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editor
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cover
T.H. Tenney, Jr., W1NLF
publisher
Hilda M. Wetherbee
assistant publisher
advertising manager

offices
Greenville, New Hampshire 03048
Telephone: 603-878-1441

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may 1973
One of the more serious problems which has plagued amateurs who operate on the vhf and uhf bands is that of rf interference — interference with television sets, stereo and hi-fi systems, intercoms and even tape recorders, practically any consumer electronics equipment that uses solid-state circuitry. Nor is the condition restricted to vhf. I was involved in a tense situation with one of my neighbors a few years ago when my 20-meter ssb signal wiped out a recording on his expensive solid-state tape recorder. No matter of electronic tricks, other than a big copper shield box, completely eliminated the interference, and the problem was only finally resolved when he and his damn recorder departed for Arizona!

Amateurs are not alone in their plight, either. Television, am and fm broadcast engineers are faced with daily interference complaints from nearby homeowners who don’t particularly appreciate the cacophonic symphony of football telecast interference to “Saturday Afternoon at the Opera,” or vice versa.

What is needed is Congressional or FCC action to require all manufacturers of tv sets, stereos and am receivers to build interference suppression into their designs. Some lead bypassing and narrow filters at the input would go a long way toward solving the present problem.

Last year, Congressman Charles M. Teague of California introduced a bill in Congress which would amend the Communications Act of 1934, requiring that “apparatus designed to receive broadcasts” would meet FCC standards to be adopted so that “all interference from any amateur station operating on its assigned frequency will be filtered out.” Unfortunately, no action was taken by Congress before it adjourned.

However, Mr. Teague has re-introduced his bill to the 93rd Congress (HR 3516) so we may have some action this year, but getting the bill re-introduced is a small part of the battle. First, the Chairman of the House Interstate and Foreign Commerce Committee must be convinced to call a hearing on the bill. To do that we will need a lot of letters. Once approved by the Committee, the bill can be presented to the members of Congress for a vote. However, all this will require a massive letter-writing campaign. You can bet that the manufacturers will be lobbying against any legislation that will make their product more complex or more expensive, so amateurs will have to work extra hard to gain favorable and speedy Congressional action.

Right now, while you’re thinking about it, write a letter to Mr. Staggers, Chairman of the House Interstate and Foreign Commerce Committee, as well as to your own Congressman, indicating your support for HR 3516. Letters of support should also be sent to Mr. MacDonald, Chairman of the Communications and Power Sub-Committee; in all probability it is this Sub-Committee which will hear HR 3516. The addresses are given below.

The Honorable Harley O. Staggers  
Chairman, House Interstate and Foreign Commerce Committee  
2366 Rayburn Building  
Washington, D.C. 20515

The Honorable Torbert H. MacDonald  
Communications and Power Sub-Committee  
Room 2125 Rayburn Building  
Washington, D.C. 20515

Because of the importance of this bill to amateurs, I will make petitions available to interested readers who send me a self-addressed, stamped envelope. This petition can be circulated among your friends and neighbors. We need all the help we can get.

Jim Fisk, W1DTY  
editor
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More Details? CHECK-OFF Page 126
low-cost RX impedance bridge

Complete calibration and application information on the simple W2CTK impedance bridge

In the September, 1970, issue of *Ham Radio*, W2CTK described a simple impedance bridge capable of independent readout of R and X values. Readers familiar with laboratory bridges will appreciate the potential of this instrument, but may doubt the accuracy of such a simple device. Less experienced readers may have shied away from this bridge since the original article showed only the use of Smith charts to interpret the bridge readings.

This article is written to compare the accuracy of W2CTK’s bridge with a Boonton 250A. Some construction points are clarified, techniques are presented to substantially improve measurement accuracy, a wider range of applications is presented, and a step-by-step procedure is included for those who are unfamiliar with bridge calculations.

**construction**

First, let’s tackle construction: Fig. 1 shows the complete schematic of the impedance bridge, but only a part of the schematic will affect accuracy. Fig. 3 shows the basic bridge. This portion is the heart of the unit and should be wired with short, heavy leads. A suggested layout is shown in fig. 4. The photograph may help with parts placement. Notice that the rear of the panel around the basic bridge has been stripped of paint to insure good grounding of bridge components. Be sure to use a composition-type potentiometer; a wirewound pot is completely useless.

A pot with a linear taper will result in the most useful dial calibration. The 56-ohm resistor can be any value from 47 to 68 ohms with no affect on final accuracy, once the R dial is calibrated with that particular resistor. Of course, this resistor must also be a composition type. Some wirewound resistors look like composition types, but are identified with one extra wide color band. Some, made during the Great War and sold surplus for years afterward are, in fact, wirewound, but do not have the identifying color band.

The variable capacitor can be any value from 150 to 365 pF. The lower values will limit the X range of the bridge, but have slightly better dial readability. The upper ranges have the opposite characteristics. Any of the values will result in an accurate bridge, but a 250-pF capacitor is about optimum. The diode can be any germanium type, similar to a 1N34. The .005-µF disc capacitor and the diode should have very short leads. Heat sink the diode while soldering it in place.

**calibration**

For convenience I will go over the calibration procedure. First, connect the basic bridge as shown in fig. 5. This hookup allows calibration of the R pot
with dc. W2CTK is correct in his statement that rf measurement accuracy will not be impaired with this procedure. The rather shallow null obtained with this bridge is the major source of error, and will limit you to about 5% of calibration accuracy on both R and X measurements. Total error consists of this 5% plus the percentage error of resistors and capacitors used to calibrate the bridge.

For convenience, the battery can be fed into the RF IN jack. The 10k resistor is included so you don’t bang the meter hard if the bridge is badly unbalanced. Connect a known resistor across the LOAD jack. Lead length is of no consequence here, since this is a dc calibration. For the same reason, wirewound precision resistors are also permissible. Touch the end of the 10k resistor to the center pin of the RF IN jack. Adjust the 100-ohm pot to bring the meter down to zero. Near zero you can touch the battery end of the 10k resistor to the center pin to improve the sensitivity of the adjustment.

If you continue turning the pot in the same direction, it will go below zero. The correct point is where the meter needle just reaches its zero resting position. Mark the R dial with the value of resistance you used for reference. Repeat the procedure for various resistors, or combinations of resistors, to obtain as complete a calibration as you wish. If you use new 5% resistors, your probable accuracy of R readout will be 10%.

Best R range for this bridge is approximately 20-ohms to about 3000 ohms. Below 20 ohms you may be limited by available X dial range — even with an essentially resistive load. Above 3000 ohms the dial graduations become quite close together, limiting the accuracy of readout. My bridge is calibrated to 5000 ohms, but it is difficult to get precise readings at that point. If you wonder about the variable capacitor in the circuit during this part of the calibration, forget it. It merely forms a convenient connection to the load jack.

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After R dial calibration is complete, disconnect the lead from the variable capacitor to the 100-ohm pot. The variable capacitor is now the only component connected to the LOAD jack. The easiest way to calibrate the capacitor is to connect a capacitor bridge to the load jack and calibrate the capacitor in about 10-pF increments from 250 to 100 pF, and in 5-pF increments below 100 pF. There is no need to be concerned about stray capacitance here, so long as it is minimized. You are interested primarily in the difference between two readings, not so much the absolute value.

If you have no capacitor bridge available, you can get an excellent calibration using the external hookup shown in fig. 6. A coil is connected to the load jack with provision for placing reference capacitors across the LOAD jack. A source of rf power is link coupled to this coil, and a vtvm ac probe is connected across the coil.
to read the peak voltage when the coil and X dial capacitor is resonant at the rf input frequency.

The important thing here is to make a rigid setup, mechanically. The coil and coupling link must be quite rigidly held with respect to one another. The rf source must be stable. The entire setup must be held in a fixed position relative to the metalwork of the impedance meter to minimize variations in distributed capacitance.

The coil can be a 3-inch length of 1-inch diameter 16-pitch Miniductor. Later, this same material can be used for the bandswitched coil, so there is no loss. Cut the coil wire about 3 turns in from one end. Heat the ends and push them out of the support bars to provide connecting leads an inch or so long. Do not cut the plastic support bars between the two coil segments. They will help maintain the coupling. Mount the coil as shown in fig. 6.

With the setup of fig. 6 assembled on a scrap of wood and connected to the LOAD jack of the impedance meter, first set the 250-pF X dial capacitor to maximum capacitance. Mark the dial accurately to indicate maximum. (It is advised to do the same for the R pot. This gives you a reference point in case the dial set-screws loosen and it is necessary to reposition them without re-calibrating.)

Feed an 80-meter rf source to the link and adjust the coil tap for a peak reading with the X dial capacitor at maximum. When this point is found, it must be maintained for the balance of the capacitor calibration. Solder it carefully in place. Connect, say, a known 100-pF capacitor to the binding posts. Re-peak the vtvm with the X dial capacitor. That point is 250 minus 100 pF = 150 pF. With only two 100-pF, one 50-pF and one 25-pF mica capacitor you can calibrate a 250-pF bridge capacitor in increments of 25 pF throughout its range. With care, you can estimate the intervening 5- or 10-pF increments with acceptable accuracy.

It would be worthwhile to buy this group of capacitors new in 5% tolerance or better. (These are available in silver mica to 1% quite reasonably.) If you use a grid dipper for this calibration you will find the dipper frequency pulls as the X dial approaches resonance, making it difficult to maintain exact frequency. For that reason it is better to use an 80-meter crystal-controlled oscillator.

This completes the calibration. You can now complete the wiring of the bridge. Fig. 2 shows a suggested coil made from the Miniductor coil stock. If you used other than the suggested 250-pF variable capacitor the tap points will have to be changed. The only criterion for selecting tap points is this: On each amateur band from 3.5 to 30 MHz set the taps so that the band can be tuned at near maximum (about 200 pF) and near minimum (about 50 pF). This is necessary to get best X dial range in measurements. The easiest way is to unsolder one end of the wire from the 100-ohm pot to the variable capacitor, install the coil, then set each tap using a grid dipper. (The 100-ohm pot would swamp the tuned

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To read the peak voltage when the coil and X dial capacitor is resonant at the rf input frequency.

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---
circuit if left in, and would make it difficult to find a dip.) Unsoldering and re-soldering this lead will not affect bridge calibration if the wire is carefully repositioned.

rf source

The next concern is a source of rf to drive the bridge. Most solid-state dippers will lack the power necessary to do a good job. Some vacuum-tube grid dippers will also be marginal. In any case, a dipper has poor stability, so I would advise building an all-band crystal oscillator. The one shown in fig. 7 covers 3.3 to 33 MHz with fundamental FT-243 surplus crystals. It will operate on the fundamental, second, third or fourth harmonic and provide ample drive for the impedance bridge. In my case I use a pair of 80-meter crystals and a pair of 40-meter crystals to do 90% of my work. Layout is not critical. Just keep your rf leads short and direct, and your bypass capacitors installed with short leads. It is worthwhile to use up some of the old vacuum-tube gear in the junkbox on projects like this. Take an evening to do the metalwork nicely! It can be housed in a wrap-around made from a discarded piece of galvanized iron flashing. A spray can of gray lacquer will give it a professional touch. This oscillator will find many other bench uses other than as a bridge driver. For example, it can be used as a driver for experimental solid-state power amplifiers, as a temporary local oscillator for converters or transmitter mixers, as a frequency marker, as a QRP CW transmitter, etc. I find it useful as an rf source for calibrating wavemeters for novices and as a reference antenna driver in antenna tinkering. If you have an old set of plug-in coils, they can be used with somewhat improved efficiency.

bridge operation

Now, let's put the bridge to work. The following abbreviated procedure will be followed with some notes on methods of improving accuracy and interpretation of the results.

initial balance

1. Set the R dial to maximum resistance.
2. Feed rf at the desired frequency into the RF IN jack.
3. With nothing connected to the LOAD jack, alternately vary the R and X dials for best null.
4. Note the exact reading in pF on the X dial.

measurement

5. Connect the unknown load to the LOAD jack.
6. Again adjust the R and X dials for best null.
7. Note the exact readings of the R and X dials.
8. The R dial reading obtained in step 7 is the actual resistive component of the load. The difference between the X dial reading of step 4 and the X dial reading of step 7 is the reactive component of the load (Cp).
9. If both X dial readings are the same the load is purely resistive.
10. If the X dial reading of step 7 is a higher capacitance than in step 4, the load is inductive. If the step 7 reading is lower, the load is capacitive.

A little trick I use to get the best null is to view the meter from an angle so a little slit of white background shows through between the meter needle and the zero mark on the meter. In this way very small meter variations can be seen. You will find that by using a crystal-controlled oscillator for the bridge driver the X dial reading in step 4 will be very accurately repeated, so once you know that number of pF for a given amateur band on a given bandswitch position, you can use the same crystal and skip the initial balance procedure. This is a big help when many measurements are necessary.

For example, I had an experimental tilted longwire antenna I wished to prune for best compromise on a number of bands. Since each pruning required a walk down the valley to the willow tree and back, it could be a full afternoon of work. However, knowing accurately what the X dial would be for initial balance setting it was possible to make a fast measurement on all bands from 80 through 10 meters and really see where the antenna was resonant. Inside of an hour I had it accurately set.

If, in step 6, you find it impossible to obtain a null, it means you ran out of X dial range. For example, if the X reading obtained in step 4 were 25-pF and your load was capacitive by 50 pF obviously you would run out of dial range. So, switch to another bandswitch position, repeat the initial balance, and perhaps now the reading in step 4 will be 200 pF. Again bridge the unkown load, and this time (assuming the load was 50 pF capacitive) the X dial will read 50 pF lower than the initial balance setting and you will have no trouble finding a null.

Of course, if the load is horribly reactive, it may be impossible to find any null. You could then grid dip the load to try to find where it was resonant, and this will tell you which way to go to get the load into the bridge range. If the load cannot be easily grid-dipped, you can...
make bridge measurements at other frequencies to find a frequency where it does fall within the bridge range. This same problem is common in laboratory impedance bridges. The Boonton 250A doesn't have nearly as much X dial range as W2CTK's simple bridge.

Try to approach that kind of accuracy with an antenna scope or other simple impedance bridge. However, I felt that, although the difference in impedance measurement was negligible, many experimenters might like to correct the bridge to read out very closely with a laboratory bridge. In this way a low-impedance load could be measured and the nearly correct reactance could be found that would make the network a pure resistance. In fig. 8 resistors of different manufacturers, in 1/2-, 1- and 2-watt sizes and all values

---

**fig. 7. Circuit for the 3.5- to 33-MHz oscillator/multiplier used as an rf source with the RX impedance bridge.**

From a point approximately 150 or 200 ohms and higher on the R dial the foregoing procedure will yield excellent accuracy. Below about 150 ohms an error creeps in which will add approximately 5% additional error, at worst. The X dial does not follow a Boonton 250A. At first glance the error appears to be large, but it is not. For example, a 22-ohm resistor measured with the Boonton measured 60-pF inductive. With the homebrew bridge it measured 130-pF inductive. From the worked-out formulas in table 1 you see that resistor (as measured by the Boonton) results in an actual impedance of 21.82 ohms. As measured by the homebrew bridge and calculated it will look like 21.35 ohms.
from 18 to 2200 ohms were checked on the Boonton and on the homebrew bridge. In all cases lead length was held to one-half inch. The line marked A is the results with the Boonton. Incidentally, the slope of the lines implies a constant series inductance of 0.0268 Microhenry; this is the resistor lead inductance.

You can construct a similar correction graph for your bridge if you wish. On a piece of 2x2 cycle log graph paper lay out the curve A line from a point 16.5 ohms on the top line to a point at 165 ohms on the bottom line. Now, select a number of composition resistors from your junkbox — values from 22 to 100 ohms. Carefully measure these on your bridge at 14 MHz using half-inch leads protruding from points of contact with the load jack. The $C_P$ values are the values of capacitance which are the difference between the initial balance value and that obtained in actually measuring the resistor. The $R_P$ values are those read off the R dial when bridging the resistor. Plot these values for a number of resistors. Then draw a line parallel to the A line and through the approximate average point of your values.

To use the chart refer to fig. 8: That chart says that at 55 ohms the Boonton would read 9 pF, but mine would read 22.5 pF. If my $R_P$ reading is 55 ohms, my $C_P$ reading will probably be about 13.5 pF too high. Incidentally, as you tinker with this bridge, perhaps measuring the same resistor on each band, you may suspect something amiss when you consistently get the same value for $C_P$. You might suspect this number to be frequency dependent, but it is not. If you ran that same resistor through the range on a Boonton, you would find a slight downward shift in $R_P$ as you go from 3.5 to 28 MHz (perhaps shifting from 28 to 27 ohms) but the $C_P$ value would consistently hang in there.

A load which is not nearly pure R (as these are) will show the expected variations in $C_P$ with frequency. If you feel that the half-inch lead length is gilding the lily, first bridge the resistor with full lead length, then repeat the measurement with half-inch leads. Don’t be surprised if the $C_P$ value of a 27-ohm resistor shifts as much as 50 pF. This effect is most noticeable at low resistances (50-ohm lines, etc.) and should serve as a warning of what can happen with sloppy clip lead lashups. I’ve seen otherwise competent engineers and technicians completely blow an rf measurement due to lack of feel for these little details.

If you are an engineering student, you will find this little bridge a valuable help in getting acquainted with rf measuring techniques. The Boonton RX meter goes all the way to 250 MHz, so you can appreciate the fact that it can get pretty hairy at times to get valid measurements.

**using the bridge**

Now, let’s look at the business of making sense out of the numbers you get from your bridge. **Table 1** is a set of formulas with worked examples to give you another method beside Smith charts as explained by W2CTK. The formulas assume $F = MHz$, $R$, $X$ and $Z$ in ohms, $C$ in pF. You may wonder what $\omega$ represents. It is $2\pi F$. A handy little trick in amateur work is to remember that, for the low end of the bands, on 3.5 MHz, $\omega = 22$, at 7 MHz, $\omega = 44$, at 14 MHz, $\omega = 88$, 21 MHz, $\omega = 132$, 28 MHz, $\omega = 176$.

The homebrew bridge reads a load in parallel values. The example in **table 1** is for an almost pure resistance. It will be seen that the bridge read a 22-ohm resistance with a 56-pF capacitor in parallel. Actually, the 56 pF was in an inductive direction. This is the same as saying, “What coil in parallel with 56 pF will be resonant on 14 MHz?” You could find this on an ARRL Type A Lightning Calculator in less than 5 seconds. In the same length of time the calculator also says it would be a half-inch diameter coil, 1-3/4-inches long, 28 turns. You know a coil of those dimensions wouldn’t likely be inside that resistor! If you are completely unfamiliar with the calculations you might be inclined to think it is a wire-wound resistor.

However, look at **table 1** and find the
parallel reactance; it is 203 ohms. Such a large value of reactance in parallel with such a small resistance will hardly affect the resistance. It is the same as hanging an rf choke across the end of a pi network for safety. The pi net sees only the 50 ohms. If you continue down to the first calculation for impedance you see the carried out all your calculations to a number of significant figures both impedances would have come out identically. This last set of values sounds more reasonable! In fact, you actually do have a 21.74-ohm resistor in series with a pair of tiny coils (the resistor leads).

Now, suppose you had been using this

table 1. Mathematical formulas which may be used with the impedance bridge if you do not use a Smith chart. In all examples f = 14 MHz, Rp = 22 ohms, Cp = 56 pF and \( \omega = 2 \pi f \).

1. Parallel reactance
   \[ X_p = \frac{10^6}{\omega C_p} = \frac{10^6}{6.28 \times 14 \times 56} = \frac{1000000}{4928} = 203 \text{ ohms} \]

2. Parallel inductance
   \[ L_p = \frac{X_p}{\omega} = \frac{203}{88} = 2.30 \text{ microhenries} \]
   or \[ L_p = \frac{159160 \times X_p}{F} = \frac{159160 \times 203}{14} = \frac{32.3}{14} = 2.30 \text{ microhenries} \]

3. \( Q = \frac{R_p}{X_p} = \frac{22}{203} = 0.1083 \)

4. \( Q^2 = 0.0117 \)

5. Absolute Impedance
   \[ |Z| = \sqrt{R_p^2 + Q^2} = \sqrt{22^2 + 0.10117} = 21.82 \text{ ohms} \]

6. Equivalent series resistance
   \[ R_s = \frac{R_p}{1 + Q^2} = \frac{22}{1.0117} = 21.74 \text{ ohms} \]

7. Equivalent series reactance
   \[ X_s = \frac{X_p Q^2}{1 + Q^2} = \frac{203 \times 0.0117}{1.0117} = 2.347 \text{ ohms} \]

8. Equivalent series inductance
   \[ L_s = \frac{C_p R_p^2}{(1 + Q^2)10^6} = \frac{56 \times 22}{1.0117 \times 1000000} = 0.0268 \text{ microhenry} \]

9. Absolute Impedance
   \[ |Z| = \sqrt{R_s^2 + X_s^2} = \sqrt{21.74^2 + 2.347^2} = \sqrt{478.1} = 21.85 \text{ ohms} \]

10. Equivalent series capacitance
    \[ C_s = \frac{C_p (1 + \frac{1}{Q})}{(1 + \frac{1}{Q}) \times 10^6} = \frac{56 (1 + \frac{1}{1.0117})}{10000000} = 4838.4 \text{ pF} \]
    or \[ C_s = \frac{159160}{F X_s} = \frac{159160}{14 \times 2.347} = \frac{32.858}{32.858} = 4840 \text{ pF} \]

Total impedance of the 2.3 microhenry inductance in parallel with a 22-ohm resistance is 21.82 ohms. The coil hardly made any change.

Any parallel network can be converted to an equivalent series network or vice versa. From table 1 you see that an equivalent series resistance of 21.74 ohms in series with an equivalent series inductance of 0.0268 microhenries results in an impedance of 21.85 ohms. Had you bridge to measure a wide-band balun for your antenna. Suppose the balun was supposed to look like 22 ohms. Unless you have a feel for the effect of reactance you might have felt the balun was junk, while, in fact, it was almost a perfect match! For that reason it is worth taking the time to work out enough examples to get familiar with the arithmetic. Then, since the little bridge is quite accurate, you can be very sure of your results.

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The impedance was figured in two ways to provide you with a means of back-checking your work. Whenever you convert from parallel to series values it will be worthwhile to use this as a proof that the series values were correctly figured.

How else can you use these numbers? Suppose you made a mobile antenna out of some odd scrap. You could end up with somewhat similar numbers to those in the example. If the antenna looked like 22 ohms in parallel with 56 pF inductive, you could make it 22-ohms resistive by merely hooking a 56-pF capacitor from whip to ground. If it looked 56-pF capacitive you could hook a 2.3-microhenry coil between whip and ground. Or, you could use the equivalent series values. If it showed 56-pF inductive on your bridge you could put about 5000-pF in series with the lead from the whip to the coax. If it looked capacitive you could put a 0.0268-microhenry choke in series from the whip to the coax. Of course, this example is pretty ludicrous, since it would be foolish to correct such a tiny inaccuracy. However, it gives you an idea of how very close you can work in antenna matching with this simple device.

**Applications**

Another application would be to transform that 22-ohm whip to 50 ohms to match a transmission line. You might look up the arithmetic of L networks in the ARRL Handbook, but perhaps you are a bit unsure that the values you figured were correct. In such a case you can use the bridge backwards: Connect the L network to the whip, make the initial balance on the bridge, and connect it to the 50-ohm side of the L net. Set the R dial of the bridge at 50 ohms. Don’t touch the bridge! Diddle the L network until the bridge nulls.

Perhaps you have an 80-40 dual dipole and want to include a balun to divorce your line from the antenna, but you can’t afford the cost of the big toroid. Take a fat loopstick from a junked BC set and wind your 1:1 balun on it. Of course, you have no idea of the characteristics of the loopstick material. Connect one end of the balun to the bridge and solder a 51-ohm composition resistor to the other end. Vary the number and spacing of turns until it looks good. Remember that with a 51-ohm impedance it takes a fair amount of reactance to ruin the final impedance. Once the balun is done, put a dab of epoxy on the wire ends to hold them in place and you are in business at practically no cost.

Perhaps you built a little synchrodyne receiver and used an unmarked surplus toroid of unknown characteristics for an antenna coil. The set works fine except that when it’s connected to a 50-ohm line it went dead. Don’t spend a lot of time guessing the proper turns ratio! Perhaps the IC you were using called for 400-ohms for best noise figure. Put a 390-ohm resistor across that winding, then bridge the antenna winding. When you get it around 50 ohms, non-reactive, put the receiver on the 50-ohm line and it will perform.

Perhaps you built a kilowatt linear from your junkbox. You carefully design-
ed the pi network, but aren’t sure the taps are correctly set on the coil to provide the proper plate load to the tube. Leave the linear turned off. Connect a composition resistor of the value you chose for the correct plate load from plate to ground. If the pi net is far from frequency you might not be able to bridge it, so set if for resonance with a grid dipper. Now look into the 50-ohm end of the pi net and adjust it to see if it will show 50 ohms with the capacitor values you calculated. If it does, you can be sure the plate sees the same load as the one you used from plate to ground. This will insure that the efficiency is up to the point you had calculated.

Of course, the impedance bridge is really useful in antenna work, but there are a few odd things you might run into. In the first place, if you bridge the coax at the transmitter end, it doesn’t say that the antenna impedance is the same. Only if you take the time to bridge a good half-wave line (or multiple of half waves) and connect the end of that line to the antenna – will you get a valid reading.

W2CTK describes bridging a half-wave line. Essentially, make up one end of the coax, couple it to the bridge, terminate the far end with a 51-ohm resistor, check and snip, reterminate, check and snip until it reads 51 ohms, non-reactive point. Snip tiny pieces off so you don’t whiz by!

If you bridge high-impedance antennas, you may run into certain quirks. My long wire showed the usual. The bridge was connected securely to the ground line coming in the basement window. This is a piece of number-4 wire about 3-feet long going to a ground rod outside the window. At that point it branches out with about 1000-feet of buried radials plus another hunk of number-4 to a second ground rod about 10-feet away. On 10 and 15 meters the bridge showed a lot of hand capacitance, and the null was quite dubious. The solution was to take the bridge outside the house, lay down a few strips of broiler foil on the ground, clamp them to the ground stake, clamp the bridge to the foil as close to the stake as possible, then lie down on the foil to put myself as near ground potential as possible. Now I had good nulls and accurate measurements. That 3-feet of number-4 lead was enough to put the bridge above ground.

Another odd factor showed up on 80 meters. The null would not go to zero and it wasn’t hand capacitance. I shut off the bridge driver and the meter still read upscale. I soon realized that this antenna was quite nearly a quarter-wave long at the frequency of the local BC station. Measuring with my rf voltmeter showed a steady 200,000 microvolts of signal. That antenna makes a good one for checking cross modulation of receivers.

**conclusion**

In conclusion, I feel that this instrument is an extremely useful device for the hamshack. With just a little care in construction and calibration it is remarkably accurate for its simplicity and low cost. I hope that the additional information presented here will encourage others to duplicate the device so that W2CTK can be properly credited with the importance of his little gem.

**reference**


*ham radio*
40-meter log-periodic antennas

How to design and build simple, high-performance wire beams that provide 8- to 10-dB gain and low swr over the entire 40-meter band

In a previous article I described two fixed log-periodic antennas of the doublet type which cover the complete frequency range from 14 to 30 MHz. These two antennas are suitable for use on 10, 15 and 20 meters. After that article appeared I received a large number of inquiries from amateurs who were interested in building a similar antenna for 40 meters. Although I didn’t have a special requirement for a 40-meter beam, the possibility of building a log periodic for 40, 20 and 15 was interesting and presented a challenge.

Since there was space available between some of the high pines and cedars on my property, the large log-periodic beam shown in fig. 1 was assembled. To reduce size and weight as much as possible, this log periodic is a skip-band type with a portion of the frequency range between 7.0 and 14 MHz deleted. Since this portion of the spectrum is not assigned to the amateur service, it is easily deleted and reduces the number of elements and the length of the antenna.

My available space only allowed a maximum antenna height of about forty feet, so I suspected that the beam would have little gain on 40 meters. However,
after running on-the-air tests for a few days, practically all the stations off the front of the antenna reported 8 to 10 dB gain from the 40-meter log periodic as compared with my non-gain 40-meter doublet. Reports from stations off the back of the beam indicated a front-to-back ratio of about 10 dB (signal strength but still retain the gain indicated by the 40-20-15 log periodic.

The first 40-meter beam I built used six elements; the gain of this antenna was about 10 dB. Another log periodic was then built with only five elements; signal reports still indicated the same forward gain.

![Diagram of a three-band log-periodic antenna for 40, 20, and 15 meters.](image)

**fig. 1.** Three-band log-periodic antenna for 40, 20 and 15 meters. Forward gain of this antenna is 8 to 10 dB.

about the same as the non-gain antenna). Gain on 14 and 21 MHz is about 10 dB, and front-to-back ratios are about 15 dB, very similar to the three-band log-periodic previously described in *Ham Radio*.

**forty-meter beams**

Since many of the operators who work 40 meters are not interested in the higher bands, I decided to try a log-periodic for single-band use on the 7.0-MHz band. This would use a minimum number of elements and reduce the overall length,

These signal reports were very encouraging, but I wanted to obtain more accurate data, especially front-to-back ratio and side selectivity. As two high trees about 250-feet apart were available to the east of the three-band log periodic shown in fig. 1, I decided to put up a 5-element, single-band, 40-meter log periodic. Since only two high trees were available, I decided to use an inverted-vee configuration (center high, element ends low).

This arrangement would probably also
be better adapted to the needs of the average amateur because the antenna could be erected with two telescoping TV masts. With the two masts 60-feet apart, a single 40-meter log periodic can be installed in a space 60-feet wide by 75-feet long.

With inverted-vee construction a center A line between the two masts supports the open center feedline and the five elements. Each of the elements droop down about 45 degrees. The dimensions of this antenna are shown in fig. 2.

At my station the 40-meter inverted-vee log periodic was installed parallel to the 40-20-15 log periodic, at the same height, but about 150 feet away. By switching between the two beams I was able to determine what losses, if any, I had sustained by going to five elements in an inverted-vee arrangement.

I estimated that I would be lucky to obtain 5- or 6-dB gain with this shortened log periodic, but after about a week of on-the-air tests, I was convinced that there was little or no difference in forward gain between the two antennas. However, the front-to-back ratio of the five-element log-periodic was not quite as good as the 40-20-15 antenna. The signal reports that I received were usually confirmed by the S-meter at my station.

dual log-periodic beam

Another 5-element, inverted-vee, forty-meter section was mounted to the rear of the first beam and headed in the opposite direction (see fig. 3). The rear elements of the two back-to-back log periodics were spaced about 20-feet apart. On-the-air tests indicated that forward gain was still 8 to 10 dB. Reports from stations to the rear or off to the side of the antenna are about equal to a non-gain antenna, indicating a 10 dB front-to-back ratio.

construction

Monofilament fish line (40-lb test) is used for the element end insulators and also serve as the element support lines. These lines are brought down to posts or ground anchors. For one of the log periodics which I built I hung a line between several small trees and tied the monofilament end insulators to these. Square lucite insulators (fig. 4) are used as center insulators and support the open-wire center feeder.

The most recent log periodics which I have built have eliminated the center A

![fig. 2. Simple single-band 5-element log periodic for forty meters. This antenna may by used in either the horizontal or inverted-vee configuration.](image)

![fig. 3. Single-band 40-meter log periodic for north-south communications consists of two back-to-back 5-element antennas (see fig. 2). This antenna, when used in the horizontal configuration, 50-feet above ground, provided 12-dB forward gain.](image)
line. In these antennas the center is supported entirely by the center feeder. However, special precautions are required during assembly if you use this method of construction; the A line is easier if you are building your first log periodic.

It will be noted from fig. 2 that the open-wire center feedline between the second element and the rear element is approximately one-quarter wavelength long. The feedpoint impedance at the center of the front element is 100 to 300 ohms; the quarter-wave line acts as a transformer between the low-impedance at the center of the second element and the feedpoint at the rear. Three methods of feeding the antenna are suggested:

1. Open-wire tuned line with an antenna tuner in the shack.
2. A broadband 4:1 balun between the log-periodic feedpoint and a coaxial feedline to the shack.
3. 300-ohm TV twin-lead from the log periodic to the shack with a 4:1 balun at the shack with coax to the transmitter. I used this method of feed since my other log periodics are fed with 300-ohm tv line.

performance

Compared with my center-fed 40-meter doublet which is 50-feet high the inverted-vee log periodic consistently provides signal reports 8 to 10 dB better. Comparison with a commercial trap vertical mounted on the roof of the house indicate essentially the same thing. These are not just spotty tests, but are consistent, reliable reports from several old acquaintances in Florida with whom I have been working on 40 meters for several months. They were quite familiar with my normal signal on 40 using the two non-gain antennas before I put up the 40-meter log periodic.

After several weeks of testing I decided to increase the height of the 5-element south beam to at least 50 feet and use horizontal elements rather than the inverted-vee configuration. The results from this change were hard to believe. The signal reports were consistently at least 12 dB better as compared to the doublet, also 50-feet high. All signal comparisons were made when fading was at a minimum and there was no skip.

The front-to-back ratio of the horizontal log-periodic antenna is approximately 12 dB. This is near the possible maximum for log periodics built and tested here over the past two years, reports from the back and sides are about the same as with the doublet I use as a standard.

As with any horizontal log periodic, the forward lobe is broader (about 100 degrees) than with most beams. This is good when you must use a fixed beam to cover a certain part of the country. Considering that most 40-meter beams are limited to 3- to 5-dB gain, the greater gain of the log periodic is certainly worth considering if you have the necessary space to put one up. By doubling the element lengths and spacing distances it should be possible to make a very excellent 80-meter beam.

I would appreciate hearing from anyone who builds and tests one of these antennas.

reference
With the increased local activity on the 432-MHz band, I decided I needed a better 432-MHz antenna. Previously, I had been using an 11-over-11 arrangement with three-half-wavelength spacing and 300-ohm feed-line. However, my fifteen watts was just not doing a satisfactory job. Received signal reports were only S3 to S7, even during good band openings.

After building several box-frame type 1296-MHz antennas with good results, I decided to try the same type of construction for 432. The box frame eliminates the need for a vertical mast between directors which detunes the array and downgrades antenna performance.

Also, I figured that if I could eliminate all the unnecessary baluns, and use copper driven elements and increase the number of Yagis, I might have a good beam. I was right. My signal reports went from S3 to S8 when switching from the

![Diagram of a seven-element 432-MHz Yagi. Boom is \( \frac{1}{2} \)" square aluminum tubing with \( \frac{1}{8} \)" walls. Reflector and directors are \( \frac{3}{8} \)" aluminum rod; driven element is \( \frac{3}{8} \)" copper tubing.](image-url)

Paul Magee, W3AED, Route 2, Box 432, Berlin, Maryland 21811

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old 11-over-11 to the new box array. K2RIW in New Jersey recently gave me a report of S9+67 dB, so the antenna is really doing the job I wanted it to.

The antenna consists of four seven-element Yagis, spaced two half-waves. The four antennas are installed on the front of a square aluminum-angle frame which measures 27-inches per side. The antenna booms are 45-inches long. The entire array is fed with 75-ohm tv-type coaxial cable, which is lighter weight and has less loss than comparable 50-ohm coax.

collection

The driven element is made from 3/8-inch copper tubing. An 8-32 screw hole is drilled at the center of the element and a double-U clip is formed around the center of the element to keep it from deforming as you tighten up the screw. The U-shaped clips I used came from an old tv antenna. Wood dowels pushed into each end of the element and a solder-filled center would also keep the element from being deformed.

The phasing-line connections are made 1-1/2-inch on each side of the center of the element (spaced 3 inches). A 6-32 screw hole is drilled all the way through the element and a 6-32 nut is soldered on one side. This can be done by polishing the copper with steel wool and sweat soldering the nut in place while it is being held temporarily with a 6-32 screw. Solder paste will speed things up; after soldering, the excess paste can be removed with lighter fluid. When connecting the phasing lines use two brass washers.

The reflector and directors were made from 3/8-inch aluminum rod I salvaged from an old Telrex tv antenna. A hole is drilled in the center of each element to pass a 6-32 screw.

![fig. 2. Phasing lines for the 28-element, 432-MHz quad array. Plexiglass or lucite spacers are used only at the junctions of the horizontal and vertical phasing lines.](image)

The 1/2-inch square aluminum boom may require some searching. However, if you can't find one at your local building-supply store, it can be obtained on special order from firms that specialize in glass store fronts. A 6-32 screw hole is drilled in the boom for each of the elements. Then a slot is filed at right angles to the boom to hold each element in place.

collection

The sides of the frame which holds the four Yagis are made from 1x1-inch aluminum angle, 1/8-inch thick. The material for the right-angle aluminum corner plates (see fig. 4) came from a local glass and store front company that builds six-inch aluminum columns.

When building the frame, attach the horizontal members to the corner angles first. Then the holes for the mast U-brackets are drilled. One of the flat faces of the aluminum angle faces toward
the Yagi antennas. The corner brackets are mounted on the outside. The individual Yagi booms are attached to the corner brackets with 8-32 screws, as shown in fig. 3.

The wind vanes on the back of the antenna shown in the photograph are made from 5x8-inch pieces of aluminum sheet, although they may not be necessary if you don't live in a high-wind area. I also added a special plate to allow double U-clamps at each cross section of the box frame. Again, this is not essential, but I live in a hurricane area.

**Phasing lines**

Each of the phasing lines is two half-waves long and made from number-14 wire, fig. 2. When using soft-drawn wire for this purpose I put one end in a bench vise and gave it a good pull. This gets rid of any future stretch and straightens the wire for immediate use.

Plexiglass spacers are used only at the junctions of the phasing lines. No additional support is required where the coaxial cable is connected. When installing the coaxial cable the shield braid should be cut back only far enough to spread the cable (1-inch maximum). After soldering, tape the connection well and tape the coax to the mast so the connection end of the coax faces down — this will help keep water out of the coax.

I used seventy-five feet of 75-ohm Jerrold CAC-82 coaxial cable with my array. This cable has a copper shield like RG-59/U and is packaged in 50-, 75- and 100-foot rolls.

**1296-MHz array**

Some readers might be interested in a four-bay, 13-element Yagi array I use on 1296 MHz which uses similar construction to the 432-MHz antenna. With this antenna and a three-stage preamplifier I have received signals from as far away as northern New Jersey and Norfolk, Virginia. Although I don't have the equipment to measure gain, performance appears to be within about 0.5 dB of the 1296-MHz Yagi described by W2COH.1 This indicates that gain is approximately 14 to 15 dB.

The boom for each of the 13-element...
Yagi beams is half-inch U-shaped aluminum angle, 0.050- to 0.075-inch thick. The driven element is brass. Other elements are aluminum rod. Element length and spacing is shown in fig. 5.

The upper and lower Yagis are placed face to face so that the phasing lines do not cross the booms. The conductors of the 300-ohm phasing lines are made from number-12 wire, spaced 1 inch. The vertical phasing lines are twisted at the center to meet the horizontal phasing line.

The design of the phasing lines on the 1296-MHz antenna is based on the fact that an impedance of 300 ohms, when connected to a 425-ohm matching section, exhibits 600-ohms impedance. When the two 600-ohm sections are connected in parallel, the input impedance is again 300 ohms. A 4:1 balun at the center feedpoint converts the 300-ohm input impedance to 75 ohms, a perfect match to 75-ohm tv type coaxial line. I used a 50-foot section of Jerrold 82 tv transmission line, which has a copper braid.

Although this 75-ohm tv coax comes pre-packaged in lengths of 50, 75 and 100 feet, any length over 50 feet is much too lossy on 1296 MHz. If you need more than 50-feet of transmission line at your station you should consider placing the first stage of your rf amplifier right at the antenna.

fig. 5. Construction of the 13-element, 1296-MHz Yagi beams used in the four antenna array. The individual Yagis are mounted on a square frame similar to that shown in fig. 3.

rf filter

A number of amateurs have had trouble on 1296 MHz because they did not place a 1296-MHz filter ahead of their rf amplifier. Many of the popular 1296-MHz preamplifiers run wide open and pick up a lot of undesired signals. Occasionally, they also oscillate when connected to a resonant antenna. The simple half-wave rf filter shown in fig. 6 solves these problems.

The half-wave filter is built into a 4-inch long brass or copper box, 1-1/8 inches square. For use with 75-ohm lines the connectors should be spaced 5/8-inch from the end of the line. For 50-ohm lines this spacing should be ½-inch. By spacing one connector ½-inch and the other 5/8-inch, the filter can be used to match 50-ohm cable to a 75-ohm transmission line.

When the filter is inserted in the line, the 10-32 tuning screw is adjusted for maximum signal. The screw is then locked in place with the locknut. I am presently using this filter ahead of three rf stages with good gain and no oscillation.

I would like to take this opportunity to thank Cy Dirickson, W3BSV, who helped with the design and testing of these antennas.

reference

How many times have you heard discussions, often heated, about the following subjects? Does a dipole antenna fed with a coaxial cable radiate more from the leg fed by the cable's center conductor than from the one fed by the shield? If so, does the use of a balun at the feedpoint correct the imbalance of radiation?

Does a coaxial cable feeding a load mismatched to cause a 4:1 VSWR have radiation from or standing waves upon its outer conductor?

Does a coaxial cable feeding a dipole antenna, with the feeder running at right angles from the antenna, have current on its outer conductor? If so, does the use of a balun at the feedpoint correct the condition of undesired radiation?

Does one leg of the dipole antenna plus a quarter-wave of the outer conductor of the coaxial feeder constitute a vee antenna, thereby causing a high-voltage RF potential to appear at the quarter-wave spot and at even multiples of it on the transmission line?

Well, I've heard these questions countless times and have even taken part in some of the arguments. The distinguishing factor about all these discussions is that no one really knew what the answers were. Oh, everyone was quite sure in his own mind that he knew the answers perfectly. But, and this is the point I want to make here, not a single person had ever taken part in an experimental determination of the truth or fallacy of the several contentions! Let's have an end to such a deplorable situation.

Three amateurs, W5TMY, W5KE and myself, each retired and blessed with ample free time, each with over thirty years of professional experience in the field of electricity and electronics, decided to do something about establishing demonstrable and reproducible facts relating to the disputed questions. My place was selected for the experimental setup as I have a backyard of ample dimensions, and my 50+ years collection of equipment and instruments contained everything we needed.

The basic equipment consisted of a Drake TR-4 transmitter, A Drake MN-4 matching device (helps minimize harmonics), 52-ohm coaxial line, a 7-MHz dipole antenna in the clear and low enough to permit an indicating device to be pulled along it, and a sensitive device for measuring relative amplitude of radio-frequency current (current, not voltage). See fig. 1 for details of this indicator.

The vinyl jacket of a portion of the coaxial cable was removed to permit
exploring the radio-frequency current on it over a half-wave expanse. The cable was run at right angles to the antenna and was at the same height as the antenna. Every effort was made to preserve absolute symmetry. A W2AU balun, especially made with a male coax connector at one end and a female connector at the other end, was used for altering the feedpoint circuit.

Experiment 1

Purpose: To ascertain whether the currents in the two halves of a dipole antenna are equal when fed from an unbalanced source, a coaxial cable.

Procedure: The antenna was energized, the radio-frequency current indicator was adjusted for 45/50th full-scale deflection at the spot of maximum current, and the indicator was pulled by means of an attached string along the length of the dipole half. Without adjusting the indicator, the action was repeated on the other half of the dipole.

Findings: The maximum current in the half fed by the center conductor of the coaxial cable was approximately 40% greater than that in the half fed by the cable's shield.

Conclusion: Feeding a dipole from an unbalanced feeder results in an imbalance of currents in the two halves of the dipole, probably resulting in a distorted radiation pattern.

Experiment 2

Purpose: To ascertain whether the currents in the two halves of a dipole antenna are equal when fed from a balanced source: a balun coupling a coaxial cable to the antenna's feedpoint.

Procedure: A balun was inserted between the cable and the antenna; then experiment 1 procedure was repeated.

Findings: The maximum current in each half of the dipole was very nearly equal.

Conclusion: The use of a balun helps to obtain balanced radio-frequency currents in the two halves of a dipole.

Experiment 3

Purpose: To ascertain whether having a coaxial cable terminated in a mismatched load causes radio-frequency currents or standing waves to be present on the outer conductor of the cable.

Procedure: A length of 52-ohm coaxial cable, more than a half-wave long and having insulation stripped from the outer conductor, was terminated with four 52-ohm Termaline dummy loads, thereby causing a 4:1 vswr to be present on the line. The line was matched to the transmitter through an MN-4 matching device, and 200 watts of rf power was fed into the line. The sensitive rf current indicator was pulled along the length of the line.

Findings: No radio-frequency current was detected on the outer conductor on the coaxial cable.

Conclusion: Having a mismatched load does not result in the radiation of rf power from a coaxial transmission line. However, this does not imply that having an unbalanced load may not cause current to be present on the outer conductor.

Experiment 4

Purpose: To ascertain whether there is rf current on the outer conductor of a coaxial cable directly feeding a dipole antenna.

Procedure: A length of coaxial cable, more than a half-wave long, stripped of its outer insulation, was strung at right
angles to the dipole and at the same distance above ground. The transmitter was loaded to 200 watts, and the sensitive rf current indicator was pulled along the transmission line. An indication of full-scale (but not pegging the meter) deflection was observed. In an effort to obtain a comparison of relative power at this maximum current point and that at the maximum current point on the dipole, the transmitter power output was reduced to a value too low to be read on the MN-4's rf wattmeter (probably less than one watt). Even at that low power it was necessary to severely shunt the microammeter on the indicator in order to prevent its being violently pegged by the antenna's rf. (Note: The point of maximum rf current was approximately one-half wave back from the feedpoint.)

Conclusion: There indeed is rf current on the outer conductor of a coaxial cable having an unbalanced feed to a dipole. This current, however, is very small. The radiated power ratio, cable versus antenna, can only be estimated; probably it lies between 1:1000 and 1:10,000. The assumption that there is a high-voltage point on a cable's outer conductor a quarter-wave back from the feedpoint is not valid.

experiment 5

This started out as a duplicate of experiment 4 but with the balun in place. No rf current was detected on the cable's outer conductor; so the experiment was terminated.

the results

Let's evaluate the results. The use of a balun gives some small advantage, both in balancing the radiation from the dipole and in diminishing the radiation from the coax.

The assumption that a mismatched (mismatched, not unbalanced) load, which engenders a moderately-high vswr, causes standing waves upon and radiation from a coaxial transmission line is without basis. Somebody will have to come up with a new excuse for all those mysterious cases of TVI, "hot" microphones, etc., that have been explained off as, "standing waves on the transmission line."

A transmission line does not transform itself into a vee antenna consisting of a half dipole plus a quarter-wave of transmission line outer conductor. Again, some new excuses are needed.

For your own evaluation of these findings, please consider that the experiments were conducted under rigid control. All findings were duplicated by another person before being accepted. Two of the persons involved are retired electronic engineers, the other a retired electrical foreman; all are experienced radio amateurs. The instruments used, with the exception of the homebuilt rf current indicator, were high-grade, equal to what might be found in a laboratory. Every effort was made to have all findings factual — not to "prove" some previously-held assumption.

Although this article is being written by one person, I want to emphasize that J. D. Odneal, W5TMY, and Ellard W. Foster, W5KE, were equal participants in the project. It could not have been conducted without their co-equal participation.

If you have reason to doubt our findings, I beg you not to dispute them solely from a theoretical basis. Duplicate the experiment, then express your opinions!
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HM-5
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*Measured over a ¾ wavelength whip

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80-meter antenna for a small lot

If you live in a stucco house on a small city lot, here's how to install an 80-meter antenna.

Housing tracts with small, uniform, close-spaced lots exist throughout the United States. In California the typical house on such a lot uses stucco construction. This is fine for the climate, but the galvanized-steel wire mesh used to support the stucco plaster is usually well grounded at each electrical outlet to the ac ground as well as to the cold-water pipe. Since this conductive, well grounded, two story, "shield can" rests approximately in the middle of the lot, it represents a non-ideal support for an amateur antenna; particularly a long, low-frequency antenna.

Faced with these facts, I tried to build an 80-meter antenna that would fit on the 60- by 100-foot lot, require no towers, be unobtrusive and be broadband enough for reasonable swr over the CW as well as phone portions of the band. I tried several configurations from U, L and V, ending up with the final Z shape shown in fig. 1. The desired broadband characteristics, in all cases, were dependent upon the "double bazooka" concept which combines the characteristics of a resonant coaxial length with a radiating dipole.

Because of the odd shape due to the lot size restrictions and the influence of the stucco-house "shield can" I found little correlation between published theory and my experimental measurements. I proceeded on a cut-try-measure-cut-try-etc. basis until the trends yielded a reasonable antenna.

The physical layout of the antenna, house and lot is shown in fig. 1. The coaxial center section of the antenna runs along the peak of the roof and then down the roof lines toward the two supporting towers.

Alfred Stahler, W6AGX, 5521 Big Oak Drive, San Jose, California 95129
trees. The coax feedline runs down vertically through the house to the transmitter. At the ends of the coaxial section are sections of open-wire transmission line with capacitance hats. The hats are made of two \( \frac{3}{4} \)-inch diameter, three-feet long, crossed aluminum rods. The dimensions of the antenna are shown in fig. 2.

Fig. 3 shows the measured swr vs frequency for several versions of this antenna. It can be seen that the influence of the Z-shape and the stucco house have drastically changed performance from that predicted in reference 1 for an isolated dipole. However, by trial and error the final geometry performs quite well over a large portion of the 80-meter band. Signal reports have been good, and the antenna seems to exhibit dipole-type directivity if the transmitting axis is assumed to be in a line with the antenna end points.

The rf voltage at the tips of the capacitance hats is very high so they should be placed well away from leaves, branches and people.

I hope that other amateurs who are restricted to life on similar house lots will be able to use this antenna configuration on 80 meters. Perhaps a similar arrangement could be developed for 160 meters.

**reference**

simple antennas
for
two-meter fm

Here is a selection of simple vhf antennas which can get you on the air at minimum cost.

The two-meter fm band is booming and the results are exciting, chiefly because of repeaters which make even crummy antennas acceptable for receiving and transmitting. Of course, if you have the money, you can spread yourself and buy commercially-made antennas which represent topnotch engineering design.

Looking through the Lafayette Catalog, for example, you can find a nice Ringo antenna which covers 135 to 175 MHz for $12.50. This is a vertical which may be used for mobile operation with the metal body of the car serving as a ground plane. It has a gain of 3.75 dB over an isotropic antenna. If there is one thing I’ve learned about verticals it is that a good ground system is necessary. However, if the thing is way up on a mast, far from ground, four radials will do the job. The radials should be slightly longer than the vertical radiating element, perhaps by 10%.

Since most mobile installations use vertical antennas it helps if the receiving antenna at the base station is also vertical. In some cases it doesn’t seem to matter.

fig. 1. Length of quarter-wave two-meter antennas.
especially in hilly country or wherever there are numerous reflections which may change the relative polarization. The usual rule, however, is a vertical receiving antenna if the source transmitter uses a vertical.

In the *ARRL Radio Amateur's Handbook* halos and other weird horizontally-polarized antennas are shown, but hams don't seem to want to mess up their expensive autos with screwball antennas. The vertical is relatively unobtrusive, especially on two meters. I have seen some halos on masts mounted to bumpers on Volkswagens, and one guy even had a 10-meter whip on the front bumper of a VW.

The two-meter antenna can be relatively short. In a motel one ham took the oven grill out of the oven and used it as a ground plane for a small vertical with a magnetic mount on two meters, driving it with a Drake TR-22. He had a barrel of fun with it, using only a watt of rf power to get out. The repeater is a great thing.

On page 429 of the Lafayette Catalog, Antenna Specialists has a roof-mount antenna for $22.95, net. It is equipped with a stainless-steel whip with copper and nickel plating for low rf resistance. For home use a 7-element Cushcraft beam goes for $13.95 net and gives a forward gain of 11 dB. That's a lot of gain, and it really makes a difference. An 11-element, 2-meter Yagi antenna, Cushcraft, has a forward gain of 13.2 dB and goes for $17.95. At these prices, it hardly pays to build one yourself. Yet, the *ARRL Handbook* is full of material that assumes you are a radio engineer, master mechanic and have the facilities of a well equipped radio laboratory and machine shop. Some hams may have such facilities on their jobs, but access to them is a different matter.

A 22-element, 2-meter Yagi, Cushcraft, has a fantastic gain of 16 dB and sells for $49.50 net. Of course, the thing has to be put up on a mast somewhere, which may be the chimney of your little house, or you can buy an expensive mast for the backyard. Being poor, I can only dream of such goodies.

Heavy-duty antenna rotors may run $69.95 or more, depending on what you select. A directional antenna must be rotated unless you are interested in operating in only one direction.

**simple antennas**

The simple quarter-wave antenna shown in fig. 1 is from 18 to about 20-inches long for the 2-meter band. Around the center of the band, 146 MHz, which is where most of the activity seems to be, a quarter-wave is about 19 inches. You can use brass rod or even copper
tubing, and no. 14 hard-drawn enamel wire clipped to a 2x4 could even be used. Such antennas, while comparatively crude, are inexpensive and they work.

Other simple vertical antennas are shown in figs. 2 and 3. These require good grounds if not far above earth, not more than 10 feet, and ground-plane radials if they are mounted on a mast. By going to half-wave center-fed antennas the ground troubles are reduced, although any antenna generally works better over low resistance ground.

A simple beam is the Lazy-H (see fig. 6). This antenna works well on the high frequencies as well as on 6 and 2 meters. It can be put up in a horizontal plane above the house on a boom and rotated.

circular antenna

By bending some copper or brass rod into a circle you arrive at the antenna shown in fig. 7. This antenna can be used in a horizontal or vertical plane and fed with coax. The coax should be kept as short as possible to avoid losses which tend to mount up at vhf. Some cable characteristics are shown in table 1. If you have an antenna with 16 dB gain and you lose 6 dB in the cable run you still have 10 dB left, but with a cheap vertical a 6-dB loss is intolerable.

rabbit ear antenna

The rabbit ear antenna, fig. 8, may be used as a horizontally polarized half-wave...
table 1. Vhf characteristics of common coaxial cables.

<table>
<thead>
<tr>
<th>impedance (ohms)</th>
<th>loss (dB/100 feet at 150 MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RG-58/U</td>
<td>52</td>
</tr>
<tr>
<td>RG-59/U</td>
<td>73</td>
</tr>
<tr>
<td>RG-11/U</td>
<td>75</td>
</tr>
<tr>
<td>RG-8/U</td>
<td>52</td>
</tr>
</tbody>
</table>

antenna (19 inches for each element at 146 MHz). See fig. 1 for other dimensions in the two-meter fm band. Some of these tv antennas are well made and others are junky. Try to get a substantial, well-built one. The 300-ohm line may be clipped near the base, leaving tabs long enough to solder to a piece of 50- or 75-ohm coax.

The length of each element can be adjusted with a tape measure or an engineer’s scale. Each element can be tuned and resonated by the sliding action or trombone-like construction. This makes a simple and convenient low-power antenna. A Drake TR-22 will work into it, but don’t try to feed a kilowatt to it unless you like smoke.

So, as the old saying goes, you pay your money-and take your choice. If you are loaded, buy a commercial antenna. If you are watching the budget try one of the simpler types. They seem to work fairly well although some of them are not much for appearance.
how to
tailor your antenna
for optimum performance

A few ideas
for building
simple antennas,
and tailoring
commercial ones
to your individual
operating habits

Tailoring your antenna for your particular area and getting it to work properly can do wonders for your enjoyment of amateur radio. If "clothes make the man," and a tramp with a shave, a warm bath and a new suit looks like a company first vice president, then you can do a lot better by tailoring your antenna for that proud feeling.

We, nearly a half-million hams, live in a myriad of locations and conditions. Few of us have found the antenna which suits ourselves let alone the rest of the fine people in this hobby.

Particularly difficult is the challenge to the apartment dweller. There are an increasing number of tract and land-rental legal restrictions written into deeds and rental agreements. More than a few communities have very restrictive laws on antennas. To all of this add the watchful eye of your spouse and your neighbors' objection and you will see just a few of the problems you face when choosing an antenna.

Space is the prime guide when choosing an antenna, with cost and appearance being secondary factors.

the dipole

This simple antenna consumes little space, is the least expensive and can be made almost invisible. By fanning out the individual wires, you can obtain satis-
factory multiband operation. The swr is most simple to bring to unity by adjusting the leg lengths and the angle between the elements. Performance can be enhanced by the addition of a balun.

Placing the dipole in a position free of wave obstruction and at least one-quarter wavelength above ground can give some real fine performance. The preferred height above ground is one-half wavelength, but we don’t always achieve perfection in our antenna tailoring.

**beams**

Utilization of the driven element, reflector and director is best seen in the beam antenna where you use aluminum tubing, coils and a rotating mechanism. You can handily operate a beam on one band or a combination of three. The most popular arrangement is the 10-, 15- and 20-meter combination. The two great advantages of such a beam are the gain and the directivity of the signal, which cuts out considerable interference. A Yagi beam, resonated to the correct frequency, balun and half-wave transmission line is the best antenna system which I have tried. This is the experience of very many other hams, too. A good, well-tailored Yagi is hard to beat.

Many amateurs are short on aluminum tubing and fittings, coils, rotators and the tailoring ability to make such an array as described above. Fortunately, there are two types of wire beams which are easy to build and inexpensive as well. The first is the three-element 20-meter wire beam shown in fig. 1. It consists of a driven element, with balun, placed one-half wavelength above a reflector of wire, which is 5% longer than the driven element. This will radiate a greater signal at right angles to the driven element. This may be increased by placing a director one-quarter wavelength in your preferred direction. The director should be 5% shorter than the driven element.

With a grid-dip meter and an antenna bridge you may adjust the driven-element to director spacing to the desired operating frequency and input impedance, with the gain checked with a ham friend a couple of hundred miles away. This antenna will really whistle.

The second wire beam is a two-element job with a little different and easier tailoring as shown in fig. 2. The driven element is made of light-weight aluminum tubing. I obtained 1/2 inch surplus aluminum tubing which was made so that one six-foot length would slide into another. With these sections I made two such lengths, each 16-feet long. These two elements are separated with a piece of wooden dowling with the stabilizing bolts attached to each side of the balun. The RG-8/U coaxial transmission line was cut to one-wavelength long at the operating frequency of 14.270 MHz and attached to the transmitter.

This driven-element dipole arrangement is attached to a bamboo spreader supported by a nylon bridle. The director
wire is 31-feet, 4-inches of number 14 copper wire, placed 6½-feet toward my desired direction. I raised this array eight feet above the roof and my signal doubled.

Now before I could brag about this, my happiness was dampened a bit when I heard the loudest station on 20 meters telling his friend in New York about his 20-meter wire beam made with three elements — all of number-25 wire. I was reading all this on the back of this beam so I know, now, he is a better tailor than I.

**verticals**

The vertical antenna is dandy for limited space as long as you observe a few good tailoring rules. Verticals require a good clear space and perform best with a good ground plane or radial system. The better these conditions are met, the better the function. However, it is a surprise how well a vertical will work with less than ideal conditions. A vertical cut to the desired frequency with one wire to a water pipe, ground stake or even a base of random chicken wire, will occasionally do a passable general and DX job. This is almost as good as a system with a system of radials or a ground-plane.

Single-band verticals can be phased in the same manner as beams for gain and directivity. I find that the vertical is the easiest of all antennas to resonate to frequency and impedance match. Furthermore, these adjustments can be made without climbing towers or raising and lowering the elements. Minimal work gives maximal success.

**quads**

This closed loop and its cousin, the Delta Loop, have a full-wave driven element and reflector working to give a fine gain and directivity. Performance is great with a quad but I can personally vouch for the large size and fragility of this type of antenna. Here is a place for you to tailor yourself a real fine antenna if you have the space and skills which I found I lacked.

**rhombics and long wires**

The rhombic is beyond the usual ham as it takes a lot of space which most of us don’t have. I saw a grand rhombic in use on field day — my only observation was that they burned out the finals in my transceiver with their tuning and transmitting. My interest in rhombics is now at a low ebb.

The long wire antenna has come into wider use lately. Recently, I heard an Alaskan operator describe a unique way of getting his long wire into a tree top. He fixed a string onto an arrow which he shot over the top of the tree and then teased up his insulated 400-foot long wire. His signal was tremendous.

My experience with my own long-wire antenna tuner, and a commercial model as well, has indicated good performance but poor in the area of tvI. I now use my long-wire antenna tuner on my bamboo fishing pole balcony antenna cut for 15 meter CW, with a short coaxial transmission line to the tuner. The swr is nearly 1:1 and I have no television interference. Fig. 3 shows my bamboo fishing pole balcony antenna which uses the metal railing as a ground plane. I use the ground in the electric base plug in the shack for the antenna tuner ground.

**miniaturizing**

The ham antenna can be shortened by use of several different techniques. You can insert a coil to shorten the overall length, or use a capacitance hat. The
addition of coils causes some lumping of the antenna which will reduce the Q factor and narrow the bandwidth somewhat, but this is minimal if your tailoring is good. Of course, bringing the ends of the elements off at an angle will for-shorten the necessary space, too. The long-wire tuner will work with one-quarter wavelength antenna with a good ground. During vacation I have used my bamboo fish pole with 40 feet of wire over a balcony to work 10 through 40 meters.

Hams are very ingenious when it comes to figuring out how to get a signal out. I know one amateur who put his miniature vertical slightly on its side in his attic and he works the world. Another friend of mine had a dipole with director and reflector in his attic. Balcony railings and drain pipes can sometimes work well as ground planes. For camouflage I have used pale blue auto spray paint on rope guys, insulators, baluns and coax.

Antenna tailoring has some very sound rules which I think should be followed. First of all, install the antenna high, in as clear an open area as possible. Avoid metal objects; this includes another antenna — such as a drooping dipole on a tower with metal or wire supports. Use rope where possible.

Resonate the antenna at the frequency you wish to use, cut the transmission line one-half wavelength long at your selected frequency and correct the input impedance to 50 ohms. Let the rest of the bands fall where they will if you have a multi-band antenna. Perfection on every band is impossible. Finally, learn to use the grid-dip meter and antenna bridge as these are your best antenna tailoring friends.

**conclusions**

A good antenna tailor will markedly improve performance on receiving and transmitting. Equally important is the fact that this improvement will often reduce or even eliminate radio, hi-fi, tv and telephone interference. Amateurs who are crowded closely together should include a bit of restraint in the use of power. A 100-watt signal will, with correct antenna tailoring, give you a lot of pleasure and relaxation. If you then add a linear often the entire neighborhood closes in. I have a friend who works the world and has one of the strongest signals from Honolulu. He uses only 500 watts. All of this is done in a large apartment unit packed with potential interference problems.

Don't think that tailoring means that you should build all of your own antennas. Most of us have neither the skill nor knowledge to compete with commercial antennas. Factory-made beams and multi-band verticals are far more attractive and function far better than what I can build. The electronic engineers who build these antennas do a good job of setting resonant frequencies and matching impedance. Their testing is done under far better conditions than most of us have at our disposal and often, after carefully following factory specifications, you will find that the antenna resonates out of the ham bands. Your intelligent adjustments will bring the swr and directivity in line with what the direction sheets show. Currently, my antenna building handicraft is reserved for dipoles, long wires and tricky little antennas for limited space. However, I have found antenna tailoring to be a challenging and rewarding part of the art of amateur radio.

**fig. 3. Fishing pole antenna with random length wire for portable operation on 10 through 40 meters.**

**ham radio**

may 1973
four-element
collinear antenna
for 440 MHz

Regardless of its design, a vertical omnidirectional gain antenna achieves its gain by the same process. It simply compresses the energy down on to the horizon where it is useful, and as a result, it wastes less radiating into the ground and up into the sky. Uhf antennas usually accomplish this by feeding several vertically mounted elements in phase so that the energy will combine itself into a pattern similar to that shown in fig. 1. These elements can all be fed in series, as Franklin, the originator of the collinear, did. This is the same system used by many commercial models (fig. 2). The elements can also be fed in parallel as I have done.

At first the series method seems much easier. A few inverted pieces of coax or a wire with some bends here and there and you’re done. However, this approach has several big disadvantages. First of all, all the construction errors are cumulative. If you’re slightly out of resonance at the
bottom, you can be sure that you're way out at the top. By its nature the series-fed collinear is a very touchy thing to get working properly and has very narrow band-width. Also, it must be supported by a low-loss pole or suspended from above. If it doesn't work when it's built, you have your hands full trying to find out why.

On the other hand, the parallel approach offers several advantages. First, all the elements exhibit 50-ohm input impedance and can be individually adjusted with a wattmeter. Secondly, the design is very rugged and the metal support pole can be grounded for lightning protection. In addition, the bandwidth of the antenna is at least 30 MHz and the elements can be positioned for either an omnidirectional or an offset pattern. Finally, it will work the first time you try it!

the dipole

Since the theory of the dipole is well known and covered in great detail in most antenna discussions, I won't dwell on it. The reason I selected the dipole over a folded dipole or a J-pole configuration is because of its simplicity and very wide bandwidth. It is constructed from 1/2-inch copper water pipe and 1/4-inch soft-drawn copper tubing. Both are excellent conductors and are readily available from most hardware stores.

As shown in fig. 3, the impedance of the dipole increases from the center to a maximum of about 70 ohms at the ends. The exact impedance depends on the length-to-diameter ratio of the element as well as the distance from other objects.

At one point along either side a place will be found that will match perfectly into a 50-ohm transmission line. This is where the gamma rod is attached. Because of all the unknown variables, this point must be found by trial and error. With the antenna described here the gamma rod is attached 3-inches from the center.

To compensate for the inductive reactance of the gamma rod and to achieve a perfect impedance match, a series gamma capacitor is required. This consists of a length of number-12 Teflon-insulated wire fitted inside the end of the gamma rod (fig. 9). A variable capacitor could be used but it would be hard to find one as inexpensive and weatherproof as the Teflon-insulated wire. Teflon was picked for its excellent electrical properties as well as for its resistance to the weather.

If Teflon is not available the center conductor of some RG-58/U coax will do, but the length will not be quite the same. If you use number-12 Teflon-insulated wire and follow the dimensions,
chances are that no tuning will be re-
required.
As with the input impedance, dipole
length is also affected by several variables.
The approximate length is given by the
formula
\[ \text{length (inches)} = \frac{5905k}{\text{freq (MHz)}} \]
The \( k \) factor compensates for the shorten-
ing effect that increasing element di-
ameter has on the length. This is plotted
in fig. 4. With a length-to-diameter ratio
of 24:1, \( k \) is equal to 0.9475. Therefore,

\[ \text{length (inches)} = \frac{(5905)(0.9475)}{\text{freq (MHz)}} = 5595 \text{ MHz} \]
or a length of 12.7 inches at 440 MHz.
Again, unfortunately, the graph of fig. 4
doesn’t take into account the additional
shortening effect of the support mast.
The increased capacitance of the mast
causes the actual resonant length to de-
crease by an additional 3½% (12½ inch-
es). This is mentioned mainly for those of
you who wish to scale this basic design to
another band. This information will get
you close enough so that only a little
trimming will be necessary.

**matching harness**

The function of the matching harness
is to split the power evenly and deliver it
to the elements in phase and at the
proper impedance. Fig. 5 shows that, in a
transmission line of even half wave-
lengths, the voltage and current are exact-
ly the same at the load as at the input.
This is true regardless of the vswr, assum-
ing a lossless line. Therefore, it follows
that the impedance is also the same at
both ends.

The graph of fig. 5 also shows that for
an odd 1/4-wavelength section the input
and the load impedance are inverted. In
other words, if at the input the voltage
peaks and the current nulls, at the load
the current would be at a peak and the
voltage would null. This relationship is
given by

\[ \text{input impedance} = \frac{Z_0^2}{Z_r} \]

Where \( Z_0 \) is the characteristic impedance
of the line and \( Z_r \) is the load impedance
(must be resistive).

Now, look at the harness schematic in
fig. 6. Since each 50-ohm dipole is fed
with a one-wavelength section the im-
pedance at the input end is also 50 ohms.
The four 50-ohm sections pair into two
tees. Therefore, the impedance at the tees
becomes 25 ohms. The tees are then
connected to a 1-1/4 wavelength section of transmission line. Therefore, from the above equation

\[
\text{input impedance} = \frac{50 \text{ ohms}^2}{25 \text{ ohms}} = \frac{2500}{25} = 100 \text{ ohms}
\]

The two 5/4-wavelength lines are then connected through a tee, providing an input impedance of 50 ohms.

**antenna spacing**

With the dipoles and the harness out of the way only two things remain. The dipole to mounting pole spacing and the dipole to dipole spacing.

The horizontal field-strength patterns in fig. 7 were plotted using one of the dipoles mounted with a clamp to a pole on the roof of my house. The skewing of the patterns is due to the large relative size and close proximity of the clamp. I found that a spacing of 2- to 2¼-inches produced the best match and the highest gain. This corresponds to a spacing of about 0.11 to 0.12 wavelengths.

I didn’t run any tests on vertical spacing, but research by others on similar antennas has shown that the maximum gain for a four-element array is achieved with a spacing of 0.97 wavelengths (26 inches at 440 MHz). This, incidentally, is the main reason for using the foam-filled coax. Belden 8219 coaxial cable has a velocity factor of 0.78 as opposed to only 0.659 for RG-58/U. Therefore, the length of harness made of 8219 cable will be correspondingly longer, thus allowing the elements to be spaced for maximum gain. If RG-58/U is used, the harness will not quite reach, and the spacing has to be reduced slightly. Since the difference is only a few inches, only a few tenths of a dB are lost, so don’t worry if you can’t find Belden 8219 coaxial cable.

**construction**

I would suggest that all the copper and
brass be polished before it is cut up, as this is much easier than doing it afterwards and will help to insure good solder joints. If you are going to use a gas stove or a torch be sure to do the actual soldering away from the flame. Otherwise, the rosin will burn and won't do its job.

Remember, at these frequencies the rf is concentrated in the outer few thousandths of an inch of conductor and a good solder joint is more important than ever. After soldering, cooling can be speeded up a bit by dripping a small amount of water on the end of the pipe farthest from the solder joint.

However, don't overdo it. Also, be very careful not to move the solder joint while it is cooling. A good solder joint will have a smooth appearance and a nice even fillet. If it's dull and grainy looking it was either moved before it solidified or was cooled too fast.

Dipole construction is simple and straightforward. A tubing cutter is a big time saver and does a very neat job. Other than that, no special tools are required. First, take the 1/2-inch pipe and cut it into eight pieces, each 5-3/4-inches long. In four of these pieces drill a 1/4-inch hole 3-inches from one end (fig. 9). From the remaining piece of pipe cut four pieces, each 4-1/2-inches long.

Next comes the 1/4-inch tubing for the gamma match. Make a 3/8-inch radius bend of 90-degrees and cut to size as shown in fig. 9. Be careful to leave at least 1/4-inch extra where the gamma rod mounts into the 1/2-inch element. The important thing here is to avoid kinks. After the 1/4-inch gamma rods have been bent, deburr the end that the wire will go into, using a small round file or a drill.

To make the support brackets cut a piece of copper or brass sheet 5/8-inch wide by 6-inches long and drill four 3/8-inch holes as shown in fig. 10. Cut and bend the brackets as shown, and then, using a vise or pliers, bend the side that is to be soldered to the pipe to conform to it.

Now, you are ready to begin soldering. First, solder the gamma rod to the pipe element. Pinch the end of the gamma rod a bit so you have a tight fit; then line it up. Hold the gamma rod and the element steady with a damp rag and start soldering. When it cools off, if it's a little out of line, it can easily be bent into shape. Next, assemble the element, temporarily

fig. 9. Construction of the gamma match. The Teflon tubing is used only to hold the wire firmly in place.
fig. 8. Gain to be expected from an omnidirection collinear array of dipole elements relative to the gain of a single element. \( N \) = number of elements.

leaving off the connector and the wire.

With the dipole laying on your bench the bracket and the gamma rod should point straight up with the bracket flush with the tee. Drill a small hole through both the bracket and the pipe, and run a screw through them to hold everything steady while you’re soldering (the screw can then be removed).

To keep the gamma rod from coming loose while you’re soldering the bracket, hold the dipole with a damp rag at the gamma-rod end. Now, solder all the parts together.

When it cools you are ready to cut the mounting hole in the support arm (fig. 11). First, cut a V-shaped hole with a hack saw, being careful to keep the saw blade parallel with the element. Then file the hole to the same radius as the mounting pole. Check your progress often by fitting it to the mast. It’s important for the spacing to be an even 2½-inches the whole length and for the dipole to be parallel with the mast.

You might think that a simple clamp would be much easier, but a glance at fig. 7 shows what that does to the pattern. Now, give the whole thing a quick going over with the polish and install the connector and the wire. Make sure no strands are sticking out beyond the insulation that could short to the copper tubing. Leave a slight bend in the wire so that it can be adjusted a little each way from the 9/16-inch depth. Jam a piece of Teflon tubing in to hold the wire securely in place.

Construction of the dipole elements, showing the layout of the gamma match.
If you have access to a wattmeter you can now temporarily mount each element on the mast and tune for minimum reflected power. Keep everything, including your body, at least ten feet away when taking a reading. Tape the coax out of the way behind the pole and run it down to the ground. Only a slight adjustment of the wire depth, if any, should be required (with 50-watts input the reflected power should be much less than a watt).

When each element has been tuned remove the rosin and polish with a solvent such as undiluted alcohol, tape over the mating end of the BNC connector and you’re ready to put on a coat of epoxy. I sprayed the epoxy on using an aerosol power pack but it can also be brushed on. Cover everything thoroughly. If it’s not covered it will corrode, and corrosion is a lousy conductor! When you are done hang the elements up to dry.

**harness construction**

The construction of the harness is very simple. The lengths are found from

\[
\text{wavelength (inches)} = \frac{11800 \text{ (velocity factor)}}{\text{freq (MHz)}}
\]

Remember that the connectors are considered to be part of the coax cable and must be included in your measurements (fig. 6). I found it easiest to stick a length of masking tape down on my work bench and mark the length out on it. Install a BNC connector on one end of the coax, connect it to a tee and then measure from the center of the tee. I intentionally made my cables a little long and then figured out how much shortening was necessary to make them the right length.

When you have finished all the matching sections assemble the harness and check for continuity between all the center pins. Now, liberally coat all the places that water could ever conceivably enter with silicon sealant.

**final assembly**

After everything is dry all that is necessary is to mount everything on the mast. If you use the Belden 8219 coax you can use the maximum gain spacing of 0.97-wavelength. If you use RG-58/U you will have to mount the elements slightly closer together. Leave a foot between the top of the mast and the top of the first dipole. Line it up and drill a hole through the pole and the pipe (fig. 11).
When you tighten the mounting bolt don’t get carried away. The copper pipe deforms quite easily. Be sure to use a lock washer or a self-locking nut. Then run the cable around to the back, away from the element, and secure it with a plastic cable tie or tape.

Next, decide what kind of a pattern you want. The omnidirectional pattern has about 6 dB gain over a dipole and the offset pattern, about 9 dB toward the front (fig. 12). If you want the offset pattern all you have to do is mount all the elements facing the same way. If you want the omni pattern point them 90-degrees apart. Mount the bottom element as far down the mast as it will easily go if you use RG-58/U or 78-inches if you use Belden 8219 coax. Don’t cheat and use a BNC right-angle connector as that would change the length of the line and mess it up. Next, mount the remaining two elements evenly between the others and secure the harness in place behind the dipoles.

**Conclusion**

If some of the materials listed are not available, don’t be put off. Improvise. The BNC connectors were selected because they are improved and weather-proof. However, if they are all sealed with silicon sealant, as I have suggested, the older type BNC connectors should work just fine. In fact, if a low-loss weather-proof connection can be devised, no connectors would be needed at all. This would save considerable money and might allow the harness to fit inside the mast out of the weather.

The pool skimmer pole I used for the mast was selected only because of its low cost and availability in California. It can be replaced by almost anything. I hope that you have as much fun building this antenna as I had — you will be pleased with the results.

**References**


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**Table 1. Parts list for the four-element 450-MHz collinear antenna.**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 feet</td>
<td>½&quot; hard-drawn copper pipe</td>
</tr>
<tr>
<td>2 feet</td>
<td>¼&quot; soft-drawn copper tubing</td>
</tr>
<tr>
<td>20 feet</td>
<td>Belden 8219 foam-filled coaxial cable</td>
</tr>
<tr>
<td>1 foot</td>
<td>1/16&quot; Teflon tubing</td>
</tr>
<tr>
<td>1 foot</td>
<td>number-12 Teflon-insulated wire</td>
</tr>
<tr>
<td>1 pint</td>
<td>clear epoxy paint</td>
</tr>
<tr>
<td>1 tube</td>
<td>silicon sealant</td>
</tr>
<tr>
<td>1 can</td>
<td>Brasso metal polish</td>
</tr>
<tr>
<td>4 sets</td>
<td>stainless-steel hardware (2&quot; x ¼&quot; bolts, nuts and washers)</td>
</tr>
<tr>
<td>4</td>
<td>½&quot; copper tees</td>
</tr>
<tr>
<td>1</td>
<td>brass sheet, 6&quot; long, 5/8&quot; wide</td>
</tr>
<tr>
<td>13</td>
<td>12- or 17-foot single-section aluminum swimming pool skimmer pole (or equivalent for mast)</td>
</tr>
<tr>
<td>3</td>
<td>UG-88E/U BNC cable-mounted male connectors</td>
</tr>
<tr>
<td>4</td>
<td>UG-274B/U BNC tee connector</td>
</tr>
<tr>
<td>1</td>
<td>UG-109A4/U BNC female bulkhead mount connectors</td>
</tr>
<tr>
<td>1</td>
<td>UG-556B/U Type-N female cable connector</td>
</tr>
</tbody>
</table>

**Fig. 12. Horizontal field strength of the four-element collinear with all elements facing front. Gain in this configuration is approximately 9 dB. Single dipole is shown for reference (dashed line).**
how to design
gamma-matching networks

A complete procedure for designing gamma and tee antenna-matching networks

When the driving-point impedance of thin linear antenna systems is known, these systems can generally be gamma- or T-matched to a transmission line with excellent results. The gamma-match is used to match an unbalanced coaxial line to either a monopole or a dipole driven element, and the T-match is used to match a two-wire balanced line to a dipole driven element.

I will first discuss the gamma matching procedure, and will follow that with the T-match, showing that it is simply an extension of the technique used to design a gamma match.

gamma match

The layout of the gamma-match, minus the capacitor, is one-half that of a T-match, as shown in fig. 1. In this illustration $L$ is the length of one-half of the driven dipole (total length of the driven monopole) and is often near one-quarter wavelength long. The length of the gamma rod, which is parallel to the driven element, is labeled $l_r$. The center-to-center spacing between the gamma rod and driven ele-
ment is $S$, and $Z_i$ is the input impedance to the gamma network, including the driving-point impedance.

When the element and gamma-rod diameters and spacings are much less than the carrier wavelength at which the system will be used, the geometry of fig. 1 is analogous to the electrical circuit shown in fig. 2.\(^1\) In fig. 2 the input impedance, $Z_i$, is equal to

$$Z_i = \frac{(H_z Z_a)(X_s)}{H_z Z_a + X_s} \text{ ohms} \quad (1)$$

where $Z_a$ is one-half the dipole driving-point impedance (or monopole driving impedance), $X_s$ is the reactance of the gamma rod and $H_z$ is the antenna impedance step-up ratio.

The reactance of the gamma rod $X_s$ is given by

$$X_s = jZ_o \tan k\ell \text{ ohms} \quad (2)$$

where $Z_o = 60 \cosh^{-1}\left(\frac{4S^2 - D^2 - d^2}{2Dd}\right) \text{ ohms}$ in air* and $k = 2\pi/\lambda$ radians per meter. The reactance, $X_s$, is positive when the


gamma rod electrical length, given by $k\ell$, is less than $\pi/2$ radians, as will be assumed here.

![fig. 1. The basic gamma match. L is one-half the length of the driven dipole.](image)

The formula for the numeric antenna impedance step-up ratio, $H_z$, is

$$H_z = \left[1 + \frac{\cosh^{-1}\left(\frac{4S^2 - D^2 + d^2}{4Sd}\right)}{\cosh^{-1}\left(\frac{4S^2 + D^2 - d^2}{4SD}\right)}\right]^2 \quad (3)$$

where $D$ is the diameter of the driven element, $d$ is the diameter of the gamma rod and $S$ is the spacing between the two. This factor is plotted in normalized form in fig. 3 for use in gamma-match designs. In plotting this graph it was assumed that $H_z$ is at least 4:1, a realistic assumption in most amateur applications.

When the antenna is a self-resonant folded monopole the length of the gamma rod approaches $\pi/2$ electrical radians and $X_s$ becomes much larger than $H_z Z_a$. In this case eq. 1 is reduced to

$$Z_i = H_z Z_a \text{ ohms} \quad (4)$$

In this case $Z_a$ is not highly resistive and a low VSWR at the junction of the folding element and the coaxial line may not be possible.

The complex input impedance, $Z_i$, of eq. 1 may be written as a magnitude $M$ and phase angle as given here

$$Z_i = M \angle \psi \quad (5)$$
where

\[ M = \frac{X_s H_z \sqrt{\frac{R_a^2}{\sqrt{R_a^2 + \left(X_s + H_z X_a\right)^2}}}}{\sqrt{(H_z R_a)^2 + \left(X_s + H_z X_a\right)^2}} \text{ ohms} \]

\[ \psi = \tan^{-1} \left[ \frac{H_z \left(\frac{R_a^2 + \left(X_a\right)^2}{X_s R_a} + \frac{X_s}{R_a}\right)}{X_s} \right] \text{ degrees} \]

To match a lossless high-frequency transmission-line characteristic resistance, \( R_o \),

\[ M \cos \psi = R_o \text{ ohms} \]

The lumped reactance, \( X_l \), added in series with \( Z_i \) to tune out or cancel the reactive component of \( Z_i \) can be determined from

\[ M \sin \psi = -X_l \text{ ohms} \]

For eq. 5 to have the correct magnitude and phase angle,

\[ X_s = H_z \left\{ R_o \frac{X_a + \sqrt{(R_a X_a)^2 + R_o \left[H_z R_a - R_o\right] \left[(R_a X_a)^2 + \left(X_a\right)^2\right]}}{H_z R_a - R_o} \right\} \text{ ohms} \]

From which

\[ X_l = -R_o \tan \psi \]

\[ = -R_o \left\{ \frac{H_z \left[(R_a X_a)^2 + \left(X_a\right)^2\right] + X_a}{X_s R_a} \right\} \] \hspace{1cm} (7)

The electrical length of the gamma rod (see eq. 2), \( k/l_\Gamma \), is equal to

\[ k/l_\Gamma = \frac{2\pi f_{\text{MHz}}}{\lambda} \approx \frac{2\pi}{(0.956)(300)(39.37)(2\pi)} \]

\[ \approx 0.03188 \text{ f}_{\text{MHz}} l_\Gamma \text{ degrees} \] \hspace{1cm} (8)

The quantity \( l_\Gamma \) is the length of the gamma rod in inches and the 0.956 coefficient is an average relative velocity along the gamma rod and radiating elements.

As I was developing eqs. 6 and 7 two ratios often appeared in my calculations. I have called these \( T \) and \( Q \):

\[ T = \frac{H_z}{Z_o} \text{ ohms}^{-1} \] \hspace{1cm} (9)

\[ Q = \frac{X}{H_z} = \frac{\tan k/l_\Gamma}{T} \text{ ohms} \] \hspace{1cm} (10)

These two ratios are useful observations because \( H_z \) and \( Z_o \) are a function of \( S/D \) and \( D/d \). That is, when \( H_z \) is determined, \( T \) can be found, and a solution for \( Q \) eliminates a separate calculation for \( Z_o \).

Fig. 4 is a normalized graph of \( T \) vs \( S/D \) and \( D/d \), and fig. 5 is a plot of \( k/l_\Gamma \) in degrees vs \( Q \) and \( T \). These graphs are extremely helpful when designing a practical gamma matching system.

When eq. 10 is substituted into eq. 6, a solution for \( Q \) is a positive discriminant root of a quadratic equation as follows,

\[ Q = A + \sqrt{A^2 + B} \text{ ohms} \] \hspace{1cm} (11)

Where

\[ A = \frac{R_o X_a}{H_z R_a - R_o} \text{ ohms} \]

\[ B = \frac{R_o \left[(R_a X_a)^2 + \left(X_a\right)^2\right]}{H_z R_a - R_o} \text{ ohms}^2 \]

When eq. 10 is used with eq. 7 a solution for the reactance of the gamma capacitor can be obtained

\[ X_l = -\frac{1}{2\pi f_{\text{MHz}}} = -[E + F] \text{ ohms} \] \hspace{1cm} (12)

This equation may be rearranged to provide the value of the gamma capacitor in pF

\[ C_{\Gamma} = \frac{10^6}{2\pi [E + F] f_{\text{MHz}}} \text{ pF} \] \hspace{1cm} (13)

Where

\[ E = \frac{R_o \left[(R_a X_a)^2 + \left(X_a\right)^2\right]}{Q} \text{ ohms} \]

\[ F = \frac{R_o X_a}{R_a} \text{ ohms} \]

In eqs. 12 and 13 the sum of \( E \) and \( F \) is positive. Otherwise, the phase angle is in the fourth quadrant and the gamma-matching capacitor \( C_\Gamma \) cannot be used. For the reactance of the gamma match, \( X_l \), to remain positive, the electrical length of the gamma rod, \( k/l_\Gamma \), must be less than 90 electrical degrees and eqs. 6 and 11 have the restriction

\[ H_z > \frac{R_o}{R_a} \] \hspace{1cm} (14)
This equation is very important to broadband array operation. That is, \( R_a \) may change considerably with frequency changes and \( H_z \) should be large enough to assure the restriction given by eq. 14. Furthermore, VSWR readings over a broad band reflect the combined characteristics of the antenna and the matching network, and a well designed gamma- or T-network will follow the inverse behavior of the antenna driving-point impedance.

Large values of \( H_z \) imply small values of \( S \) together with large wire diameter ratios, \( D/d \). At the same time, the electrical length of the gamma rod, \( k_{11} \), should be greater than about 15 electrical degrees to minimize ohmic circuit losses as well as to maximize antenna system bandwidth. However, large values of \( H_z \) along with large design values of \( k_{11} \) can lead to construction errors and/or instability in \( H_z, Z_o, T \) and \( Q \). When the driven element diameter is not very large an \( H_z \) of more than 20 to 30 may not be practical.

When the driven element or parasitic elements of an array are arbitrarily pruned, element length and/or spacing, to obtain a resistive driving-point impedance, the forward gain may be reduced. There are many combinations of \( R_a, X_a, H_z, Z_o \) which satisfy eq. 6. Also, many combinations of \( D, d, S \) and \( C \) which are correct solutions, but not necessarily best.

For example, if it is desirable to reduce the length of the gamma rod, eq. 10 shows that \( Q \) will be reduced (\( T \) is inversely related). Looking further, eq. 6 shows that a reduction in \( Q \) requires an increase in \( H_z \), and eq. 2 shows that an increase in \( H_z \) requires an increase in \( D/d \) or a decrease in \( S/D \) (or combination of both). From eq. 3 it can be seen that an increase in \( D/d \) increases \( Z_o \), while a decrease in \( S/D \) decreases \( Z_o \). The ambiguity here is eliminated by plotting \( T \), given in eq. 9 and plotted in fig. 4.

![fig. 3. Antenna impedance step-up ratio, \( H_z \), as a function of element diameters and spacing.](image-url)
practical gamma-match

Some time ago I obtained a homebrew 10-element, two-meter Yagi-Uda type inline end-fire array with somewhat unusual spacings and element lengths. Measurements with the antenna's dissimilar diameter folded-dipole driven element connected to 300 ohm open-wire line indicated that its best overall performance was near lower end of the 144-MHz band. An analysis of element lengths and spacing confirmed this observation, and calculations indicated that best performance was at about 144.6 MHz.

Since I wanted to use the antenna at a somewhat higher frequency, 145.4 MHz, I discarded the folding element (which transfers any antenna driving-point impedance, real or complex, to the transmission line) and shortened all the elements. I did not change element spacing or boom length, so performance was compromised somewhat. However, calculations indicated that the array’s performance was much improved over the 145.35- to 146.25-MHz segment of the band. The free-space driving-point impedance, $Z_a'$, is slightly inductive, about 14 + j3 ohms at 145.4 MHz where I'll be using the antenna most of the time.

To use the previously discussed gamma-match design equations, the free-space input impedance, $Z_a'$, must be divided by 2. Therefore, $Z_a' = 7 + j1.5$ ohms. Since I planned to use 50-ohm polyfoam RG-8/U with the antenna, $R_o = 50$ ohms.

The diameter of the driven element is 0.375 inch and the diameter of the gamma rod, which is made from number-12 wire, is 0.0808 inch. The spacing between the elements, $S$, is approximately 0.6029 inch (0.375-inch long insulator plus one-half the diameter of the driven element, plus one-half the diameter of the gamma rod).

With these figures, the gamma-match design procedure can begin by finding two simple ratios:

$$\frac{D}{d} = 4.64$$

$$\frac{S}{D} = 1.61$$

When these two ratios have been found, the antenna impedance step-up ratio, $H_z$, can be found from fig. 3. In this case, $H_z$ is equal to approximately 11.0. The quantity $T$ can be determined with the help of fig. 4, approximately 0.046 ohm$^{-1}$ in this case. Now, calculate $A$ and $B$ and use those quantities to find $Q$:

$$A = \frac{R_o X_a}{H_z R_a - R_o} \approx +75 \approx +2.77 \text{ ohms}$$

$$B = \frac{R_o \left[ \left( \frac{R_a}{R_o} \right)^2 + \left( \frac{X_a}{R_o} \right)^2 \right]}{H_z R_a - R_o}$$

$$\approx \frac{2562.5}{27} \approx 94.9 \text{ ohms}^2$$

$$Q = A + \sqrt{A^2 + B}$$

$$\approx +2.77 + \sqrt{102.57} \approx 12.9 \text{ ohms}$$

With the quantities $Q$ and $T$ known, the electrical length of the gamma rod, $l/\Gamma$, in degrees can be determined with the help of fig. 5. In this case the gamma rod is approximately 31.0 electrical degrees long. This can be converted into inches by rearranging eq. 8.

$$l/\Gamma \approx \frac{k/\Gamma}{0.03188f_{MHz}} \approx \frac{31}{0.03188(145.4)}$$

$$\approx 6.69 \text{ inches}$$

To find the required gamma capacitance, calculate the quantities $E$ and $F$ from eq. 13.

$$E = \frac{R_o}{R_a} \left[ \frac{\left( \frac{R_a}{R_o} \right)^2 + \left( \frac{X_a}{R_o} \right)^2}{Q} \right]$$

$$\approx \frac{2562.5}{(7)(12.9)} \approx 28.38 \text{ ohms}$$

$$F = \frac{R_o X_a}{R_a} \approx 50 \frac{(+1.5)}{7} \approx 10.7 \text{ ohms}$$

$$C_\Gamma = \frac{1000000}{2\pi (E + F) f_{MHz}}$$

$$\approx \frac{1000000}{35700} \approx 28 \text{ pF}$$

50 May 1973
Thus, the gamma-matching network consists of a gamma rod made from number-12 wire, approximately 6.69 inches long with an axial center-to-center spacing of 0.6029 inch from the parallel driven element. The gamma capacitor is about 28 pF, which can be provided by the 7- to 45-pF variable I happen to have in my junkbox.

This same basic design procedure can also be used if the driving-point impedance is slightly capacitive. For example, if my two-meter array driving-point impedance had been 14 - j3 ohms at 145.4 MHz, \( Z_a \) for design purposes would be 7 - j1.5 ohms. The values for \( D/L, S/D, H_z, T, A \) and \( B \) would be the same as for the previous case, although the \( A \) quantity would have a negative sign. This changes the magnitude of \( Q \) to 7.36 ohms. Referring to fig. 5, the length of the gamma rod is approximately 20.0 electrical degrees, and its length is

\[
\text{\( l \Gamma = \frac{k\lambda}{0.03188 f_{\text{MHz}}} \)}
\]

\[
\cong \frac{20}{0.03188(145.4)} \cong 4.31 \text{ inches}
\]

Now, calculate the quantities \( E \) and \( F \) and determine the value of the gamma capacitor:

\[
E = \frac{R_o}{R_a} \left[ \frac{(R_a)^2 + (X_a)^2}{Q} \right]
\]

\[
= \frac{2562.5}{(7)(7.36)} \cong 49.73 \text{ ohms}
\]

\[
F = \frac{R_o}{R_a} X_a \cong \frac{50(-1.5)}{7} = +10.7 \text{ ohms}
\]

\[
C \Gamma = \frac{1,000,000}{2\pi [E + F] f_{\text{MHz}}} \]

\[
= \frac{1,000,000}{35,700} \cong 28 \text{ pF}
\]

Thus, when the gamma rod is shortened from 6.69 inches to about 4.31 inches, and no other changes are made, the gamma network will properly terminate the 50-ohm coaxial feedline into an antenna impedance of 14 - j3 ohms.

### Testing the Design

Using an adjustable gamma rod 7.5 inches long and a 7- to 45-pF variable gamma capacitor, I assembled the gamma match to the antenna. When the antenna was erected horizontally, 18-feet above the ground, with the gamma rod adjusted to 6.75-inches long and the gamma capaci-

![Gamma-matching system for the 144-HMz Yagi beam antenna.](image)

As can be seen, at the design frequency of 145.4 MHz the standing-wave ratio is extremely small. Calculations indicated that the driving-point impedance of this modified home-brew array becomes slightly capacitive at both 144.9 and 146.3 MHz. Therefore, I began to shorten the length of the gamma rod and increase the gamma capacitance to see if I could obtain a constant vswr. With a gamma rod length of 5.5625 inches and the gamma capacitor set to 35 pF I obtained what I was looking for:

- 146.3 MHz 1.38:1 vswr
- 145.4 MHz 1.03:1 vswr
- 144.9 MHz 1.16:1 vswr

I then twisted the antenna boom 90° so that the antenna was vertically polarized on the metal mast. Without touching the gamma adjustments, I slipped the boom back and forth until I obtained a minimum vswr of 1.3:1 at 145.4 MHz.
The boom was locked at this point, and both the gamma rod and gamma capacitor were adjusted (in that order) to obtain a minimum vswr of 1.09:1.

I then started to raise the height of the array by increasing the height of the mast. When the array was about two feet higher (13 quarter-wavelengths above ground) the vswr was maximum at 1.6:1. Above

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>VSWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>146.3</td>
<td>1.10:1</td>
</tr>
<tr>
<td>145.4</td>
<td>1.02:1</td>
</tr>
<tr>
<td>144.9</td>
<td>1.04:1</td>
</tr>
</tbody>
</table>

**Performance**

Essentially all of the two-meter stations in Tucson, about 35 miles from my station, are vertically polarized, and my propagation is by diffraction over the north end of the Santa Rita mountain range. In running tests with K7RMH in Tucson, I was delighted to find that my British dual-eight skeleton slot antenna, which is 3 to 4 feet higher than the homebrew array, was only about 3 dB better with the same power input. That is, with one-watt rf input, at K7RMH's station I was S9 +30 dB with the homebrew array and S9 +33 dB with the skeleton slot.

Upon further testing with a two-position coaxial switch in the feedline for rapid switching between the line tuner and the RG-8/U coaxial cable, I discovered that the coaxial switch generates a vswr of 1.5:1 at the transmitter. This results in
about a 1.0 dB loss at K7RMH's station which suggests that the K7RMH signal readings are intensity, not power, sensitive. This indicates that a change of 3 dB at K7RMH is a power change of 6 dB.

Calculations indicate that the gain of the skeleton slot is about 4 dB better than that of the homebrew array. I am using Propagation calling for papers on antenna measurements.

It may be that the recent article by W3TQO which described how to determine antenna impedance by direct SWR measurements may prove popular with amateurs. I hope to try this procedure sometime to confirm my calculations on

about 35-feet of 300-ohm open-wire feedline to the slot antenna, and 50-feet of RG-8/U polyfoam coax to the homebrew array. Assuming that 1 dB more is lost in the coaxial line than in the open-wire feeder, and that the height gain of the slot antenna is 1 dB better, the test results check out very well.

impedance measurements

A problem many amateurs face when designing their own antenna is measuring the driving-point impedance. Often, they do not have the necessary equipment or the technique is long and drawn out, and provides erroneous results. This seems to be underscored by an article in the July, 1972, IEEE Trans. on Antennas and the homebrew two-meter array to see how it works out.

Another possibility is the simple complex impedance bridge described by W2CTK. When compared to a commercial RX bridge the accuracy of the W2CTK bridge is quite good. A complete discussion on the use of this instrument appears elsewhere in this issue.

In the absence of impedance measurements, the amateur must generally resort to existing published material which provides the driving-point impedance for various antenna configurations. However, with different (unscaled) antenna layouts, the magnitude and phase angle of the driving-point impedance will be different.

However, a review of some of the

![Graph](image-url)
available material suggests that, most of the time, the resistive, $R_a$, and reactive, $X_a$, portions of the antenna driving-point impedance will fall within the following limits:

$$+ 3 \leq R_a \leq +175 \text{ ohms}$$

$$-70 \leq X_a \leq +55 \text{ ohms}$$

For estimates of the driving-point impedance, consult references 1, 2, 4, 7, 8, 9, 10, 11, 12, 13 and 14. Computer programs have been developed for calculating the driving-point impedance vs the layout of the antenna, but unfortunately, these programs are generally not available to amateurs.

another design approach

When $H_z$ can have a value of 4.0, fig. 3 suggests that the S/D ratio can be any value when D/d = 1.0. In this case a decision as to what value of S/D to use can depend upon a desired $k_l$. Using this approach, $Q$ is determined first as a function of the $A$ and $B$ terms on eq. 11. At the same time $k_l$ should be greater than about 15 electrical degrees — I would use one of the 18- to 45-degree lines in fig. 5 if I were not insisting upon a specific gamma-rod length. Then $T$ can be obtained from fig. 5 as a function of $k_l$, and $Q$.

With $T$ determined, S/D lies along the abscissa of fig. 4 where D/d = 1.0.

For example, consider a self-resonant vertical monopole antenna on a good ground plane with an assumed driving-point impedance of $34 + j17$ ohms at 145.4 MHz. Therefore, $R_a = 34.0$ ohms and $X_a = 17.0$ ohms. With a polyfoam RG-8/U feedline, $R_o = 50.0$ ohms. Since the antenna impedance step-up ratio, $H_z$, must be larger than the ratio $R_o/R_a$ (see eq. 14), if a value of 4.0 is chosen for $H_z$ in this example it will satisfy that requirement.

With $H_z = 4.0$, the diameter ratio D/d may be found from fig. 3 to be 1.0. Assuming driven element and gamma rod diameters of 0.375 inch, the values for $A$, $B$ and $Q$ are as follows:

$$A = \frac{R_o X_a}{H_z R_a - R_o} = \frac{+850}{86} \approx +9.884 \text{ ohms}$$

$$B = \frac{R_o [(R_a)^2 + (X_a)^2]}{H_z R_a - R_o} = \frac{72250}{86} \approx 840.1 \text{ ohms}^2$$

$$Q = A + \sqrt{A^2 + B} \approx 9.884 + \sqrt{937.78} \approx 40.51 \text{ ohms}$$

fig. 6. Voltage and current distribution of the gamma-matching network designed to match the 50-ohm coaxial line to the 10-element beam at 145.4 MHz ($Z_a = 7 + j1.5$ ohms). Voltage and current values are based on power input of 1 watt.
Using a selected gamma-rod length of 36.0 degrees, the length of the rod in inches is
\[
L_\Gamma = \frac{kL_\Gamma}{0.0318f_{\text{MHz}}}
\]
\[
= \frac{36}{0.0318(145.4)} = 7.766 \text{ inches}
\]

When \( kL_\Gamma \) is 36.0 degrees, \( T = 0.018 \) ohms (see fig. 5). When both \( T \) and \( D/d \) are known, the spacing-to-diameter ratio \( S/D \) can be found from fig. 4. In this case, \( S/D = 3.3 \). Therefore, the center-to-center spacing is
\[
S = 3.3D = 3.3(0.375) = 1.24 \text{ inch}
\]

Now, the quantities \( E \) and \( F \) may be determined, and the value of the gamma capacitor, \( C_\Gamma \), calculated:
\[
E = \frac{R_\circ}{R_a} \left[ \frac{(R_a)^2 + (X_a)^2}{Q} \right]
\]
\[
\approx 72250 \approx 52.46 \text{ ohms}
\]
\[
F = \frac{R_\circ}{R_a} X_a = \frac{50(+17)}{34} = +25.0 \text{ ohms}
\]
\[
C_\Gamma = \frac{1,000,000}{2\pi [E + F] f_{\text{MHz}}}
\]
\[
\approx \frac{1,000,000}{70,711} \approx 14.14 \text{ pF}
\]

Therefore, the completed gamma-matching network consists of a 0.375-inch diameter gamma rod, about 7.75-inches long, with a 14pF gamma capacitor.

teet match

Although the previous discussion pertains to the gamma match, the same design philosophy may be applied directly to the tee match. If you want to tee-match a balanced transmission line to an isolated thin linear antenna at the driving impedance point, the driving-point impedance, \( Z_\alpha' \), and the line characteristic resistance, \( R_\alpha' \), are halved and the procedure for findings \( S/D, D/d, kL_\Gamma \), and \( C_\Gamma \) for one arm of the tee-match follows that for the gamma match. The results are merely imaged to, or flipped over, to the other arm of the tee- or double-gamma configuration.

For example, to match a balanced feedline to the previously discussed home-brew array, which has an input impedance of \( 14 + j3 \) ohms, the gamma-match values on page 51 would be used in each arm of the tee-match to provide a match to balanced 100-ohm transmission line. If you want to use 300-ohm balanced line, use the same gamma-match design procedure. However, use \( R_\circ = 150 \) ohms for each arm of the tee.

acknowledgement

I want to thank W7ERU for his assistance. Without his computations, reasonable limits and graph plotting would have been a tedious task.

references

grounded vertical-tower antenna system

Using your tower as a grounded vertical radiator to obtain efficient five-band operation with one tower

After completing a triband three-element quad and erecting it on top of a 54-foot grounded tower, I decided to use the whole tower on 40 and 80 meters as a vertical radiator. A search of the antenna books, magazines and other available sources revealed relatively little information on the grounded vertical radiator. I then decided to do a study of the problem. On-the-air requests for information has prompted this article.

As shown in fig. 1, the three-section telescoping tower is self supporting, crank-up and tilt-over. A gamma rod using 1¼-inch heavy-wall aluminum conduit was attached to the bottom section of the tower using 1½-inch aluminum angle. Its spacing from the tower was varied from 6 to 18 inches with minimal electrical variation. It was fixed at 15 inches as an optimum mechanical electrical compromise.

To ensure electrical continuity the three telescoping sections of the tower were bridged with flashing copper straps.

Various ground-plane systems have been evaluated. The first system I tried consisted of two 100-foot lengths of 3-foot-wide fence wire on either side of the tower. Twenty-five-feet of this wire was east of the tower and 75-feet was to the west of the tower. This was an attempt to obtain a pattern advantage towards the west. This worked quite well for a year, but since these two lengths of wire were on top of the grass in the backyard, they presented a considerable hazard to anyone walking through the yard.

The last ground-plane system I tried has been in use for more than six months. A plan view of this system is shown in fig. 2. A fence was built on wooden posts...
with the bottom wire installed 6-inches above the ground. I used poultry fence wire for this fence because each vertical wire is electrically welded to each horizontal wire, so there are no noisy electrical connections.

This wire provides approximately 0.6 square foot of surface area for each lineal foot of length. As shown in fig. 2, the total length of this wire is 190 feet. Seventy-feet of this fence is east of the tower and 120-feet is to the west (including the dog-yard fence). Additionally, 60-feet of the same fence wire is nailed to the rear of the house to augment the fence wire on the posts.

The four directions seen by the base currents provide approximately 2.4 square feet of conductor area per lineal foot of ground plane. This is reduced as the distance from the tower base is increased.

The fence wire is connected to the base of the tower with three lengths of %-inch copper tubing: two to the fence on the posts and one to the fence wire nailed to the side of the house. All connections, including fence wire interconnections, are made by brazing with brass rod. No buried wires or radials are used except the %-inch copper tubing connections which are 2-inches deep in grass sod.

**electrical measurements**

Preliminary electrical measurements indicated that a 10 to 250-pF variable capacitor connected in series with the end of the gamma rod would cancel the inductive reactance seen at that point.

A breadboard layout was constructed and tried out at the tower base. The variable capacitor was adjusted to produce zero reactance as shown on a General Radio model 916A rf impedance bridge. Resistive readings were taken at 50-kHz increments from 3.5 to 4.0 MHz and from 7.0 to 7.3 MHz. The 80-meter band showed 5 to 6 ohms resistive and the 40-meter band showed 42 to 60 ohms resistive.

**impedance matching**

With the electrical characteristics available, solution of the impedance-matching problem was done by use of a graphic method (see fig. 3). The method allows a solution by using only a straight edge, a
compass and graph paper. Simple arithmetic is all the mathematics that is required. Additionally, a visual choice of alternate solutions is immediately available during the graphic solution. The accuracy of constants produced is better than available equipment parts.

**fig. 3.** Graphic solution of the impedance-matching problem. See reference 1 for more information on using this technique. The input impedance of the antenna is shown on the graph at P1 (5.2 + j275). The distance from P1 to P2 is 292; since it is in a negative direction this line represents a capacitance reactance of 292 ohms. To get to the 50-ohm point, P4, you must traverse P2 to P3, representing a shunt inductive reactance of 20.8 ohms, and from P3 to P4, a series inductive reactance of 22.5 ohms. An alternate solution is to go from P1 to A1, from A1 to A2, and from A2 to P4. This provides the alternate matching network consisting of three capacitors.

The graphic solution shows that for operation on 75 and 80 meters, an inductive reactance of 20.8 ohms in shunt and an inductive reactance of 22.5 ohms in series will convert the 5.2 (average ohms) resistive component to 50 ohms for matching to the 50-ohm coaxial line. The use of ferrite toroids makes a compact low-Q L-network. By using the rf bridge while building the inductors it is possible to get them right on.

When these inductors are housed in a metal weather-resistant box at the tower base there may be some minor change in the characteristics of the gamma rod and the matching components. If low VSWR is not attained re-measure the resistive component with the shield box closed. Then, make another graphic solution and rebuild the required components.

The 40-meter data shows that the resistive component is within tolerance for low VSWR without need for a matching network. A dpdt rf relay switches the coaxial line from the L-network on 80 meters directly to the variable capacitor for use on 40.

**observations**

The tower was elevated from 22- to 32-, 40-, 48- and 54-foot levels with only small changes in the electrical characteristics. Therefore, it would appear that any tower from 25- to over 75-feet in height should be capable of being used as a grounded vertical radiator on 40 and 80 meters, with appropriate matching networks.

Most enterprising amateur antenna design enthusiasts can bum, beg, borrow or otherwise obtain the use of a radio frequency impedance bridge. Most colleges and electronics companies have such a bridge. A permanent solution to the problem of availability of an rf impedance bridge would be the construction of a Macromatcher by a group or club.

The bridge used must differentiate between the resistive and reactive components with fair accuracy if you want to properly design the required components to couple the grounded tower, with gamma system, to the coaxial transmission line.

This vertical radiator system has relatively little loss due to ground losses and has proven to be an excellent radiator on both 40 and 80 meters. It could be used on 160 meters with reduced efficiency. In this regard, the vertical radiator would be superior to a horizontal dipole, unless the dipole was half-wavelength above the
fig. 4. Alternate antenna control system which uses latching relays to control motor direction and band switching. Microswitches S1 and S2 are limit switches on the vacuum variable capacitor. The turns-count switch is actuated each time the vacuum-variable shaft makes one revolution. Resistors R1 and R2 are pilot-lamp current-limiting resistors. Resistor R3 prevents current surges when the motor is cold. The motor is a 24-volt, 1/12 hp unit geared down to drive the vacuum variable. The low-Q series and shunt inductors are wound on 2" Amidon toroidal cores.

operation

Both forward and reflected vswr meters are used in the coaxial line. By controlling the motor driven vacuum-variable capacitor until the forward meter peaks and the reflected meter dips to minimum, the exact null-out of the reactance can be seen. The use of the reversing switch and slow speed on the geared-down motor makes it possible to get right on.

Either of two control systems may be used to provide complete control of the remote tuning system located at the base of the tower. One system was described previously. A more complex control system is shown in fig. 4. This system has several features worth considering. The most important advantage is its ability to automatically reverse the motor field, hence direction of the vacuum-variable capacitor, when actuating either of the limit microswitches.

A second advantage of the control system in fig. 4 is the use of latching relays which require no holding current (and hence, no electrical noise). With these relays, once the armature has been shifted and latched by a short burst of current, it can be dropped out by another short burst of current through the unlatching solenoid.

A third remote-control system is on the drawing board and in the parts-collecting stage. This system will follow the general design of the automatic solid-state antenna tuner described by WA9AQC.

conclusion

The operational results obtained in the past few months prove conclusively that
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 REFERENCES

ham radio

the vertical tower antenna is an excellent omnidirectional radiator. With the control system outlined here low vswr can be obtained throughout the 40- and 80-meter bands. This broadband effect is the result of the massive tower structure and the effect of a large top-hat of quad (or Yagi) elements.

Unfortunately, there is another set of characteristics for an omnidirectional radiator when used for receiving. Because such a structure is broadband, unless high- and/or low-pass filters are provided, image frequencies and/or broadcast band harmonics could reduce the signal-to-noise to interference ratio. However, the necessary filters are also easy to design using the graphic solution technique. Additionally, signals from all directions may produce interference on the desired operating frequency.

To some, this project may seem an overwhelming task to undertake, however, for those of you who have small back yards and want to get on 40 and 80 meters without using a narrowband Z-shaped doublet or a droopy vee, may find it a necessity. Those of you who are dedicated antenna design and construction enthusiasts should find this a rewarding project.

Acknowledgement is made to Stanley Steinberg for engineering, grammatical and editorial comments, and to Stanley Dlugosz, W3EVB, for the excellent photography presented here. Last, but by no means least, apologies to an understanding wife for many delayed meals and for many piles of junk in the wrong places.
Complete description of a continuously-loaded multiband trap antenna that fits in a suitcase

Some amateurs like to take their equipment with them when they travel. Mobilizing these days is very easy with modern rigs and the many fine commercial antennas which are available. It is not so pleasant though, to work mobile in today's traffic, and many traveling hams hanker for a ragchew in the comfort of their motel room at the end of the day. What is required here is a portable antenna.

A loaded whip, helical or whatever, needs a groundplane. It is also prone to detuning when moved; these considerations prompted me to look for an alternative and I decided on a dipole.

the antenna

The 5BI Suitcase is a continuously-loaded trap dipole antenna for 80, 40 and 20 meters. It is 65-inches long when assembled, and may be dismantled to fit diagonally into a suitcase. The maximum dimension when dismantled is 33 inches. I have tested it to an input power of 500 watts PEP.

Any antenna which has its radiating portion compressed is going to be inefficient. However, with today's compact high-power transceivers these inefficiencies are less important. What is required of any antenna before it can be used is resonance at the required frequency and an ability to match the transmitter output. When designing a loaded antenna it is necessary to decide on your favorite operating frequency and wind the anten-
na to suit. Any deviation from this frequency will cause a marked rise in vswr.

The design impedance is determined by the spacing between the sides of the dipole, i.e., the proximity of the two coils. In the case of the prototype the impedance was in the order of 300 ohms on 80 meters.

Before attempting to construct this antenna two pieces of test equipment are essential. Every amateur should possess an antenna bridge of some sort. I recommend the Omega Noise Bridge because of its simplicity and low cost. With this instrument it is possible to read off resonant frequency and impedance quickly and without resorting to math. There have also been a number of constructional articles on similar devices in recent amateur magazines. The other piece of test gear to have on hand for this project is a grid-dip oscillator.

**construction**

The antenna is wound on two pieces of rigid 1-inch diameter polyethylene plumbing pipe, 31-inches long. My antenna is designed to resonate on 3.60, 7.10 and 14.20 MHz, but as will be explained, it is not difficult to change the resonant frequency.

Each side of the dipole is wound identically. Starting from one end, wind 153 turns of number-24 plastic-insulated copper wire. Anchor it at 153 turns and wind a further 9 turns (for the 14-MHz trap) and anchor it again. Now, wind 84 turns for the 7-MHz section and follow this with 15 turns for the 7-MHz trap. Finally, wind 206 turns on each for the 3.5-MHz section.

The traps are resonated as follows: the 14-MHz trap is resonated with 50 pF and the 7-MHz trap is tuned with 100 pF. The capacitors I used were 500-volt micas.

The antenna is used in conjunction with a balun transformer and 70-ohm coax feedline. My balun is constructed from two pieces of Mullard FX1588 ferroxcube ring. Make two windings with number-14 copper wire, one of 10 turns and the other of 2 x 5 turns. Connect as shown in fig. 1. This provides an impedance of 50 ohms on 20 meters, 80 ohms on 40 meters and 50 ohms on 80 meters. This is well within the matching capability of most modern transceivers. Of course, if you really wanted to get fussy, a separate balun could be constructed for every band.

**tuneup**

It is important that, when in use and during testing, the antenna be well clear of surrounding objects. The antenna is assembled using a piece of wooden broomstick at the center, giving 2½-inch

---

fig. 1. Continuously-loaded trap dipole is small enough, when dismantled, to fit into a suitcase. Antenna can be erected in just a few minutes.
spacing for the windings. If desired, the traps may be pruned, although I found them to be uncritical. This would be best accomplished by adjusting the trap tuning capacitance although you’ll find the figures given to be fairly close.

The antenna is then connected to the bridge and the 20-meter section resonated, if necessary. This is done by connecting a short length of wire to each of the dipoles before the trap. The 40-meter section is adjusted next. In my case 15 inches were added to each 40-

meter section and placed at right angles to the plane of the antenna.

On 80 meters I finished up with 4 inches added to the end of the coil. Keep an swr bridge in the line and see that the antenna doesn’t swing against any objects; this will alter the resonant frequency.

Keep people away from the ends of the dipole while you’re transmitting. I haven’t had any corona problems, but the antenna talks due, no doubt, to the electromagnetic concentration in the turns. I found the directivity to be about nil.

No difficulty was experienced with rf feedback although trouble had been expected. The transceiver I use is a Yaesu FtDX 400, which is about the same as the FtDX 560 sold in the United States.

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More Details? CHECK-OFF Page 126

on antennas by CushCraft
In the realm of ham radio antennas the second best, and even third best, will get you communicating. Unless you are telepathic you don't make any contacts by dreaming of the ultimate antenna. Too little space, too low, no money, etc., are often self-comforting excuses.

yard-high antennas

Good low antennas perform well for short and medium distance communications and can produce surprises, even in the realm of DX contacts. Low antennas can be built conveniently and economically and are less prone to deterioration by weather extremes. They perform well when they have a large aperture area and, for this reason, should preferably be full-dimension types. Also, the full-dimension type is easier to match and is less critical of design as compared to the smaller dimension DDRR types.

Take a single-element quad, lay it over horizontally, and mount it three- to four-feet above ground and you have a full-dimension low profile antenna, fig. 1.

This close-to-ground position lowers the antenna resistance of a square full-wavelength antenna to a value that provides direct match to 50- or 70-ohm line. I built versions for 10, 20, 40, 80 and 160 meters and with appropriate length trimming a direct match was obtained on each of these bands. The equation used for determining wire length was:

$$\text{Length}_{\text{ft}} = \frac{984}{f_{\text{MHz}}}$$

Resonance was found by shortening the antenna between two and three percent. For example, typical wire lengths for 40 and 80 meters were 132 and 245 feet, respectively.

Supports for the antennas were four metal fence posts. The antenna wire sizes varied between number 12 and number 16, insulated. In construction the radiating wire is passed through one hole of the antenna insulator. A short piece of
wire through the opposite eye holds the antenna at each metal fence post. Typical dimensions are given in fig. 2.

On 40, 80 and 160 meters good signal reports are obtained for what is considered normal short and medium distance communications for each of the particular bands. For these ranges signal level readings compare favorably with good antennas of greater height. Performance falls off in the DX range of each of these three bands, indicating further work is needed to lower the vertical angle of radiation. As yet, I have not done any experiments with ground systems beneath the antenna, feed arrangements that include the radiating antenna and ground or tilting the low profile plane.

The economics of this arrangement is attractive because no high support structure is required. It is made from inexpensive wire, and in most cases, the length of transmission line can be made short. Low height means experimental ease. Our tests were made in the 3- to 5-feet above ground range. However, you can anticipate little change in matching if the antenna is raised up 8- to 10-feet and supported on ordinary wash poles.

Space requirements are modest and, in many situations, the erection of a full dimension antenna is possible where it is not feasible to erect a half-wavelength 80- or 160-meter dipole. For example, the 80-meter versions fit into an area that is only about 62-feet square. Performance on the 10-, 15- and 20-meter bands is poor as compared to good high antennas on these high frequencies. As mentioned previously, no experimentation has been done on ground systems that may well bring down the vertical radiation angle and improve performance on 10, 15 and 20.

**two-band version**

The shape of such a low antenna need not necessarily be square. It can be made to fit the erection site. The directive characteristics of other than the square configuration have not been thoroughly investigated.

A two-band 80-160 combination has been checked out and performs very well on both bands. This combination consists

---

**fig. 2. Dimensions for the low horizontal quad on 40, 80 and 160 meters.**

<table>
<thead>
<tr>
<th>BAND</th>
<th>SIDE</th>
<th>TOTAL WIRE LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>40M</td>
<td>33 ft</td>
<td>152 ft</td>
</tr>
<tr>
<td>80M</td>
<td>81.5 ft</td>
<td>246 ft</td>
</tr>
<tr>
<td>160M</td>
<td>133 ft</td>
<td>532 ft</td>
</tr>
</tbody>
</table>

---

**fig. 3. Combination 80- and 160-meter antenna for a long, narrow lot. For 80-meter operation, jumper A to B; for 160 meters, jumper A to C.**
of a closed square for 80 meters while the 160-meter version is rectangular as shown in fig. 3. A good direct match is obtained on both 80 and 160 meters. Wire jumpers are used to select either 80- or 160-meter operation.

multiband open configuration

Tests were made with the far-end open for a square 80-meter version of this antenna, fig. 4. The open plan requires the use of a tuner. The T-network type described in the January, 1973, issue of ham radio permitted a match on all bands, 6 through 160 meters. Performance was acceptable on 160 meters even though the overall wire length is a bit under one-half wavelength.

If you want a direct match on 80 meters, you need only place a short across the open end of the square. If you desire full-wave performance on 160 meters and have the available space, use the same idea in setting up the antenna for all-band operation. Again, a short connected across the opening will provide a direct match on 160 meters whenever it is desired.

The 160-meter open rectangle, fig. 5, also loaded on all bands using the T-network tuner. Good results were obtained on 40, 80 and 160. Due to the long sides the configuration became a good directional gain antenna on 10, 15 and 20, maximum off the far ends.

double-barrel long wire

High band results encourage further study. It is interesting that the separation between wires is about one wavelength on 15 and 20, the two bands of good directivity, fig. 6. This provides side cancellation.

If the far ends are terminated in Beverage fashion, how much better would the antenna perform than a regular Beverage? What would be the optimum height for a given band, pair of bands, trio of bands? What is the ratio or improvement using four wires?
There have always been exciting possibilities for low antennas. The proof is in the rather surprising performance obtained in mobile operations. Fixed installations are not so limited in size, and the performance, economics and esthetic aspects of low antennas should not be ignored.

46 element MULTIBEAM 70/MBM 46
(for 432 MHz)

Gain — 22.1 DBI
50 Ω coax feed
Power rating — 1kw
Length — 104 ins.
Width — 18 ins.
Weight — 6 lbs.
Hor. Beam — 24 dgs
Wind load — 38 lbs.
(at 100 mph)

The MULTIBEAM virtually comprises four 12 element yagis, stacked and bayed to form a single compact array. For even more gain the MULTIBEAM can be stacked in pairs, or quads for up to 28 DBI gain, sufficient for successful moonbounce work.

Write for details of MULTIBEAM and stacking kits.
homemade antenna insulators

With the advent of various new wire beams and antennas, there is a need for inexpensive, lightweight antenna insulators and feedline spreaders. Here is how you can fabricate these items using readily available materials.

Obtain lengths of dowel rods at your lumber supply house or hardware store. These wooden rods come in 36-inch lengths and in various sizes from less than 1/4-inch to 1-inch in diameter. For number-14 antenna wire, or smaller, half-inch dowels are adequate. For larger wire, use the 3/4- or 1-inch size. For invisible antennas and open-wire feedline spreaders the 1/4- or 3/8-inch sizes are correct.

Measure off the lengths desired, taking into account the probable usage and the size of the pan used to impregnate the rods in paraffin or bees wax. Mark the holes to be drilled (fig. 1). Various size holes are chosen for the expected wire size. When the dowel is sawed apart to make the correct lengths, the larger holes will make slots in the ends of the dowels. Result in a fire! An aluminum Sara Lee pound cake pan is just right for up to 7.5-inch long rods. The pan can be placed in another larger pan of heated water to make a double boiler.

When the wax is completely melted gently lower the drilled dowels into the pan. Under constant supervision, allow the dowels to boil and bubble for about 30 minutes. By that time the wax will be absorbed as much as possible. When all bubbling ceases, remove the dowels. They are ready for use.

The smaller hole may be used to accept the antenna wire itself, or to pass a serving wire through (in the case of feedline spreaders) to connect to either the antenna or the halyard. Larger holes drill; then re-drill with a larger size at the ends of the insulator. Saw at points X. Smooth the ends with a file or sandpaper and file or saw a slot in the ends where no hole half was made at the original dowel rod ends.

Obtain several cakes of paraffin wax; read the instructions with care. The wax must be cautiously melted, preferably in a double boiler. If an open flame is used extreme caution must be taken to prevent splashing or other hazards that would
may be used to accept a tie ring to a halyard, if desired. Keep all holes as small as practical.

A. David Middelton, W7ZC

**multiband coaxial dipole**

Although many amateurs use single-band coaxial dipoles, I have built a multiband unit that performs quite well on all bands, 80 through 10 meters. The layout of the antenna is shown in fig. 2. In case it looks familiar, the idea came from a similar, all wire antenna in the A.R.R.L. Radio Amateur's Handbook.

The coil in each of the traps consists of 21½ turns of B&W coil stock, 2-inches in diameter, 8 turns per inch (B&W 3900). The tuning capacitor is a ceramic 47-pF unit rated at 6000 working volts. The coax braid and center wire are soldered together at the ends. The braid is carefully cut at the center for the feedline – the center conductor of the feedline is connected to the braid of one antenna section while the feedline braid is connected to the braid on the other antenna section.

With the dimensions shown in fig. 2 antenna provides very low swr over the phone segments of both 40 and 80 meters. On the higher bands the swr is less than 1.5:1 over most of the band. For best performance on the CW ends of the bands, the antenna would have to be made slightly longer. Adjust the length of the coax sections for the 7.0-MHz band, and the length of the end wires to resonate the antenna at 3.8 MHz.

H.W. Rieben, W4BDK

---

![Diagram](image)

**fig. 2. Multiband coaxial dipole provides excellent performance on 40 and 80, and usable performance on the other amateur bands. Trap coil L1 is 21½ turns of B&W coil stock, 2" diameter, 8 turns per inch.**

**portable vhf ground plane**

Although I am not Scotch, my resilience factor goes up and down everytime some new (and expensive) piece of ham gear is wanted, but no funds are at hand. It is my opinion that ham equipment is too specialized (and therefore limited) in today's consumer market. However, that's only an opinion and a moot point at that. I am sure the EIA would vehemently argue with me on the subject.

Since I have been in ham radio for many years – although certainly not an old timer – I really get excited when a new idea, for old equipment, comes along. Especially when it doesn't cost too much money. Take, for example, that quarterwave mobile whip standing in the corner of my room. That's the only thing left after the two-legged sharks stripped my automobile of my ham gear. Alas, it was never recovered.

Now, what could be done with a no-hole trunk-mounted whip for two meters? Well, after hunting around the house for a few weeks, an old economy type camera tripod was discovered. This tripod did not have a handle adjustment lever for the camera plane as the more common tripods do. It was constructed of brass tubing with a minimum closed length of 15-inches and a fully extended length of 48 inches. Just perfect for a three-radial portable ground-plane antenna.

The tripod mounting hole for the camera uses a Standard ¼-20 machine bolt. So, a piece of sheet aluminum (3x4x0.2") was drilled and tapped for
\(\frac{1}{4}-20\) at its symmetrical center. The sheet metal was then mounted to the tripod top with a \(\frac{1}{4}-20\) bolt. It resembled a miniature table with long, skinny legs. The whip could then be mounted to the table top by tightening the antenna set screws. Thus, a variable-angled-radial groundplane antenna for two meters.

From experiments using a Bird 43 watt-meter, it was determined that the lowest swr of 1.12:1 occurred when the 15-inch tripod legs were angled almost horizontally to the ground. Of course, the tripod was placed well above ground during these tests. The test frequency was 146.94 MHz.

It is feasible that this construction method would work quite well with almost any type of whip, perhaps a 5/8-wave or even CB antennas. Just vary the length of the tripod legs and the angle and see what develops.

John Sego, K9DHD

effective radiated power

Effective radiated power, not transmitter power, is what counts. Your ERP, especially on two meters, may only amount to less than half of your transmitter’s output due to loss in the feedline. This can be reduced by installing exotic coaxial cable, costing over $100.00, or by using some alternative.

Look at the figures. Loss at 144 MHz per 100 feet of RG-58/U is 5.7 dB, RG-58/U foam, 4.1 dB, RG-8/U, 2.5 dB, RG-8/U foam, 2.2 dB, 3/8-inch Heliax, 1.3 dB, 300-ohm tv twinlead, 1.55 dB, and 300-ohm open-wire tv feedline, 0.75 dB.

Foam-filled coax has a slight advantage, but it may not be worth the extra cost, especially for lines less than 100-feet long. The solid sheath Heliax cable is much better, but a 100-foot line of this cable with the special fittings, would cost close to $100.00, so it is out for most hams.

Tv 300-ohm lead-in has low loss and since it was specifically designed for use up to 200 MHz or so, it should be best. On a cost basis it is the most for the least, but its superiority may be neglected by the average ham.

Some objections have been heard regarding its operation during wet weather, but they do not seem to be justified. There are many tv antennas operating around 200 MHz that do not seem to lose weak signals when wet, or show mismatch, although it may exist. A coat of floor wax on the twin lead will prevent moisture changes.

No difficulty in either mismatch or weak signals has been noted on two antennas I feed with this line. Open-wire 300-ohm line is the ultimate in efficiency and is unaffected by moisture. The difficulty is matching it to the usual 50-ohm input impedance termination. An impedance-matching unit is required, and if built of low-loss components it has negligible insertion loss. In fact, the ERP is usually increased due to the better impedance match.

The impedance matching unit shown in fig. 3 can match any balanced line to any unbalanced line (coax); it will even match 72-ohm coax to 52-ohm coax, if desired. This line tuner will also increase the rejection QRM generated by other services (tv, fm, etc.). It reduces harmonics by about 30 dB, and due to its perfect balance to ground, reduces noise pickup. Of course, a 300-ohm termination is required at the antenna.

This line matcher is actually easier to use than a gamma matching system. Use a 1-to-1 folded dipole, or a step-up dipole for a beam. I use 3/16-inch tubing and number-12 wire for the folded dipole on my beam. It provides a perfect match and is not at all critical.

Using the beam design shown in the *ARRL Handbook*, a beam with a gain of 6 to 8 dB is easily realized. This, with my 10 watter, provides an ERP of at least 40 watts if 100-feet of 300-ohm line is used—four times the power at less cost! If I used RG-8/U the beam would only offset the line loss and my ERP would be 10 watts. Using a half-wave dipole, I would only have an ERP of about 2 watts if
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Order No. 499 Flush body mount $6.50

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RG-8/U coax was used for the feedline. The 2-meter line tuner consists of a 22-inch length of 1/4-inch copper pipe and a small tuning capacitor, which may be a small variable or two pieces of metal about 1 1/2 inches square, spaced about 1/8 inch. Bend the tubing into a U about 2-inches wide and connect it as shown in fig. 3. Use a good ground at the center.

fig. 3. Two-meter line matcher provides good match between 300-ohm twinlead to the antenna and short section of coax to your transmitter. Power loss in 300-ohm plastic twinlead at 144 MHz is about 1.55 dB per 100 feet. Open wire 300-ohm line is only .75 dB per 100 feet.

Tune the line matcher for maximum forward power and least reflected with an SWR bridge known to be accurate at 144 MHz.

My 300-ohm feeders are soldered on about half way up, and the 50-ohm short line to my rig is terminated with a gamma match with the tap about 5 inches up. It works — consistent daily contacts are made over 100 miles from a difficult seashore location surrounded by hills and mountains.

Alf Sheffield, VE7CB

printed circuit tool

When working with printed-circuit boards a pair of fingernail clippers makes an excellent tool for clipping off excess wire after a component is soldered in place. I have found that fingernail clippers are much better for getting into limited space than small sidecutter pliers.

Don Farrell, W2GA

code practice

A tape recorder is a great help for improving code speed. You can record messages off the air or practice material from W1AW, then play it back at your leisure. If your machine has two speeds, for example, you may record at 3-3/4 IPS and play it back either at the same speed or at 7 IPS. This means that a recording at 10 wpm may be heard at 20 wpm if you wish.

One problem in copying code is the tendency of anticipating what is coming. You may write down letters not actually sent. This habit may be overcome by sending words like "txulg" instead of plain language. Or, plain language may be sent backwards. In this way, the listener is forced to copy only what he actually hears.

Most tape recorders don't have a reverse at normal speed, but here is how to overcome this limitation. Simply put a twist in the tape between the feed reel and the sound head. Of course, this greatly reduces the output volume so you will have to turn up the gain. It also drives the recorded channel in its reverse direction. Letters like R and P sound the same in both directions, but L will come out as F, and U will be D. The word "the" will be heard as "eth," and so on. The letter Z in reverse is not a letter at all. If you copy correctly, you will not write down anything because you cannot recognize it.

I have found this method valuable for increasing my code speed and strengthening the habit of copying only what I hear.

I. Queen, W2OUX
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May 1973
vhf fm receiver

Dear HR:

The Allied Radio Shack stores sell a receiver listed as the Realistic Weatheradio cube which tunes the area of 162 MHz. By turning the converter oscillator slub approximately two turns, the radio will tune the two-meter fm band in the area of 147 MHz. I have been quite successful in doing this with little effort. Also, an fet rf amplifier would increase the usefulness considerably. Possibly a ham could build the two-meter fet transmitter described in the February, 1971, issue of Ham Radio and come up with the world’s smallest hand-held fm transceiver.

Carl Markle, Jr., K8IHQ
Silver Spring, Maryland

sloping dipole antenna

Dear HR:

The excellent article by W5RUB in the December, 1972, issue of Ham Radio dealing with the DX ability of the sloping dipole antenna prompts me to write. I had been using an off-center fed 66-foot dipole, the so-called Windom antenna. Results were only so-so. It was decided to extend the overall length of the antenna to 88 feet, so 22 feet were added onto the short end, thus giving a balanced center-fed antenna. The East end was raised to a height of 75 feet. The West end is only 25 feet above ground. The antenna runs roughly East-West and is fed with 300-ohm twin line. My dc power input usually runs about 175 watts, and the measured efficiency of the final runs about 60-62 percent, putting 100 to 110 watts into the feedline.

The expected North/South maxima are quite evident; also the tilt toward the West definitely favors contacts in that general direction. Numerous VKs and ZLs have been worked, also American Samoa, KS6, and VK9, Norfolk Island. I have noticed that when abnormal (poor) conditions appear, I have had some unexpected QSOs, but only in directions North or South from my location. These odd responses to my CQs were from a Russian DXpedition to Antarctica on the one hand; and over the pole from Tibet, Burma and Indonesia. These contacts took place during periods of magnetic disturbance when East-to West circuits were definitely no good. On the other hand, contacts with Europe are more difficult, S-meter readings from that area being down roughly two S units.

Summing up, the antenna performance has been surprisingly good with respect to the directions which it favors. For the economy-minded ham, perhaps two such antennas, both sloping down from the same high pole, might be the answer to effective DXing on the lower-frequency amateur bands.

Neil Johnson, W2OLU
Tappan, New York

digital counters

Dear HR:

I’m writing to add a crucial remark to the information on counters by Roy Lewallen in the December, 1972, issue of
Admittedly, the decoding is easy enough, but consider the case of a counter going from a count of 7 to 8. Every flip-flop must change its state (A, B and C go from 1 to zero, and D goes from zero to 1). This means that the clock pulse should normally be slow enough to allow full propagation through the counter. In the case of the Fairchild μL923, for example, the propagation is 80 nanoseconds per flip-flop, or about 320 nanoseconds for the counter; hence, the input clock frequency is limited to about 3 MHz.

Now, consider the case where the five flip-flops are used in a "2x5" code:

Admittedly, the decoding is easy enough, but consider the case of a counter going from a count of 7 to 8. Every flip-flop must change its state (A, B and C go from 1 to zero, and D goes from zero to 1). This means that the clock pulse should normally be slow enough to allow full propagation through the counter. In the case of the Fairchild μL923, for example, the propagation is 80 nanoseconds per flip-flop, or about 320 nanoseconds for the counter; hence, the input clock frequency is limited to about 3 MHz.

Now, consider the case where the five flip-flops are used in a "2x5" code:

The corresponding code generated is seen to be:

<table>
<thead>
<tr>
<th>Code</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
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<td>1</td>
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</tr>
<tr>
<td>2</td>
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<td>1</td>
<td>1</td>
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<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

This 2x5 code is very similar to Morse code with zero = dash, and 1 = dot. Note that between any two counts of the counter only one flip-flop changes state at a time. Hence, the input clock frequency is limited by only a single propagation of 80 nsec, or a limit of about 12 MHz.

I contend that this scheme is just as easily decoded as BCD, and further, in the long run is less expensive because of the slower ICs which may be purchased. I have successfully used this circuit to 10 MHz, and have tested it to 12 MHz.

Stephen R. Alpert, W1GGN
Auburn, Massachusetts

Swan cw monitor

Dear HR:

Recently, my attention was called to an apparent oversight on my part regarding the CW monitor for the Swan 350 which appeared in the ham notebook section of ham radio for June, 1972, page 63.

This oversight concerns the existence of R1204 (470k), R1202 (470k) and C1204 (0.1 μF) connected from pin 2 of V12 (6GK6) to point “R” in the Swan 350 audio circuitry. With these components in the circuit, V12 will be biased off during transmit and the CW monitor will not be audible. Removal of the connection between pin 2 of V12 and R1202 (or complete physical removal of all of these components, if desired) will eliminate this problem. No ill effects should be noted by this change.

I removed these components years ago during the trial installation of one of the factory CW monitor modifications and never re-installed them since no detrimental effects were noted. All other comments received from builders of the monitor have been favorable, especially those concerning the absence of chirp or yoop during keying.

Paul K. Pagel, K1KX
Enfield, Connecticut

May 1973

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All our beams come complete with adjustable reactance tuned gamma match network which can handle 4 KW plus on CW and SSB.

WILSON MONO BAND BEAMS

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Description</th>
<th>Gain 8.5 DB</th>
<th>Gain 5.5 DB</th>
<th>Gain 13 DB</th>
<th>Gain 14 DB</th>
<th>Gain 16 DB</th>
<th>Gain 15 DB</th>
<th>Gain 14 DB</th>
<th>Boom Length</th>
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</thead>
<tbody>
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<td>M340</td>
<td>3 ELE. 40 METER BEAM (full size)</td>
<td>$420.00</td>
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<td>M240</td>
<td>7 ELE. 20 METER BEAM (full size)</td>
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<td>M620</td>
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<td>M520</td>
<td>5 ELE. 20 METER BEAM</td>
<td>$178.45</td>
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<td>M420</td>
<td>4 ELE. 20 METER BEAM</td>
<td>$146.95</td>
<td>$78.35</td>
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<td>M320</td>
<td>3 ELE. 20 METER BEAM</td>
<td>$99.95</td>
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<td>M715</td>
<td>7 ELE. 15 METER BEAM</td>
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<td>M615</td>
<td>6 ELE. 15 METER BEAM</td>
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<td>M515</td>
<td>5 ELE. 15 METER BEAM</td>
<td>$44.65</td>
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<td>M725</td>
<td>7 ELE. 20 METER BEAM</td>
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<td>M625</td>
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<td>$241.45</td>
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<td>M525</td>
<td>5 ELE. 15 METER BEAM</td>
<td>$115.45</td>
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WILSON DUO BAND BEAMS

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<tr>
<th>Model No.</th>
<th>Description</th>
<th>Gain 8.5 DB</th>
<th>Gain 5.5 DB</th>
<th>Gain 13 DB</th>
<th>Gain 14 DB</th>
<th>Gain 16 DB</th>
<th>Gain 15 DB</th>
<th>Gain 14 DB</th>
<th>Boom Length</th>
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<td>DB62</td>
<td>6 ELE. 20 &amp; 2 ELE. 40 INTERLACED BEAM</td>
<td>$498.75</td>
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<td>DB52</td>
<td>5 ELE. 20 &amp; 2 ELE. 40 INTERLACED BEAM</td>
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<td>DB32</td>
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<td>DB76</td>
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<td>DB65</td>
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NEW NOW AVAILABLE

<table>
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<tr>
<th>Model No.</th>
<th>Description</th>
<th>Gain 8.5 DB</th>
<th>Gain 5.5 DB</th>
<th>Gain 8.5 DB</th>
<th>Gain 13 DB</th>
<th>Boom Length</th>
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<tr>
<td>DB67</td>
<td>7 ELE. 20 &amp; 6 ELE. 15 INTERLACED BEAM</td>
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<tr>
<td>M52046</td>
<td>5 ELE. 20 on an extra heavy duty 46' boom. (includes re-enforced element)</td>
<td>$572.25</td>
<td>$228.75</td>
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</table>

If not available from your dealer write direct to factory for catalog or information and fast service. All prices F.O.B. factory. Wilson beams are available at the following dealers:

- HENRY RADIO STORES, LOS ANGELES, CALIFORNIA
- AMATEUR ELECTRONIC SUPPLY, MILWAUKEE, WISCONSIN
- HAM RADIO OUTLET, BURLINGAME, CALIFORNIA
- HARRISON RADIO, LONG ISLAND, NEW YORK

WILSON ELECTRONICS
P. O. BOX 116
PITTMAN, NEVADA 89044

More Details? CHECK-OFF Page 126

may 1973
Problem-solving handbooks

Highly popular Editors and Engineers books from Sams give amateurs everything they need to know about radio operation and technology. They’re authoritative, clear, and easy to follow. You’ll want them for your library.

**Famous E&E RADIO HANDBOOK—19th Edition**
By William I. Orr, W6SAI
The completely updated electronics industry standard for engineers, technicians, and advanced amateurs. Shows how to design and build all types of radio-communications equipment. Includes ssb design and equipment, RTTY circuits, latest semiconductor circuits, IC’s, and special circuitry. No. 24003—$14.95

**SINGLE SIDEBAND: THEORY & PRACTICE**
By Harry D. Hooton, W6TYH
A basic text covering the origin of ssb, derivation of signals, sideband selection, ssb generators, carrier-suppression techniques, carrier generators, speech amplifiers and filters, balanced mixers and converters, low-power ssb transmitters, linear r-f power amplifiers, and much more. No. 24014—$6.95

**SEMICONDUCTOR AMATEUR PROJECTS**
By Louis M. Dezettel, WSREZ
For the ham who still takes pride in using his hands and head, here are 16 useful, money-saving accessories, using easy-to-build semiconductor circuitry. Units are for measuring equipment, increasing power and adding convenience, etc. No. 24025—$4.95

**MARINE SINGLE SIDEBAND**
By Donald M. Slone and Pierre B. Goral
Covers the why and how of single sideband; interpreting specifications, alignment tests and measurements, installations, securing a limited coastal license, high-seas telephone service, and marine radio terminology. No. 24029—$5.95

**RADIO AMATEUR OPERATING HANDBOOK**
By Marshall Lincoln, WDQGS
This single-source working guide is a practical aid for improving the operating methods and techniques of hams. No. 24028—$4.95

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By Edward M. Noll, W3FQJ
By building QRP equipment you learn solid-state technology, since these rigs include transistors and/or integrated circuits. The low-cost units described have power ratings from less than 100 milliwatts up to about 20 watts. Both cw and phone rigs are included. No. 24024—$4.25

**73 VERTICAL, BEAM, AND TRIANGLE ANTENNAS**
By Edward M. Noll, W3FQJ
Design and construction of 73 different antennas used by amateurs, each built and air-tested by the author. Also construction of noise bridges, transmission-line tuners, and measurement methods. No. 24021—$4.95

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By Louis M. Dezettel, WSREZ
Covers radio-wave propagation as it applies to amateur band frequencies, reception and transmission pertaining to ham equipment, and the special field of antennas and how to feed them. Provides you with everything needed to pass the theory sections of the FCC exams. No. 24022—$7.95

**RADIO AMATEUR'S F-M REPEATER HANDBOOK**
By Ken W. Sessions, Jr., K6MVH
The definitive work on amateur f-m repeaters. Includes: Preparing and obtaining sites for repeaters; How to build a repeater; Repeater applications; and an f-m repeater directory. No. 24008—$6.95

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By Louis M. Dezettel, WSREZ
Shows how to accomplish virtually all performance tests on amateur transmitters, receivers, and antennas, and how to make required adjustments. No. 24007—$5.50

**HAM AND CB ANTENNA DIMENSION CHARTS**
By Edward M. Noll, W3FQJ
Tabulates dimension data in feet and inches for all popular antenna configurations. With this data, an antenna can be dimensioned for a specific frequency range according to license class and mode of operation. No. 24023—$1.95

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The all new

220 MHz Clegg FM-21 Transceiver puts you in tomorrow's channels today!

220 MHz FM is the early solution to overcrowded 2 meter channels. Here's your chance to get in on the ground floor of the FM future. The new FM-21 all solid-state transceiver is an opportunity to "do it right" this time and start with the leader. The FM-21 uses only 1 crystal in any channel . . . one crystal gives you a separate transmit and receive frequency as well as automatic 1.6 MHz programming in the repeat mode. We call this unique triple-duty crystal feature Clegg Crystal Saver Frequency Control. For the complete story, see your Clegg Dealer or call or write us today for detailed data sheet and avoid the crowd.

Amateur Net $299.95

NOW!

220-225 MHz 5/8 wavelength trunk mount gain antenna HM223

AVAILABLE FREE

with the purchase of an FM21 for the month of May.

$26.49 Value
The new solid-state Conway Masteranger multimeter provides a comprehensive range of measurements not previously available on a portable instrument of this type.

The high input sensitivity of the Conway Masteranger permits accurate measurement of very low-level voltage and currents. Input resistance on most voltage ranges is 100 megohms, voltage sensitivity is 1.5 millivolts full-scale, ac of dc, and the current range of the instrument is 0.15 µA to 1.5 amperes. Accuracy is 1.5% of full scale. The Masteranger will also measure rf voltage up to 1000 MHz.

In addition to voltage and current measurements, the Conway Masteranger measures resistance to 10,000 megohms, and has 13 decibel ranges from -80 to +66 dBm. The built-in overload protection circuitry protects the instrument to ±1200 volts on all voltage ranges; current and resistance ranges are similarly protected.

The Masteranger can be used as a null detector with high sensitivity of 20 µV per division (or 1 nanoamp per division), thus enabling use as a null detector for any bridge application or for fm discriminator alignment. When used with a calibrated microphone, the sensitive solid-state multimeter can be used as a sound-level meter. And, at very low current measuring ranges, the unit is capable of measuring contact potentials between dissimilar metals. These are just a few applications where the high sensitivity pays off.

The instrument may be powered from the self-contained battery pack or power-line operated from 115 or 230 volts ac, 50/400 Hz with an accessory power supply. Other available accessories include a 50 kV high-voltage probe, 1000-MHz rf probe, 150-ampere current shunt, capacitive high frequency voltage divider (300 volts maximum to 1000 Hz), coaxial T-connector for measuring vswr to 1000 MHz and a peak-to-peak measuring probe allowing factual quantitative p-p measurement.

The Conway Masteranger is supplied in a high-impact cabinet plus leather carrying case and batteries, input coaxial cable, two banana plugs and clips and an instruction manual. The instrument is priced at $150.00. For more information, write to Conway Electronic Enterprises Ltd., 88 Arrow Road, Weston, Ontario, Canada, or use check-off on page 126.
radio handbook, new edition

Seventy years ago farsighted experimenters were communicating by wireless using spark transmitters and magnetic detectors. Today the science of radio communications has been revolutionized by solid-state devices and integrated circuits.

The completely new and up-to-date 19th Edition of the Radio Handbook was written especially by William Orr, W6SAI, to keep the amateur radio enthusiast informed of the latest principles and equipment encompassing the broad radio communications field. In fact, this handbook is recognized as the leading independent authority in the field of radio amateur high-frequency and vhf communication, covering more than three decades of development in the art of electronic communication.

The book contains authoritative, detailed instructions for designing, building, and operating all types of radio communications equipment. A complete understanding of the theory and construction of all modern circuitry, semiconductors, antennas, power supplies, full data on workshop practice, test equipment, radio math and calculations is provided.

In addition, the coverage includes construction information on new high-frequency linear amplifiers of 1- and 2-kW PEP output, a solid-state LED-readout receiver, a high-performance two-meter moonbounce converter, solid-state vhf fm amplifiers, etc.

There are 976 information-packed pages supported by numerous diagrams and photographs. A glossary of terms is provided to identify the symbols used throughout the text. This invaluable reference is a must for both novice and advanced radio amateurs, electronics engineers and technicians – literally anyone interested in the popular radio communications field.

Topics covered include introduction to radio; direct-current circuits; alternating-current circuits; semiconductor devices; vacuum-tube principles; vacuum-tube amplifiers; radio-frequency power amplifiers; special circuitry for vacuum tubes and semiconductor devices; single-sideband transmission and reception; communication receiver fundamentals; generation and amplification of radio-frequency energy; rf feedback; frequency modulation and repeaters; radioteletype and specialized transmission and reception; amplitude modulation and audio processing; radio interference (RFI); equipment design; station assembly and transmitter control; mobile and portable equipment; receivers, converters and transceivers; exciters and transceivers; high-frequency and vhf power amplifiers; power supplies; radiation, propagation and transmission lines; antennas and antenna matching: high-frequency directive antennas; vhf and uhf antennas; high-frequency rotary-beam antennas; electronic test equipment; the oscilloscope; construction practices; radio mathematics and calculations.

Hardbound, 976 pages, $14.95 ($17.95 in Canada) from Comtec Books, Greenville, New Hampshire 03048.

broadband preamplifier

Data Engineering's new Model 150 broadband preamplifier provides the user with the opportunity to improve the sensitivity of his hf receiver for a-m, ssb, CW or fm. Covering a frequency range of 1 to 30 MHz, the unit features 36-dB gain at 1 MHz, dropping to 19-dB gain at 30 MHz. The unit features a maximum 3-dB noise figure.
The new Alpha sub-audible tone encoder/decoder has been especially designed for use in the Motorola Motrac series of two-way radios. The heretofore expensive and difficult task of converting so called "non PL" Motrac to the use of tone is made simple and practical with the Alpha unit.

The new unit utilizes thick-film hybrid modules that contain all the active circuitry used for the encoding and decoding of tone. These thick-film modules fit into a unique gold-plated edge connector on the printed-circuit board allowing direct plug-in-plug-out operation for ease of maintenance, modification or change of tone frequency. The thick-film hybrid technique also makes possible an exceptional degree of reliability under severe environmental extremes including high vibration and temperature. The frequency determining modules are laser trimmed to the precise frequency required and are therefore not subject to the reliability problems of reeds and the frequency stability problems of tunable types of tone.

The Alpha SS-80J/192 is completely compatible with all Motorola, General Electric and RCA sub-audible tone systems and is available in standard or special frequencies from 20 to 250 Hz.
Provision has been made to accommodate up to six tone frequencies which may be electronically switched if required. The unit also has the capability of automatic revert for common encode or common decode configuration. The multi-frequency circuitry can be provided from the factory or added in the field. Complete step-by-step instructions are provided. For additional information write to Alpha Electronic Services, Inc., 8431 Monroe Avenue, Stanton, California 90680, or use check-off on page 126.

coaxial cable stripper

Xcelite has just added to its line of quality professional hand tools a coax stripper/cutter, designed specifically for use with the popular RG-59/U coaxial cable. Featured is a three-position selector lever. With the lever in position 1, the hardened and ground blades cut cleanly through the jacket, shielding and dielectric without fraying to expose the undamaged conductor. Position 2 removes the jacket and shielding, while position 3 strips the jacket off without damage to the shielding, or dielectric. With the selector lever disengaged, the entire coax cable can be cut neatly to length. Handles have cushion grips for user comfort and to lessen fatigue.

The no. 590 Coax Stripper/Cutter has a list price of $4.75. It is available nationwide through Xcelite's local distributors. Additional information may be obtained by writing for Product Bulletin 572L, available from Xcelite Incorporated, Orchard Park, New York 14127, or use check-off on page 126.
Heathkit® 2-Meter FM gear is here!

NEW Heathkit
2-Meter
FM Transceiver
179.95*

- All solid-state design - Can be completely aligned without instruments - 36-channel capability - independent push-button selection of 6 transmit and 6 receive crystals - 10-Watts Minimum Output - designed to operate into even an infinite VSWR without failure - Optional Tone Burst Encoder - mounts inside, gives front-panel selection of four presettable tones

The Heathkit HW-202 comes with two crystals used in initial set-up and alignment, give you simplex operation on 146.94. Kit includes microphone, quick-connecting cable for 12-volt hook-up, heavy duty alligator clips for use with a temporary battery, antenna coax jack, gimbal bracket, and mobile mount that lets you remove the radio from the car by unscrewing two thumbscrews. The HWA-202-2 Tone Burst Encoder provides four presettable pushbuttons for instant repeater access. Fixed station operation is as easy as adding the HWA-202-1 AC Power Supply. The HA-202 2-Meter Amplifier puts out 40 watts for 10 watts in, and externally it's a perfect mate for your HW-202.

Kit HW-202, 11 lbs., mailable ............ 179.95*
Kit HWA-202-2, Tone Burst Encoder, 1 lb. 24.95*
Kit HWA-202-1, AC Power Supply, 7 lbs. 29.95*
Kit HWA-202-3, Mobile 2-Meter Antenna, 2 lbs. ....................... 17.95*
Kit HWA-202-4, Fixed Station 2-Meter Antenna, 4 lbs. ....................... 15.95*

HW-202 SPECIFICATIONS - RECEIVER - Sensitivity: 12 dB SINAD* (or 15 dB of quieting) at 5.5 uV or less. Squelch threshold: 3 uV or less. Audio output: 2 W at less than 10% total harmonic distortion (THD). Operating frequency stability: Better than ±0.0015%. Image rejection: Greater than 55 dB. Spurious rejection: Greater than 60 dB. IF rejection: Greater than 75 dB. First IF frequency: 10.7 MHz ± 2 kHz. Second IF frequency: 455 kHz (adjustable). Receiver bandwidth: 22 kHz nominal. De-emphasis: 6 dB per octave from 300 to 3000 Hz nominal. Modulation acceptance: 7.5 kHz minimum. TRANSMITTER - Power output: 10 watts minimum. Spurious output: Below -45 dB from carrier. Stability: Better than ±0.0015%. Oscillator frequency: 6 MHz, approximately. Multiplier factor: X 24. Modulation: Phase, adjustable 0-7.5 kHz, with instantaneous limiting. Duty cycle: 100% with ±0 VSWR. High VSWR shutdown: None. GENERAL - Speaker impedance: 4 ohms. Operating frequency range: 143.9 to 148.3 MHz. Current consumption: Receiver (squelched): Less than 300 mA. Transmitter: Less than 2.2 amperes. Operating temperature range: -10° to 122° F (-20° to +50° C). Operating voltage range: 12.6 to 16.0 VDC (13.8 VDC nominal). Dimensions: 23/4" H x 81/4" W x 95/8" D.

*SINAD=Signal + noise + distortion

Noise + distortion

86 may 1973

More Details? CHECK-OFF Page 126
NEW Heathkit
2-Meter Amplifier for cleaner
FM copy on the fringe... 69.95*

40 watts nominal out for 10 watts in —
requires only 12 VDC supply.

Fully automatic operation — with any
2-meter exciter delivering 5-15 watts drive.

Solid-state design — all components
mount on single board for easy,
lightweight, economical operation.

If you're regularly working from a fringe area, the
new Heathkit HA-202 can boost your mobile output
to 40 watts (nominal), while pulling a meager 7
amps from your car's 12-volt battery.

Install it anywhere...in the trunk, under the hood
or dashboard. Use it with any 2-meter exciter de-
ivering 5-15 watts drive. Features fully automatic
operation. An internal relay automatically switches
the antenna from transmit to receiver mode when
you release the mike button.

All solid-state design features rugged, emitter-
ballasted transistors, combined with a highly effi-
cient heat sink, permitting high VSWR loads. Tuned
input-output circuits offer low spurious output
to cover the 1.5 MHz segment of the 2-meter band
without periodic readjustment. All components
mount on a single printed circuit board for easy,
4-hour assembly. Manual shows exact alignment
procedures using either a VOM or VTVM. And in-
stallation is just as simple.

Kit includes transceiver connecting cable, antenna
connector. Operates from any 12 VDC system
— additional power supplies are not required. Add
HA-202 power to your mobile 2-meter rig, and
boom out of the fringe. Kit HA-202, 4 lbs.

HA-202 SPECIFICATIONS — Frequency range: 143-149 MHz. Power
output: 20W @ 5 W in. 30 W @ 7.5 W in. 40 W @ 10 W in. 50 W @
15 W in. Power input (rf drive): 5 to 15W. Input/output imped-
ance: 50 ohms, nominal. Input VSWR: 1.5:1. Max. Load VSWR:
3:1. Max. Power supply requirements: 12 to 16 VDC. 7 amps max.
Operating temperature range: -30°F to -140°F. Dimensions:
3" H x 4⅛" W x 5½" D.

...and here! New Heathkit
VHF Wattmeter/SWR Bridge... 29.95*

Perfect tune-up tool for your 2-meter gear. Tests transmitter output in
power ranges of 1 to 25 watts and 10 to 250 watts ±10% of full scale.
00 ohm nominal impedance permits placement in transmission line
permanently with little or no loss. Built-in SWR bridge for tuning 2-
meter antenna for proper match, has less than 10-watt sensitivity.
Kit HM-2102, 4 lbs.

HM-2102 SPECIFICATIONS — Frequency range: 50 MHz to 160 MHz. Wattmeter accuracy:
±10% of full-scale reading.* Power capability: To 250 W. SWR sensitivity: less than 10
W. Impedance: 50 ohms nominal. SWR bridge: Continuous to 250 W. Connectors: UHF
type 50-230. Dimensions: 5⅛" W. 5½" H and 6½" D, assembled as one unit.

See them at your Heathkit Electronic Center —
or fill out coupon for FREE Heathkit catalog

HEATH ELECTRONIC CENTERS
ARIZ.: Phoenix, 2727 W. Indian School Rd.; CALIF.: Anaheim, 330 E. Ball Rd.; El Cerrito, 6000
Pomona Ave.; Los Angeles, 239 S. Flower St. Pomona, 335 Grove Ave.; Redwood
City, 2001 Middlefield Rd.; San Diego (La Mesa), 832 Center Dr.; Woodland Hills, 22504 Vent-
ura Blvd.; COLO.: Denver, 990 W. 36th Ave.; DENNIS, 48089 39th St. (Rte. 46). FLA.: Miami (Hialeah),
4705 W. 16th Ave.; GA.: Atlanta, 5245 Roswell Rd.; ILL.: Chicago, 60522 W. Devon Ave.; Downers Grove,
224 Ogden Ave.; IND.: Indianapolis, 2112 S. 62nd Ave.; KANSAS: Kansas City (Mission), 5060 Lamar Ave.; MD.
Baltimore, 1713 E. Joppa Rd.; Rock-
ville, 5542 Nicholson Lane; MASS.: Boston (Westley); 155 Worcester St.; MICH.: Detroit,
1405 W. Eight Mile Rd. & 1810 E. Eight Mile Rd.; MIA.: Minneapolis (Hopkins), 101 Shady
Oak Rd.; MO.: St. Louis, 9256 Gravois Ave.; N.J.: Fair Lawn, 35-57 Broadway (Rte. 4); N.Y.
Buffalo (Amherst), 37B Sherwood Dr.; New York City, 35 W. 40th St.; Jericho, L.I., 15 Jericho
Turnpike, Rochester, Long Ridge Plaza; OHIO: Cincinnati (Woodlawn), 1033 Springfield
Pike, Cleveland, 5443 Pearl Rd.; PA.: Philadelphia, 6318 Roosevelt Blvd.; Pittsburgh, 1482 Wm.
Penn Hwy.; TEXAS: Dallas, 2715 Ross Ave.; Houston, 3705 Westheimer; WASH.: Seattle, 221
Third Ave.; WIS.: Milwaukee, 5215 Fond du Lac.

More Details? CHECK-OFF Page 126

May 1973
New digital V.O.M. works well in near field environment. Only $299.

Here's the best low cost digital voltmete ever made for broadcast and communication use. It's got all the resistance range, voltage resolution, high ac accuracy you'll ever need plus 30 second warm-up to full accuracy. Fluke's new Model 8000A measures in 26 ranges ac/dc volts, amps and resistance from 100 mV to 1200 V, 0.1 A to 2 A, and 100 milli/ to 20 mega. Basic dc accuracy, 0.1%. Full year guarantee. Option choice includes rechargeable battery pack, printer output, deluxe test leads, HV probe, RF probe, 600-amp ac current probe, carrying case, dust cover and rack mount. Unique self-zero eliminates offset uncertainty. Electronics are securely mounted in high-impact case. Service centers throughout U.S., Canada, Europe and Far East for 48-hour turnaround repair.

Get all the details from your nearest Fluke sales office. Dial toll-free 800-426-0361 for address of office nearest you.

SAVE 50% OR MORE
ALL NEW CRYSTALS — hermetically sealed

<table>
<thead>
<tr>
<th>Price per Item</th>
<th>List Price</th>
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<tr>
<td>44.5850 $1.75 each</td>
<td>7.00000 $2.25 each</td>
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<tr>
<td>44.9183 3 for $5.00</td>
<td>12.00000 3 for $6.00</td>
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<tr>
<td>70.80000 pdd.</td>
<td>1.30000 pdd.</td>
</tr>
<tr>
<td>9.73750 $1.50 each</td>
<td>6.69444 4 for $5.00</td>
</tr>
<tr>
<td>8.25833 pdd.</td>
<td>$3.50 pdd.</td>
</tr>
<tr>
<td>100' 22 ga. twisted pair — good for intercom, telephone, etc.</td>
<td>$1.50 pdd.</td>
</tr>
<tr>
<td>Solid Brass Padlocks — 2 keys &amp; 8&quot; chain</td>
<td>$3.50 pdd.</td>
</tr>
<tr>
<td>IN1202</td>
<td>$1.75 pdd.</td>
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Limited Quantities

Fairchild Time Base Plug in for 766H Series Oscilloscopes

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<th>Price per Item</th>
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<td>8187/4PR65A</td>
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IN-X-SALES

BOX 222 . MEDFORD, MASS. 02155

Turner's new amplified Super Sidekick, a base station communications microphone, has two gain controls: one on the top for normal volume adjustments and another on the bottom for matching the Turner Super Sidekick to various transceivers. This microphone has been designed specifically for the amateur, business band and communications field. It uses a dynamic interior for extreme ruggedness and durability and is unaffected by temperature and humidity. It has a built-in IC amplifier which provides a perfect impedance match with all a-m/ssb transceivers.

The amplifier gain control on the bottom of the Turner Super Sidekick uses a rugged die cast case. The base and neck are black with a polished bright chrome head. The cable is a three-conductor coiled cord. The microphone is activated by pressing down on the touch bar and can be locked on by moving the slide lock forward. The Turner Super Sidekick has a list price of $80 and is available from the Turner Division of Conrac Corporation, 909 17th Street N.E., Cedar Rapids, Iowa 52402. For more information use check-off on page 126.

May 1973
tone encoders

Powered directly by any 12-Vdc 2-meter fm transceiver, the new Ross and White tone-burst encoders allow automatic entry into tone access repeaters. Keyed by closing the transmitter microphone switch from the 12-Vdc keyed source, the encoder generates a half second tone burst which modulates the transceiver and activates the repeater.

Two models are available. The two tone model TE-2 sells for $39.95, and the five tone model TE-5 sells for $49.95 postage paid. Both are sold on a 10-day trial, money-back guarantee basis. Installation is simple with the complete instructions provided for your make and model of transceiver. The battery powered models will continue to be available for hams preferring that arrangement.

For full data including specifications, write direct to the Ross and White Company, 50 West Dundee Road, Wheeling, Illinois 60090 and ask about tone burst encoders. You can get the same information by using check-off on page 126.

solid-state general-coverage receiver

A new and improved version of its popular S-120 series a-m and short-wave table radios has been introduced by Hallcrafters. The new model S-125, called Star-Quest II, provides the user with an all-transistor, completely self-contained...
TALK POWER!

TEMPO

up to 135 W OUT

with 1 to 25 w drive

from mobile, base or

HT . . .

Solid State

Micro-Strip

Circuit

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Cables supplied

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ON POPULAR COMPONENTS

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16.9 MHz

- Ceramic filters at 455 kHz

SEMICONDUCTORS

- VHF power transistors by CTC-Varian

- J and MOS FETS

- Linear ICs — AM/FM IF, Audio PA

- Bipolar — RF and AF popular types

INDUCTORS

- Molded chokes

- Coil forms — with adjustable cores

CAPACITORS

- Popular variable types

QUALITY COMPONENTS

- No seconds or surplus

- Name brands — fully guaranteed

- Spec sheets on request

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- Prices below large mail-order houses

WRITE FOR CATALOG 173

AMTECH

P. O. BOX 624, MARION, IOWA 52302

(319) 377-7927 or (319) 377-2638

dry desoldering tool

Solder removal is fast, economical, and convenient with the new "Soder-Wick," dry desoldering tool. Used in conjunction with an ordinary soldering iron, it quickly removes solder from all sizes of electronic joints and connectors.

Used in the computer, aerospace, telephone and communications industries, "Soder-Wick" is useful for initial building, repairing, or rewiring of circuits or for salvaging parts from bargain computer boards or surplus chassis.

No special equipment is needed to remove solder from integrated circuits, printed circuits or telephone connections. Simply touch "Soder-Wick" to the heated joint and solder is drawn up immediately. Flux contamination is eliminated, and residue if any, is non-corrosive and non-conductive. In just one second, solder can be removed for as little as half a cent per connection.

Rolls of "Soder-Wick" fit conveniently into tool box or pocket, and are available in four sizes to match the joint and quantity of solder to be removed. Each roll contains five feet of wick and sells for $1.49 per roll.

For further information, contact Jensen Tools and Alloys, 4117 North 44th Street, Phoenix, Arizona 85018, or use check-off on page 126.
ALPHA-NUMERIC KEYBOARD AND CONTROL PANEL. Has a 44 key keyboard plus space bar, character lamp panel, function control switches and built-in audio tone generator. All mounted in an attractive molded sloping front enclosure with rubber feet and removable bottom plate. Keys are replaceable and can be relocated. Make your own format! Stock Number K10152... POSTPAID... $22.50

USASCII - II ALPHA - NUMERIC KEYBOARD
Brand new from a leading video terminal manufacturer. Beautiful, well made with the look and feel of an expensive electric typewriter. Sixty five keys + space bar. All alphas + 10 numerals + 20 control keys + 1 locking "shift" key. Diode matrix for ASCII is easily converted to use as morse or TTY keyer. Attractive slanted tier. Tri-color key scheme-replaceable keys. Stock # K10096... POSTPAID... $39.50

NEW - GUARANTEED R.F. TRANSISTORS. FACTORY MARKED

<table>
<thead>
<tr>
<th>TYPE</th>
<th>CHARACTERIZED AT</th>
<th>Po/Gp</th>
<th>Ft</th>
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<td>50W</td>
<td></td>
<td>$30.00</td>
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</tbody>
</table>

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ID-101K P.C. Board Kit $49.95
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TONE ENCODER
Eight pre-adjusted tones. Duration and Output adjustable. PLL circuitry for extreme stability. Choice of continuous or Tone burst operation. Tone burst operation requires no batteries. Easy to install. Includes three special single or dual tones.

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(Specify any freq. above 1200 Hz)

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May 1973 93
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80 through 10 meters

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- No dissimilar metals to cause noise.
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- Exceedingly low radiation angle makes DX and long haul contacts a cinch...whether roof or ground mounted.
- Very low RF absorption from insulating materials.

The 18AVT/WB is constructed of extra heavy duty, taper swaged, seamless aircraft aluminum with full circumference, corrosion resistant compression clamps at all tubing joints. This antenna is so rigid, so rugged...that its full 25' height may be mounted using only a 12" double grip mast bracket...no guy wires, no extra support...the 18AVT/WB just stands up and dishes it out!

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Get the strength, the performance and the price you want...from the man who sells the complete line of quality Hy-Gain equipment.

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More Details? CHECK-OFF Page 126
AT LAST — THE LONG AWAITED TEEC SSTV SYSTEM!

TEEC HCV-1B
SSTV Camera

Features
- Positive and Negative color reversal switch.
- Normal-Reverse yoke switch.
- Built-in power supply for 115 or 220 V, 50/60 Hz.
- Meets all SSTV regulations as well as those of foreign countries.
- F 1.9 Soligor or Cosmocar lens.

Size: 6" x 14 1/2". 29 Transistors, 11 IC's, 24 diodes. 7735A Vidicon.

$325.00 FOB Hendersonville, Tenn.

TEEC HCV-2A Monitor

Features
- 6.25" diagonal screen.
- Removable picture tube filter for added viewing flexibility.
- Tuning meter aids tuning in of SSTV signal.
- Manual vertical trigger pushbutton allows re-start of scan at any time.
- Noise immunity circuits allow viewing under high noise conditions.
- IC's and Transistors plug into sockets on 1 plug-in glass-epoxy gold plated circuit board.
- 115 or 220v 50/60 Hz Power Supply.
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Size: 15 1/2" x 8 1/4". 26 lbs.

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USED TEST EQUIPMENT
All checked and operating unless otherwise noted, FOB Monroe. Money back (less shipping) if not satisfied.

<table>
<thead>
<tr>
<th>Description</th>
<th>Price</th>
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<td>HP1000F - Freq. stand. w/scpe-Acc. 1ppm</td>
<td>125</td>
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<td>HP100ER - Freq. stand. w/scpe-Acc. 0.5ppm</td>
<td>195</td>
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<td>HP212A - Pulse Gen. var. width and rate</td>
<td>65</td>
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<tr>
<td>HP430CR - Microwave pwrs, mtr-rack med.</td>
<td>50</td>
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<tr>
<td>HP522B - Freq. Counter-10Hz-120kHz-digital</td>
<td>45</td>
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<td>L &amp; N7 - 750 Voltbox 3-750v Acc. 52%</td>
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<td>NE 14-20C - Freq-counter (sim. HP524C)</td>
<td>290</td>
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<td>PRD707 - Broadband Microscope osc. 9-2.2GHz</td>
<td>170</td>
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<td>PRD708 - Broadband Microscope osc. 2.4-2.7GHz</td>
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<tr>
<td>Republic VA260 Q-mtr (sim. Boonton 160OA)</td>
<td>185</td>
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<td>Singer SPA-1 Spec. Anal w/ps less rf unit</td>
<td>375</td>
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<tr>
<td>Singer SB-56 Spec. Anal complete. 0-40MHz coverage — 10Hz resolution</td>
<td>1465</td>
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<tr>
<td>Solitron 200A SCR tester checks anode, gate voltages current, leakage and holding</td>
<td>165</td>
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<td>Stoddart NM20A RF intens mtr 10-250kHz, complete with acc.</td>
<td>630</td>
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<td>Stoddart NM52A-RFI mtr, 375-1GHz, w/acc.</td>
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<td>Tek RM15-DC-15GHz GP scope</td>
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<td>Tek 181 Time mark generator</td>
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<td>Tek 190A Const. Ampl. Gen. 35-50MHz</td>
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<td>Tek 531 DC-15MHz scope-takes plug-in plug</td>
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<td>Tek 945 (mil 545) 30MHz scope w/dual trace</td>
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<td>Weinschel 70 Prec RF step attn DC-1GHz</td>
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<td>Weinschel PB-1A Prec RF power bridge</td>
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<td>SG24/3RM3 - Sweep Gen. 15-400 MHz, CW, AM.</td>
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<td>FM Xtal markers, scope-Dev. to 20%</td>
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<td>TS2695/D - Crystal diode test set (1N21, etc.)</td>
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<td>TS-403A-Sig. Gen. (HP616) 1.8-4GHz</td>
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</tr>
<tr>
<td>URM 7 - RF mtr (sim. NF-105) 20-400MHz</td>
<td>750</td>
</tr>
<tr>
<td>URM-26 - Stand. Sig. Gen. 3-400MHz</td>
<td>225</td>
</tr>
<tr>
<td>USM24C - Scope-8MHz, time-base, triggered</td>
<td>125</td>
</tr>
</tbody>
</table>

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OTHER HAL PRODUCTS INCLUDE:

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID-1 Repeater Identifier (wired circuit board)</td>
<td>$75.00*</td>
</tr>
<tr>
<td>ID-1 (completely assembled in 1/4&quot; rack cabinet)</td>
<td>$115.00*</td>
</tr>
<tr>
<td>HAL ARRL FM Transmitter Kit</td>
<td>$50.00*</td>
</tr>
<tr>
<td>W3FFG SSTV Converter Kit</td>
<td>$55.00*</td>
</tr>
<tr>
<td>Mainline ST-5 TU Kit</td>
<td>$50.00*</td>
</tr>
<tr>
<td>Mainline AK-1 AFSK Kit</td>
<td>$27.50*</td>
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</table>

NEW FROM HAL—TOP QUALITY RVD-1002 RTTY VIDEO DISPLAY UNIT. Revolutionary approach to amateur RTTY... provides visual display of received RTTY signal from any TU, at four speeds (60, 66, 75, and 100 WPM), using a TV receiver modified for video monitoring. Panasonic solid-state TV receiver/monitor, or monitor only, available.

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*Above prices do not include shipping costs. Please add 75¢ on parts orders, $2.00 on larger kits. Shipping via UPS whenever possible; therefore, street address required.

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- 2 supplied
- Completely solid state
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  - Xmt: 2.7 A (Hi power) or 1.2 A (Lo power)
- Voltage required: 13.8 VDC
- Antenna impedance: 50 ohms
- Freq. adjusting trimmers
- Size: 7 1/16" W x 2 3/8" H x 9 1/16" D. (18 x 6 x 24 cm)
- Weight: 5 1/2 lbs. (2.5 kg)

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- Frequency deviation: adjustable to ±15 kHz max.
- Factory set to ±6.5 kHz
- Automatic VSWR protection

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<table>
<thead>
<tr>
<th>Frequency Standards</th>
<th>Price</th>
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<tbody>
<tr>
<td>100 KHz (HC13/U)</td>
<td>14.50</td>
</tr>
<tr>
<td>1000 KHz (HC6/U)</td>
<td>4.50</td>
</tr>
<tr>
<td>Almost All CB Sets, Trans. or Rec.</td>
<td>2.50</td>
</tr>
<tr>
<td>(CB Synthesizer Crystal on request)</td>
<td></td>
</tr>
<tr>
<td>Any Amateur Band in FT-243 (Except 80 meters)</td>
<td>1.50</td>
</tr>
<tr>
<td>80 Meter Range in FT-243</td>
<td>2.50</td>
</tr>
<tr>
<td>Color TV 3579.545 KHz (wire leads)</td>
<td>1.60</td>
</tr>
</tbody>
</table>

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Prices MFA-2 $210.00 BOX 1201H
MFA-22 $275.00 CHAMPAIGN, ILL.
Shipping $3.00 extra 61820
Rugged Giants

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* Three Hi-Gain 10, 15, 20M long johns.
** Log-periodic antenna for MARS use 13 to 30 MHz.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>HEIGHT</th>
<th>EXTENDED</th>
<th>NESTED</th>
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<tr>
<td>TM-240</td>
<td>40’</td>
<td>22'</td>
<td></td>
</tr>
<tr>
<td>TM-358</td>
<td>58’</td>
<td>22½'</td>
<td></td>
</tr>
<tr>
<td>TM-370/370HD</td>
<td>70’</td>
<td>27’</td>
<td></td>
</tr>
<tr>
<td>TM-480</td>
<td>90’</td>
<td>28’</td>
<td></td>
</tr>
<tr>
<td>TM-5100R</td>
<td>100’</td>
<td>29’</td>
<td></td>
</tr>
</tbody>
</table>

More Details? CHECK-OFF Page 126
"INTRODUCTORY PRICES"

ST-5 BOARDS ONLY ........................................ $ 5.25
ST-5 KIT OF ELECTRONIC PARTS ....................... $ 47.50
ST-5A BOARDS ONLY ....................................... $ 5.25
ST-5A KIT OF ELECTRONIC PARTS ......... ........ $ 54.00
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May 1969
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June 1969
FEATURING: Solid-state single-band SSB transceiver, External-anode tetrodes, FM communications receiver, RTTY tuning unit, Top-loaded vertical.

August 1969
FEATURING: Homebrew Parasitic Reflector, Solid-state Q-5er, Frequency calibrator with mos IC's, New multiband quad antenna, Troubleshooting with a scope.

September 1969
FEATURING: FM techniques and practices, IC power supplies, 1296-MHz varactor tripler, Tunable bandpass filters, Amateur microwave standards.

October 1969
FEATURING: Hot Carrier Diodes, Low-cost linear IC's, Diversity antennas, solid-state 432-MHz exciter, Tropospheric duct communications.

November 1969
FEATURING: Op Amps theory, selection & application, WWV receiver, Multiband antenna, Electronic key, Six-meter collinear.

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118 May 1973
WANTED: Members for Ham Flying Club being formed in Morrisstown, N. J. area. For details contact M. Kovar, W2ZN, 3 Puddingstone Ct., Morris-town, N. J. 07960 (201) 267-2921.

CW OPS. 30 Hz SELECIVITY eliminates QRM. Adjustable, lossless filter plugs into headphone jack. Drives phones (1000 ohms or more), $17.95. Send for literature. Autek, Box 1494M, Canoga Park, Cal. 91304.

CLEAN OUT — ton of parts. Too old to build. SASE for bargain list. K. A. Trites, 1918 E. 12th St., Des Moines, Iowa 50316.

THE EGYPTIAN RADIO CLUB Inc. will hold its Ham-Picnic Sunday, June 24, 1973 at 700 Chouteau Slough Rd., Granite City, Illinois. Something for everyone — prizes — games for the children — food at the club house — parking for swaps — etc. Details from K9KXP.

STELMAN # TA-1 TELEPHONE ADAPTER, $125. Heavy duty equipment slides $15 ea. Components, equipment, etc. inquires invited, catalog available. B. F. Williams Co., P. O. # 7057, Norfolk, Va. 23509.

WANTED: Magnetics specialist or college professor thoroughly familiar with conventional magnetic theory to assist the editor in evaluating a new concept in explaining magnetism. Write to Jim Fisk, WIDTY, editor, Ham Radio Magazine, Greenville, N. H. 03048.

RESISTORS: Carbon composition brand new. All standard values stocked. 1/2W 10% 50/$1.00; 1/4W 10% 40/$1.00; 10 resistors per value please. Minimum order $5.00, 15W RMS IC Audio Amplifier — Panasonic. Frequency response 20Hz-100kHz, 1/2% distortion. Price $6.50. Postpaid. Face Electronic Products, Box 161-H, Ontario Center, New York 14520.


THE MADISON COUNTY (Indiana) Amateur Radio Club presents their spring Hamfest Sunday May 19, 1973 from 10 a.m. till 5 p.m. 4 miles north of Anderson (west of state road 9) at the Madison County Civil Defense building (old Linwood school). The Talk-In frequencies are 146.94 and 146.82 MHz FM and 3.92 MHz SSB. All buyers, sellers, and visitors are welcome. Plenty of refreshments and prizes.

CANADA'S MOST UNUSUAL Surplus and Parts Catalog. Jam packed with bargains and unusual items. Send $1. ETCO-HR, Box 741, Montreal, Canada.


FIGHT TVI with the RSO Low Pass Filter — $115

March 73 — write for brochure. Taylor Communications Manufacturing Company, Box 126, Agincourt, Ontario, Canada.


"P.C.'S" I can supply boards for any construction article that includes the full size artwork. Many in stock. Write D. L. McClure, W8JDR, 19721 Maplewood Avenue, Cleveland, Ohio 44135.

KANSAS — The Central Kansas ARC will hold their Annual Hamfest, Sunday, June 3, at the 4-H Complex, Kenwood Park, Salina. Also a dinner Saturday night. Registration Sunday at 9:00 a.m., with a program for the OM, YL, XYL and harmonic. Covered-dish lunch supplied by the club. Talk-in on 146.34-94 and 3920kHz. For information write W9ODE, William Peck, 1028 W. Ash, Salina, Kansas 67401.

H5 N5 C5 E5 T5 S5 U5 P5 J5 G5 F5 D5 A5 R5 Q5 M5 L5 K5

HAM RADIO
GREENVILLE, NH 03048

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May 1973
ANNOUNCING

VHF COMMUNICATIONS now has world sales rights for the famous J-BEAM line of amateur VHF and UHF antennas.

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EIGHT OVER EIGHT Cat. No. 2/16 Gain 12.6 dB
Slot Fed Double 8 Yagi

Width 40" Length 102" Height 46"
102 cm. 260 cm. 116 cm.

Horizontal Beamwidth between half power points 40"
Weight 9 lbs. Wind loading 65 lbs. at 100 m.p.h.
VIDEO ADAPTER converts oscilloscope into flexible 1024 letter RTTY readout for under $400. High-performance H.F. frequency synthesizer replaces VFO and delivers clean R.F. output with calibration accuracy, stability, and resolution. 100 times better than today's best amateur rig. Write for full information. Petal Logic Systems, Box 51, Oak Harbor, WA. 98277.

THE BURLINGTON AMATEUR RADIO CLUB VE3RAB is celebrating the centennial of the Town of Burlington, Ontario by operating a centennial station for the duration of 1973. The special call sign VE3RAB will be used and acknowledgement of contacts will be with a colourfull QSL card. Operation during all major contests.

STOLEN IN WISCONSIN RAPIDS. Wisconsin on February 12, 1973: Regency HR-2A, serial number DM714148 with Topaka FM 6-channel add-on transceiver and deck. Please contact Police, Wisconsin Rapids, Wisconsin 54494 or Edward W. Voigtman, W9GSS, 4050 Crestwood Court, Wisconsin Rapids, Wisconsin 54494.

THE ROYAL CANADIAN MOUNTED POLICE will be operating an amateur station at Ottawa, Ontario, to commemorate their 100th anniversary, from 23 May 1973 to 30 August 1973 from 1200 hours GMT to 0400 hours GMT daily. The call sign VE3RCP has been approved. A commemorative QSL card will be sent to all amateurs visiting Ottawa during this period may visit this station which will be in a large exhibit in the R. C. M. P. Training Center, on St. Laurent Blvd., Ottawa, Ontario. For further information please write to the Commissioner, R. C. M. Police, 1200 Alta Vista Drive, Ottawa, Canada. KIA OR2.

THE F.M. DIVISION of CVT, Inc. (Poughkeepsie Amateur Radio Club) will hold an Auction on Saturday, May 5th. 1973, between 7:00 p.m. at Gerring Park, Fishkill, N.Y. Attention: Telecommunications Branch.

FOR SALE, KWS-1, $375; 754A, $250; ZEUS, $225; 752A, $350; Swan 250, $200; TX-62, $60; Model 15 TTY, $40. G.E. Progress line transistorized supply for standing ads not changed each month. Non-commercial ads $2.80. Please contact Police, Wisconsin Rapids, Wisconsin 54494 or Edward W. Voigtman, W9GSS, 4050 Crestwood Court, Wisconsin Rapids, Wisconsin 54494.

THE F.M. DIVISION of CVT, Inc. (Poughkeepsie Amateur Radio Club) will hold a Ham-fest and Auction on Saturday, May 5th, 1973, between 11:00 a.m. and 7:00 p.m. at Gerring Park, Fishkill, N. Y. near routes 52 and 84 intersection. Talk-in on W2CVT 154.215, with 4 channel deck, $160. WB2PMF, Grantham, BD Hendicott Ave., Union Beach, N. J. 07735. 201-264-7631.

THE ROYAL CANADIAN MOUNTED POLICE will be operating an amateur station at Ottawa, Ontario, to commemorate their 100th anniversary, from 23 May 1973 to 30 August 1973 from 1200 hours GMT to 0400 hours GMT daily. The call sign VE3RCP has been approved. A commemorative QSL card will be sent to all amateurs visiting Ottawa during this period may visit this station which will be in a large exhibit in the R. C. M. P. Training Center, on St. Laurent Blvd., Ottawa, Ontario. For further information please write to the Commissioner, R. C. M. Police, 1200 Alta Vista Drive, Ottawa, Canada. KIA OR2.

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HAMFEST — Wabash County ARC Fifth Annual Hamfest Sunday May 20, rain or shine. Admission is still only $1. Flea market, food, tech talks and much more. For information write Bob Mitting. 663 Spring, Wabash, In. 46992.

MODERNIZE FOR PEANUTS! Frame & Display QSL’s with 20 pocket plastic holders. Two for $1.00, $3.00 for 50. All children’s written and YXL’s admitted free. CVT, Inc., c/o R. W. Perry, RD 1, Glen Ave., Fishkill, N. Y. 12524.

RESISTORS: A-B. Stackpole 5%, $4. Meeco RN60D, 18g Signetics N7441B, $1. List SASE. I. C. S. Company, Box 622, Bellaire, Texas. 77401.

FOR SALE. 808S1, $350; Swan 250, $200; RX-60, $60; Model 15 TTY, $40; G.E. Progress line transistorized supply for standing ads not changed each month. Non-commercial ads $2.80. Please contact Police, Wisconsin Rapids, Wisconsin 54494 or Edward W. Voigtman, W9GSS, 4050 Crestwood Court, Wisconsin Rapids, Wisconsin 54494.

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May 1973

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$9.95

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• All are powered by 12 volts
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<thead>
<tr>
<th>Package</th>
<th>Description</th>
<th>Price</th>
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<tbody>
<tr>
<td>LAE MW35 “STANDARD” Package</td>
<td>(Free Standing Crank-Up Tower 9.5 Sq. Ft. - 50 MPH) (35 Ft.) CDR AR-22R Rotator* 100 ft. RG-58A/U Coax 100 ft. 4 Cond. rotor cable</td>
<td>Complete with one of the following antennas: HY-GAIN TH2MK3 HY-GAIN TH3JR HY-GAIN DB10-15A HY-GAIN HY QUAD HY-GAIN TH3MK3 *TR-44 rotor w/cable add: $ 35 HAM-M rotor w/cable add: $ 65</td>
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<tr>
<td>HY-GAIN DB 10-15A</td>
<td>$620</td>
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<td>HY-GAIN HY QUAD</td>
<td>$650</td>
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<td>HY-GAIN 204BA</td>
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<td>HY-GAIN TH3MK3</td>
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<td>HY-GAIN TH6DXX</td>
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<td>HY-GAIN THGDXX</td>
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<td>HY-GAIN TH2MK3</td>
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<td>HY-GAIN DB10-15A</td>
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<td>HY-GAIN HY QUAD</td>
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<td>HY-GAIN TH3MK3</td>
<td>$339</td>
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LAE W51 “DELUXE” 51 Ft. Package (Free Standing, 9 Sq. Ft. - 50 MPH) CDR TR-44 rotor* 100 ft. RG58A/U coax cable 100 ft. control cable Complete with one of the following antennas: HY-GAIN DB 10-15A HY-GAIN HY QUAD HY-GAIN 204BA HY-GAIN TH3MK3 HY-GAIN TH6DXX HY-GAIN THGDXX Free stdg. base incl. NO/CHARGE *HAM-M rotor w/RG8/U add: $ 60 |

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