147.69/09 or 146.52. For information and pre-registration contact: Bill Cusick, W3GJC, Apt. 706 - Garner House, Hatboro, PA 19040. (215) 441-8048.

PENNSYLVANIA: The 2nd annual Southern Alleghenies Hamfest, May 13, 8 AM to 5 PM, Bedford County Fairgrounds one mile west of Bedford on Rt. 30 and 1/2 mile west of Rt. 220 bypass. Sponsored by the Bedford, Altoona, Somerset, PA, and Cumberland, MD ARCs and Blue Knob Repeater Association. Admission $3.00. Inside spaces $5.00 each, outside tailgating $2.00. Visit nearby restored Old Bedford Village at special Hamfest rates. Talk in on Bedford repeater 145.49 and 146.52 simplex. For more information call Tom Gutshall, W3BZN (814) 942-7334.

PENNSYLVANIA: The tenth annual Northwestern Pennsylvania Hamfest, May 5, Crawford County Fairgrounds, Meadville. Gates open 8 AM. Bring your own tables. $5 per table to display inside. $2 per car space outside. $3 admission, children under 12 free. Refreshments. Commercial displays welcome. Talk in on 145.13, 147.21, 147.03. Details: C.A.R.S., PO Box 653, Meadville, PA 16335. Att: Hamfest Committee.

PENNSYLVANIA: The 30th annual Breeze Shooters' Hamfest, Sunday, June 3, 9 AM to 4 PM, White Swan Amusement Park, PA. Rt. 60 near greater Pittsburgh International Airport. Free flea market and free admission. Family amusement park, food on site. Registration $2.00 or 3/$5.00. Talk in on 28/88 or 29 MHz. For information: Don Myslewski, K3CHD, 359 McMahon Road, North Huntingdon, PA 15642. (412) 863-0570.

TENNESSEE: The Radio Amateur Club of Knox County will hold its 18th annual Hamfest, May 26 and 27, Kerbella Temple Auditorium, Knoxville. Saturday 9 to 5. Sunday 10 to 4. Admission $3.00. Radio and computer forums, dealers, indoor/outdoor flea market. Free parking. Talk in on 147.90/30. For information: Larry Poore, N4EHR, 4320 Felty Drive, Knoxville, TN 37918. (615) 687-3154.

VIRGINIA: The Tenth annual Manassas Hamfest, Sunday, June 3, Prince William County Fairgrounds, VA. RT. 234, 1/2 mile south of Manassas. 7 AM tailgate setup. 8 AM general admission. Tailgating, indoor exhibits, food available on grounds, YL program, CW proficiency awards. Admission $4 per person, under 12 free. Contact: Bob Kelly, KA4NES, General Chairman, Manassas Hamfest, c/o Ole Virginia Hams ARC, Inc., Manassas, VA 22110. (703) 361-9468.

WASHINGTON: The Yakima ARC's Central Washington State Hamfest, May 12 and 13, Hobby Building, Central Washington State Fairgrounds, Yakima. Saturday from 9 AM to 5 PM with lunch available. Sunday from 8 AM to 2 PM, breakfast and lunch available. Registration $4.00 advance, $5.00 at the door. Dealers' displays and a free swap and shop with plenty of tables. Talk in on 146.01/61 and 146.34/94. For pre-registration: Bob Rutherford, PO Box 9211, Yakima, WA 98909.

THE 574TH AND 565TH S.A.W. BNS. will hold their second reunion July 1984 in St. Louis, MO. Former members please write to Chas. A. McGaffin, San Mateo Rd., San Mateo, FL 32088. Phone (904) 328-9576 or to Angel M. Zaragoza, W6ZPR, 1571 - 9th St., San Bernardino, CA 92411. Phone (714) 889-2380 for full details.

OPERATING EVENTS

"Things to do..."

MAY 11 AND 12: HANDI-HAM System's special events station, WØEQO, will operate from Camp Courage, Maple Lake, MN, during the System's 15th annual Spring Convocation. For a special certificate SASE to: Handi-Hams, 3915 Golden Valley Rd., Golden Valley, MN 55422.

MAY 12 AND 13: ARMED FORCES DAY AT WEST POINT. The Meadowlands ARA will operate at the U.S. Military Academy in honor of Armed Forces Day 1984 using the club station call N2BMN. To confirm QSO send large SASE (8½ x 11) with 37¢ U.S. postage to POB 324, Little Ferry, NJ 07643.

MAY 19: In observance of Armed Forces Day, the U.S. Air Force Museum at Wright-Patterson Air Force Base, will host the operation of an Amateur Radio special event station. Listen for K8DMZ from 1400Z to 2200Z. To commemorate the event, the Museum will issue a special certificate for each two-way contact.

MAY 19: In recognition of the 35th annual Armed Forces Day celebration, Amateur Radio Station W4ODR, located aboard Naval Air Station Memphis, Millington, Tennessee, will be operating from 1400Z to 2200Z. Special certificates and QSL cards will be available to those who work W4ODR. QSL to ARS W4ODR, PO Box 54278, Millington, TN 38054.

MAY 19: ARMED FORCES DAY military-to-Amateur cross band operations will be conducted from 19/1300 UTC to 20/0245 UTC May 1984. East coast stations commence operations at 19/1300 UTC and west coast stations commence operations at 19/1600 UTC May 1984. Military stations will transmit on selected military frequencies. The military operator will announce the specific Amateur band frequency being monitored. Entries must be postmarked no later than 26 May 1984 and submitted to the respective military commands. Stations copying AIR send entries to: Armed Forces Day Test, 2045CG/DONJM, Andrews AFB, DC 20331. NAM, NAV or NPG to: Armed Forces Day Test, HQ Navy-Marine Corps MARS, 4401 Massachusetts Ave., N.W., Washington, DC 20390. WAR to: Armed Forces Day Test, Commander 7th Signal Command, Att: CCN-PO-OX, Fort Ritchie, MD 21719.

MAY 25 AND 26: ROYAL CANADIAN Air Force (RCAF) Telecommunications reunion. To honor the 50th anniversary of Air Force communications the reunion will be held at the Canadian Forces School of Communications and Electronics at Kingston, Ontario, for all active duty and retired members and spouses. For more information write to Air Force Telecom Reunion Committee, CFB Kingston, Kingston, Ontario K7L 2Z2.

MAY 26: NISKA-DAY '84. The Niskayuna, NY, High School Club Station, WB2OKK, (OK Kids) will operate from 1500Z to 2100Z to commemorate the 175th anniversary of the community of Niskayune. For a commemorative QSL card SASE to ARS WB2OKK, Niskayuna High School, 1626 Balltown Road, Niskayuna, NY 12309.

JUNE 2 AND 3: W.I.N.O., the Wireless Institute of Northern Ohio, an organization sponsored by the Lake County ARA, will operate a special events station to commemorate Ohio Wine Week. Listen for K080 operating from an actual winery in Madison, Ohio. A special 8½ x 11 certificate will be available from: K080, WINO Weekend, 7126 Andover Drive, Mentor, Ohio 44060.

JUNE 8 AND 9: Madison County ARC will operate club station W9VCF, portable from the historic Eight Street Festival in Anderson, Indiana. A special certificate will be offered to persons contacting the club station during the festival or any club member during the month of June. Send log info and $1.00 donation to Madison County ARC, c/o Frank M. Dick, WA9JWL, 921 Isabelle Drive, Anderson, IN 46013.

JUNE 9 AND 10: The Knox County ARC will operate a special event station to commemorate Galesburg Railroad Days, an annual event for Galesburg, Illinois. Listen for W9GFD. For a special commemorative QSL card SASE to Knox County ARC, W9GFD, 1694 Bluebird Drive, Galesburg, IL 61401.

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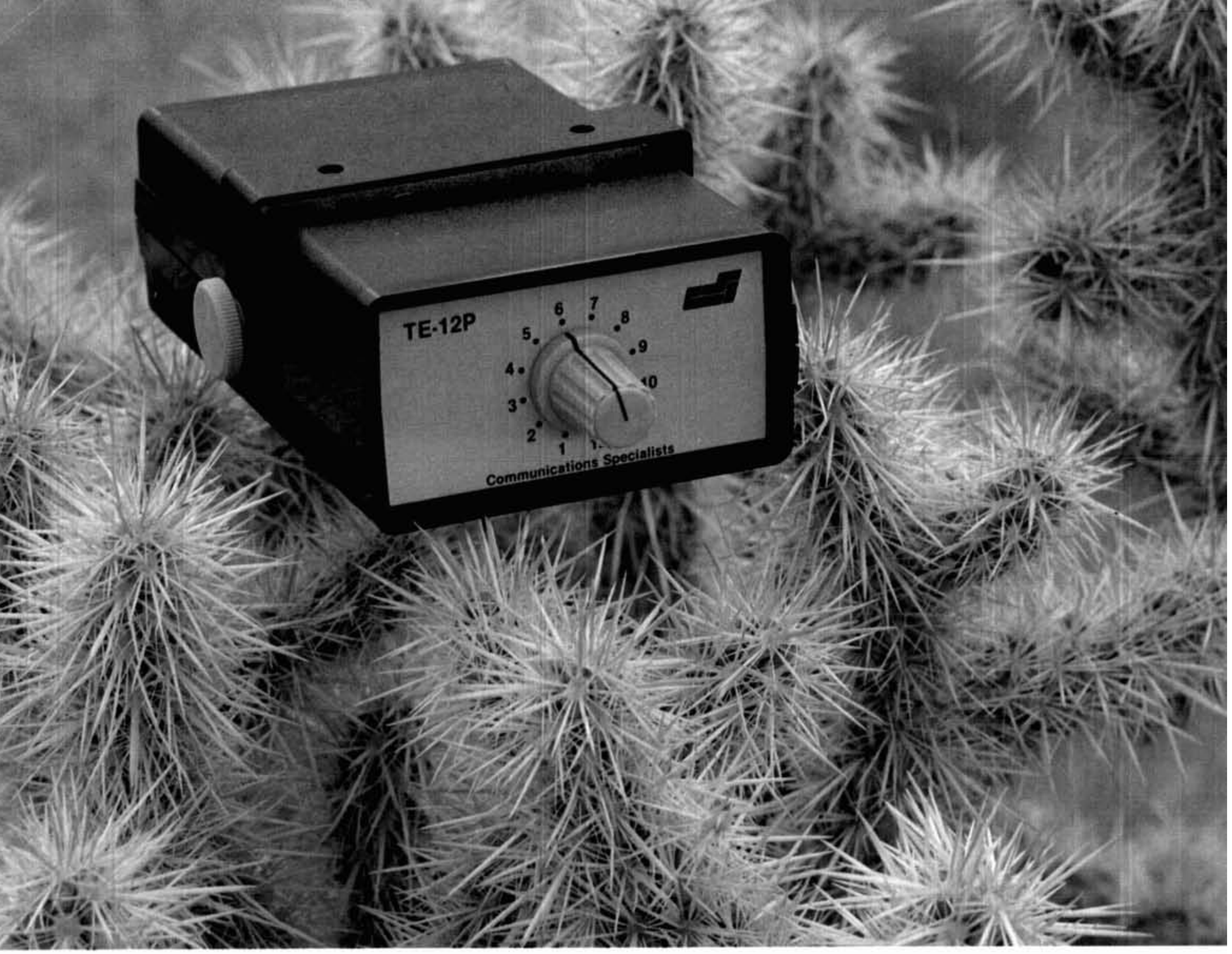

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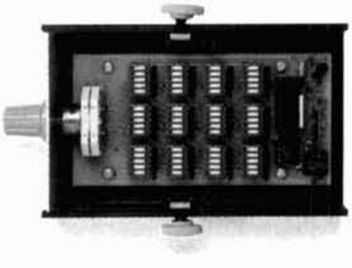

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74.4 WA	91.5 ZZ	110.9 2Z	136.5 4Z	167.9 6Z	
77.0 XB	94.8 ZA	114.8 2A	141.3 4A	173.8 6A	
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