73

JULY 1966

60¢—How About That?

Amateur Radio

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de W2NSD/1

never say die

Amateur radio convention?

Have you ever considered the possibility that we amateurs could be self-governing? Suppose, for example, that a yearly national convention was held for the review of our hobby and that the actions of the delegates to the convention were held binding on us all. Clubs around the country could send a delegate to represent their interests. This would encourage club activities and would get most active amateurs to join clubs in order to have a say in their rules.

The convention might run similarly to the international conferences with committees being established to sort out the ideas and present the result of their study to the convention for vote.

We might have a committee to study contests and recommend changes in rules or even the elimination of no longer needed contests. They might also suggest needed contests. Obviously the members of the committee would be those interested in contests. The certificate hunters could have their committee and on a yearly basis hash out their problems and keep up to date. Ditto the DXers, RTTYers, traffic nets, and every other phase of amateur radio.

Maybe every other year would be enough. It sounds like a lot of work. I do think it would get a lot more fellows interested in the running of amateur radio and that the end result would be much faster progress.

If we were to set up such a convention or conference system of changing our rules I am quite sure that we would find the FCC quite willing to go along with it. We know darned well that the FCC doesn't like the present rule making system. If we give them a reasonable alternate I think they would buy it.

Intruders

One of the difficult and growing problems in amateur radio is the intruder. This takes the shape of mysterious RTTY signals running endlessly, obviously commercial CW signals or just plain short wave broadcasting. While we are reasonably sure that such signals in our 20 meter band are illegal, we are never sure of those down on 40 or 80 meters and w hesitate to make an issue of their activit when we are not sure of our own ground We know that the ITU agreements do includ some sort of sharing arrangement for thos lower bands so we are cautious.

The lack of agressive retaliation to this ir trusion has encouraged stations in countrie who take their ITU commitments lightly (c who are uncommitted at all) to step in and us our bands wherever we permit the QRM leve to accommodate them. Perhaps I might d gress for just a bit at this point to throw pointed barb at the champions of QRP. agree with them that it is indeed delightfu to work 100 countries using 100 watts powe and if they find this entertaining I agree tha they should continue to do what is fun fc them. But I think that they should not fee at all pious about this little hobby of their and try to shame others into following the example for it is the high power stations tha are holding our frequencies for us, not th QRPers. As soon as the QRM level drops th commercials move in. Though I do not advc cate the use of higher than legal powers b operators, I do think that we would hav little to lose and much to gain if the worlc wide power level were set at one kilowat Thirty years ago this was a bit hard to ger erate, but today it is hardly out of reach c any average amateur.

What can we do about the intruders? Firs of all we can organize ourselves and deter mine to keep our ham bands for hams. W know of several methods of ridding ourselve of unwanted signals and I am sure that a littl thought and asking around will turn up som more practical approaches to the problem. certainly would be interested in publishin any information available on the subject an will do all I can to help coordinate any effort that organize.

The number one approach, of course, is t find out as much about the intruding signal as possible and report them to our own gov

(Continued on page 88)

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Editor's Ramblings

Helping out

One thing hams have always been famous for is helpfulness. Hams have helped out in emergencies, for public events, for servicemen's phone patches and in many other ways. They also used to help out young hams and others interested in amateur radio. In fact, at one time, most hams got their knowledge of electronics and amateur radio from older hams who were glad to help out. But things have changed a lot now. You can be licensed even without talking to a ham. Needless to say, hams who get on the air this way tend to be ignorant of old ham traditions, whether the traditions be good or bad. They're often impolite on the air and operate their equipment improperly, causing interference to other hams or to other services. Why? Because they don't know any better. They can memorize the license manual and study books and listen to code records, but that can't teach the things an older ham can. The example, teaching and friendliness of other knowledgeable hams can do far more to improve the competence and attitude of hams than having to take a government test can.

So what can be done to try to help young hams? The best way is probably through strong local radio clubs. A good club with plenty of activities—hamfests, auctions, contests, club building projects, GOOD speakers, demonstrations, participation in Field Day or VHF Parties, a good newsletter—can attract plenty of hams and prospective hams. Encourage newcomers: welcome them to the club, show them how to do things, give them old parts and tell them how to use them, invite them to visit your shack, teach them the code, give them old books and magazines (they can have a free sample of 73 if they write us), give them good advice, encourage them and set a good example. You'll find that it won't be long before they're pretty good hams. Hamming is a social hobby. It's more fun with other hams to visit and work with than with just talk on the air. There's no substitute for personal contact and encouragement.

And in line with this need to help r hams, I mentioned in May that we at 73 c answer the many technical questions we from the readers. K6HPR suggested that m be he and a number of EE's or other quali hams would be willing to help answer qu tions about ham radio. If you'd like to h out and think you can, why not send y name and qualifications in and we'll see w can be done. Maybe each month we co publish a list of people willing to help It might take a lot of time, but the work be very rewarding.

The ARRL Handbook and semiconductors

I often read and use the ARRL Amat Radio Handbook. If any single publicat could be considered the "bible" of amat radio, it must be the Handbook.* I can imagine any ham shack without at least of its many editions, and most hams seem get a new one every few years. But there one thing about the Handbook that both me. It's not that the Handbook seems m a textbook or project book than a handbo Or that the yearly editions are so similar. M radio theory changes very slowly, if at and the main object of the book is to prov a useful reference with enough change to courage hams to buy a new copy every years.

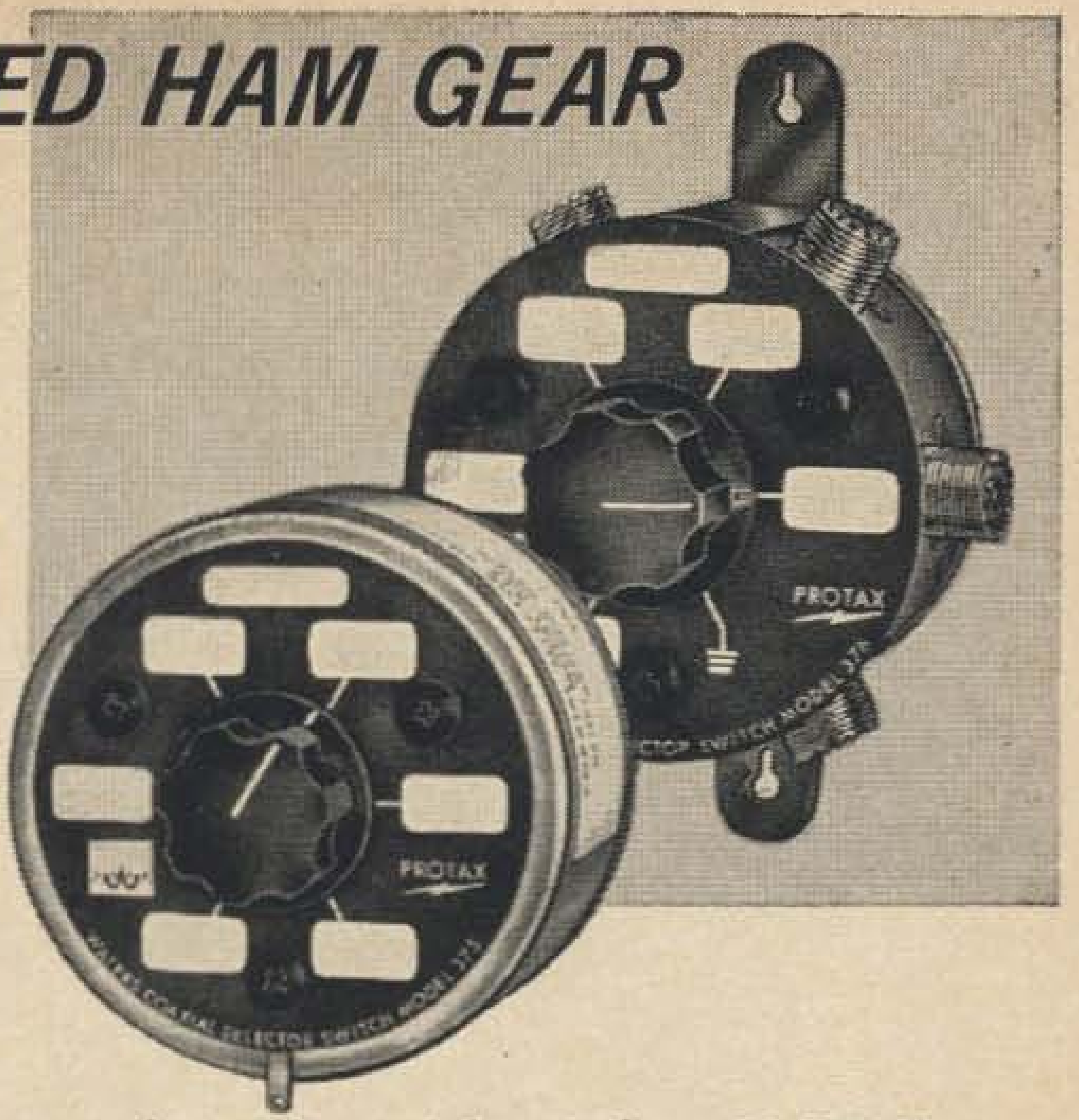
But I really am bothered by the Handbo treatment of semiconductors. Why does it tually ignore most current communicati practice? Any casual observer of electro can see that semiconductors have been are being accepted by all branches of e tronics as rapidly as economics, performa and (most important) engineering talent all The reasons are obvious. Semiconductors h many advantages over tubes for most u

(Continued on page 118)

*The ARRL refers to QST as the bible, but that se a peculiar analogy to me.

CONVENIENCE ENGINEERED HAM GEAR

by *Waters*



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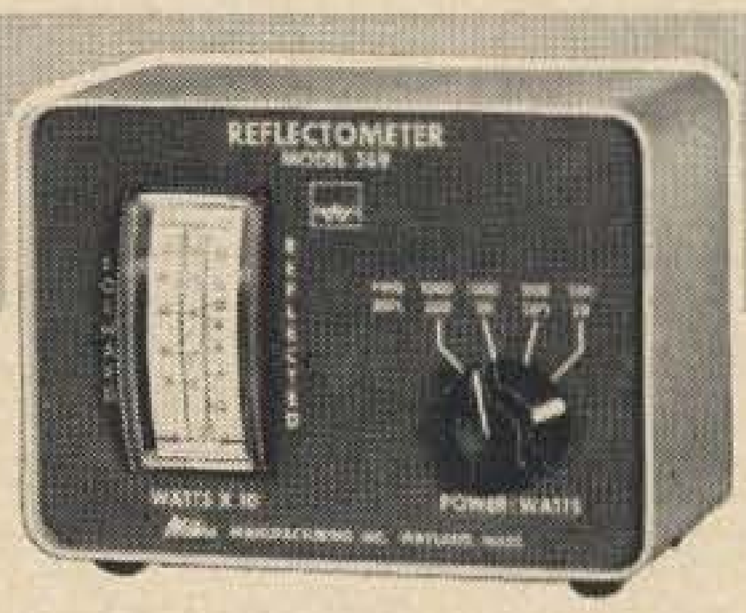

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The ultimate in phone patches providing effortless, positive VOX operation . . . and it also connects tape recorder for both IN and OUT. Built-in Waters "Compreamp" increases low telephone line signals while simultaneously preventing overmodulation. "Compreamp" also operates alone (without patch) with station mike.

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MARS HF Mixer and Amplifiers

This mixer takes 80 to 10 meter input and puts out a kilowatt on 1.5 to 27 MHz for MARS operation.

If there is one thing most amateur transmitters are not, it is *truly* all band. Most hams who are introduced to the MARS program find that their equipment is not designed for operation outside the ham bands. This poses a problem: Do I alter my existing equipment? Do I attempt to use surplus equipment? Do I buy new equipment? Existing ham equipment can be altered in some cases but can it be altered without some losses in operating flexibility efficiency, etc.? Besides many operators do not wish to alter late model equipment. Using surplus gear is ok if you can find something late enough to be state of the art, sideband, and not a TVI generator. To buy new equipment with all band capability costs $$$ and you don't find that in the old junk box.

Like many inventions, this circuit was devised out of necessity. This station was operating a low power all HAM BAND transmitter. Then came MARS and the necessity of being able to operate, preferably with some power, on frequencies other than those covered by a ham transmitter. The result could hardly be called a compromise. The unit designed and built gives any ham band transmitter truly all band, high power operation without alteration of the existing equipment. It will operate from 1.6 to 30 MHz, at legal maximum power, and best of all, most of the parts were dug out of a well stocked junk box.

Glen and George are pilots in the Air Force. George designed both of the units and built the 60 watt amplifier. Glen built the mixer and the kilowatt amplifier, and wrote the project up.

Circuit description

The principle is simple and tried. The frequency converter is a device by which a frequency corresponding to the input signal is translated to the desired output frequency. A frequency converter is also known as a fre-

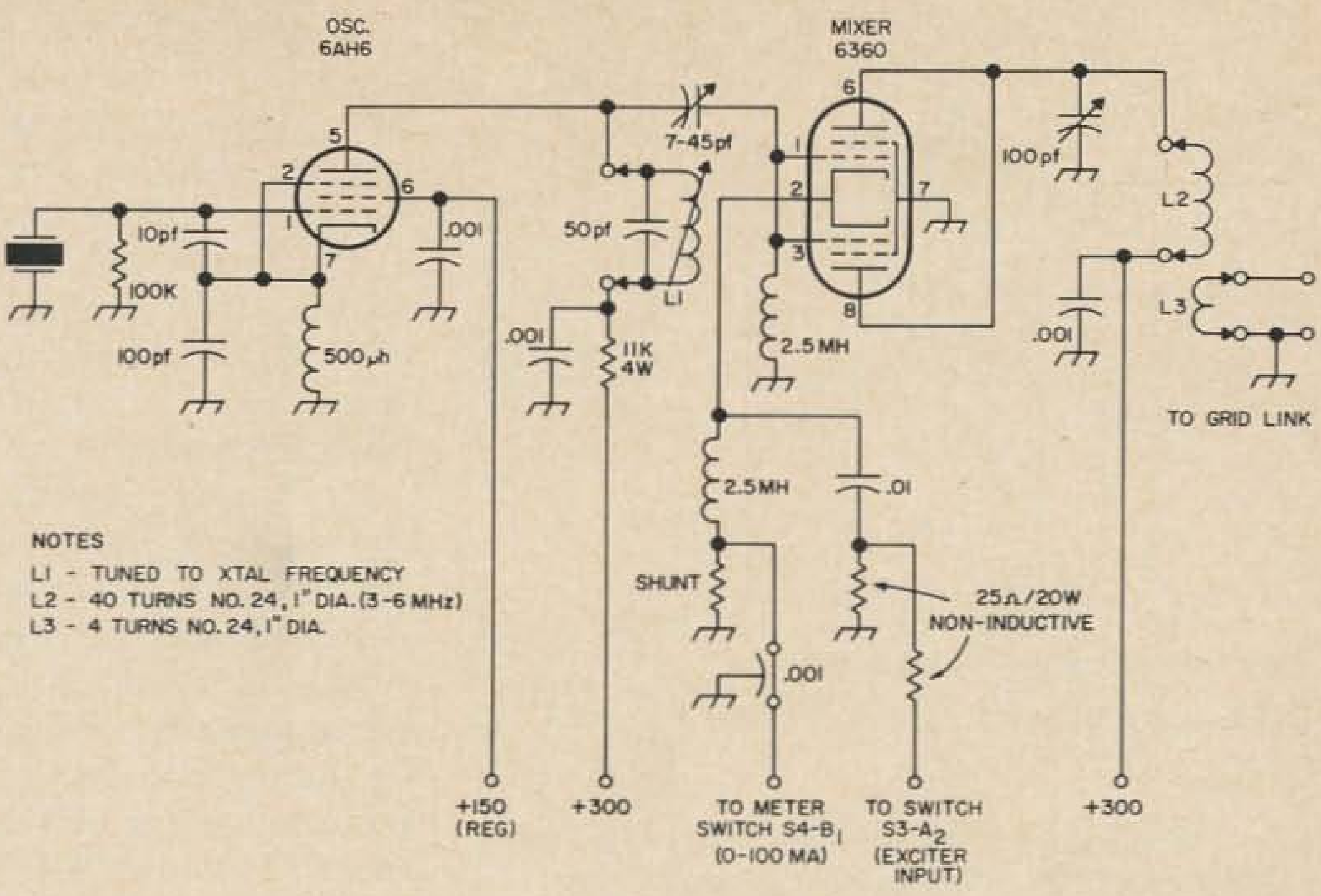


Fig. 1. Crystal oscillator and mixer that generates low level output to drive the final.

quency translator or frequency mixer. All these names are descriptive of the function in which two RF voltages are fed into a device which produces a complex output wave from which the sum or difference frequency component may be selected. Normally, mixing or frequency conversion takes place at low power levels, on the order of 500 mw to 1 watt. However, in this particular instance the frequency conversion takes place at a considerably higher power, and is then further amplified.

The circuit is fairly straightforward and follows well established principles. The 6AH6 Colpitts crystal oscillator was selected because of its excellent stability characteristics. Output from the oscillator is fed to the grid of a 6360, used as a mixer stage, through a variable trimmer condenser to facilitate mixer grid drive adjustment.

Selection of the mixer tube and circuit had to meet certain conditions: have sufficient output to drive an amplifier, be small in physical size, have high enough plate dissipation to idle with oscillator drive applied. The 6360 met all these conditions. With the screen and grids at DC ground the tube is biased below cut-off for operation in the non-linear region.

Since cathode drive must be about 20 times that required for grid drive, the oscillator sig-

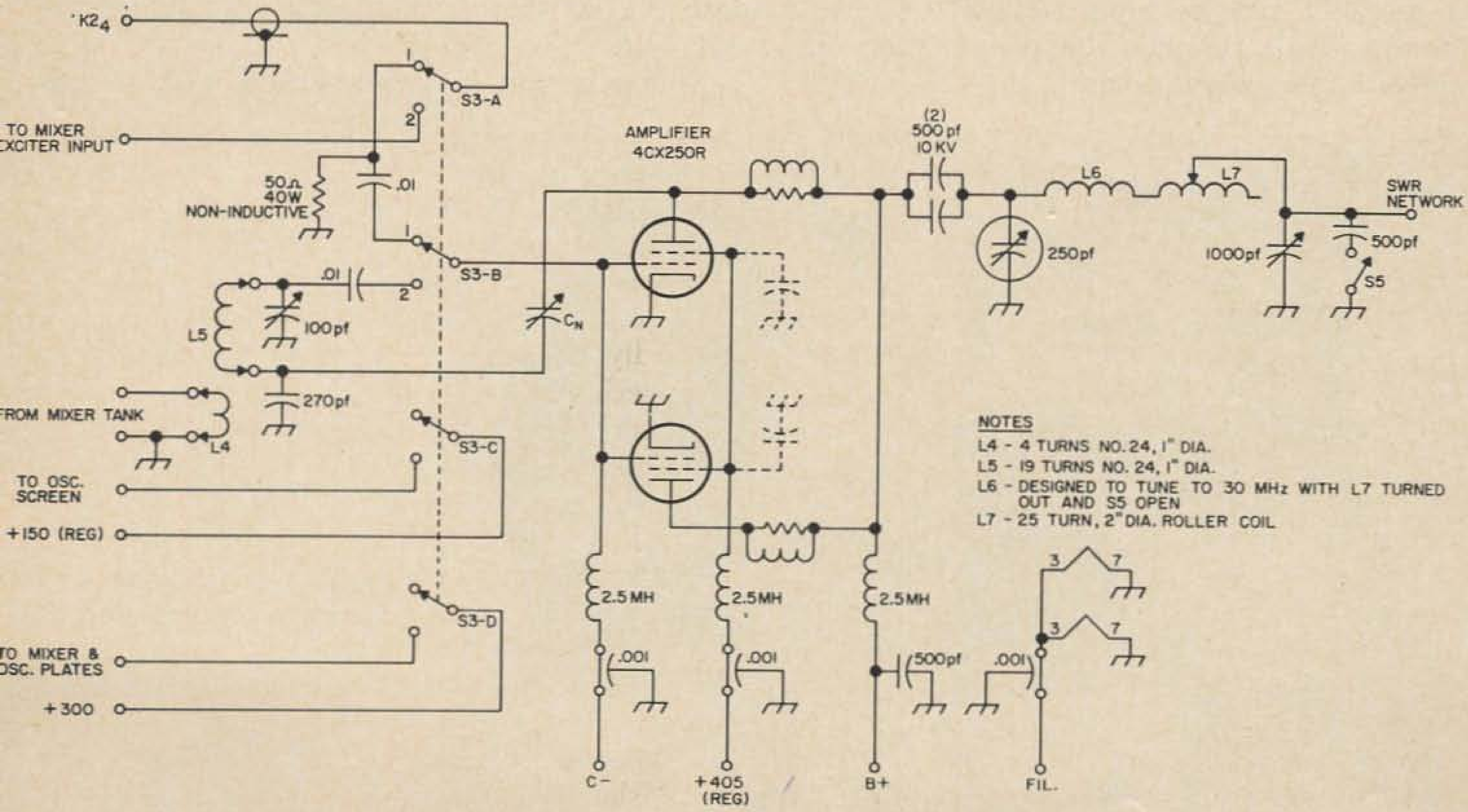


Fig. 2. 4CX250R kilowatt amplifier for HF MARS or ham frequencies.

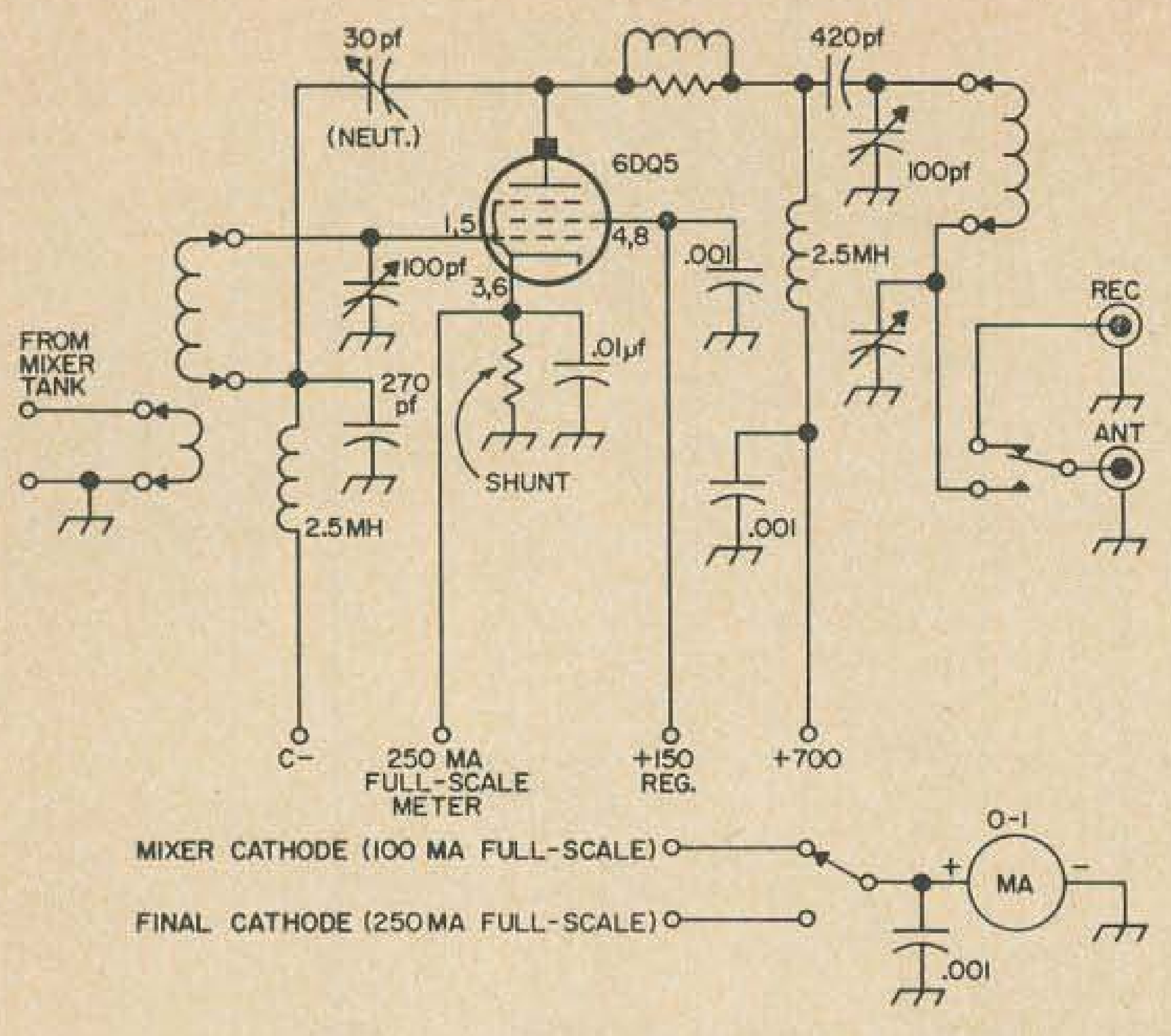


Fig. 3. "Low power" 6DQ5 amplifier for those who don't want or need a full kilowatt. The unmarked loading capacitor is 500 pf.

nal is fed to the grid and the exciter signal is fed to the cathode.

A combination of exciter impedance match, swamping, and signal voltage divider is used in the cathode input. The output of the mixer is link coupled to the amplifier grid tank. This was done for three reasons: an additional tuned circuit to further attenuate unwanted mixer products, isolation of the amplifier grid circuit, and ease of neutralization.

When the unit is used as a straight amplifier on the bands covered by the exciter, the oscillator screen and plate, and mixer plate voltages are switched off, the amplifier grid tank is switched out, and the exciter input is switched to a passive input network. The exciter now feeds through the passive network directly to the amplifier grid.

The amplifier section is a straightforward class AB1 linear employing a pair of 4CX250R tubes. The output is a pi-net using a modern vacuum variable, an ancient roller coil, and a standard variable capacitor.

The final touch was the addition of an SWR bridge. This is placed in the circuit such that it is usable even when the exciter is operated "bare foot." Bare foot operation is accomplished simply by not turning on the B+.

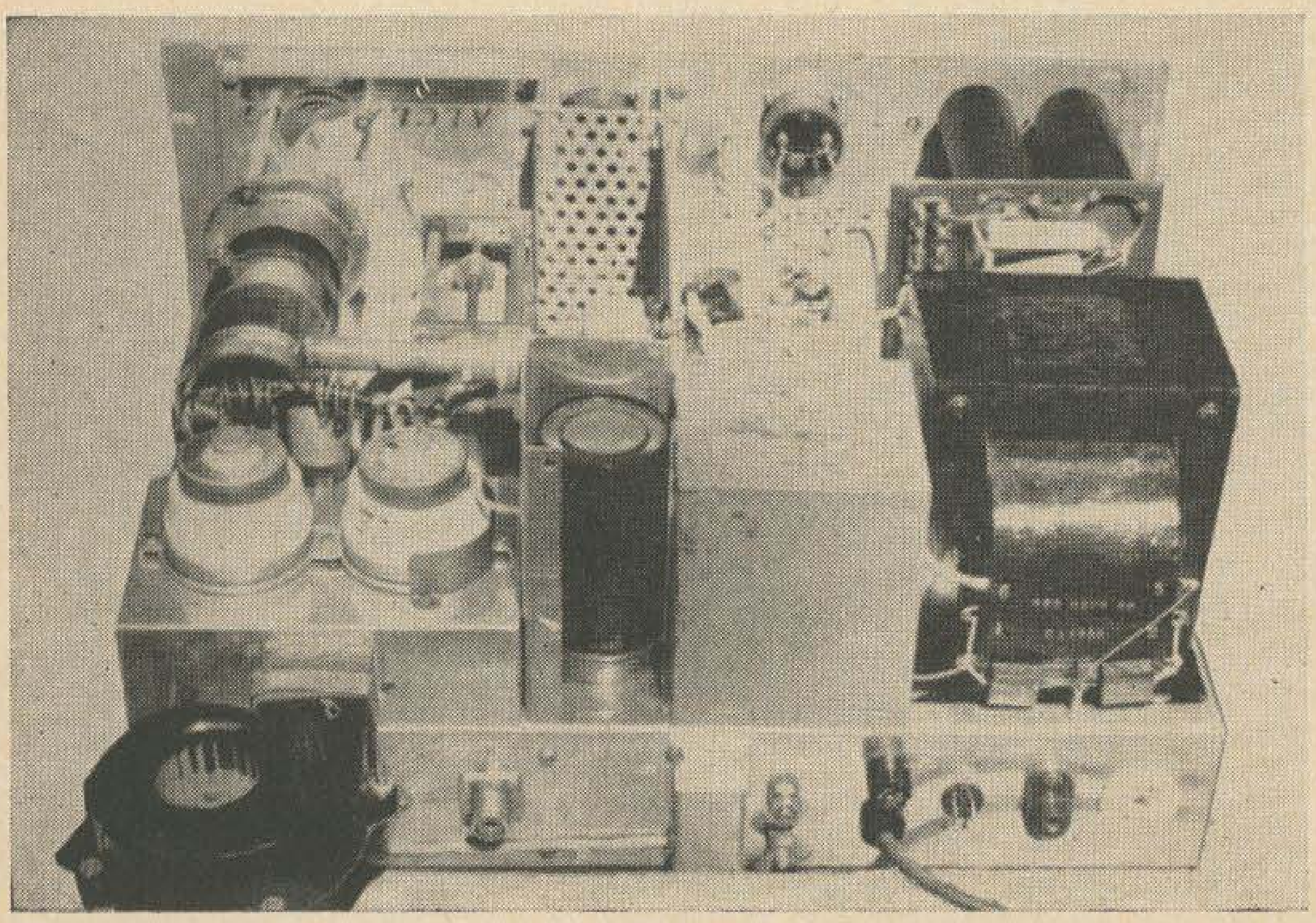
The power supply can be designed around the builder's junk box. The circuit shown utilized what was available at this station. A few items should be kept in mind. The screen supply to the 6AH6 and the 4CX250R should be regulated. The grid bias to the final must be adjustable to properly set the operating parameters for AB1 operation. The plates of the 6AH6 and 6360 should not exceed 300-VDC.

Construction

This particular unit was built on a 13x17x3" chassis. The vertical height was kept down to fit behind an 8¾ inch front panel.

The parts layout is shown in the photographs. The various sections are all shielded with solid aluminum sheet stock. The high voltage supply and final RF sections are shielded with perforated stock for personal protection from the power supply and RF shielding of the amplifier section. The final grid tank coil is mounted in a "tin" can. The lid being attached to the chassis around the coil socket, and the bottom of the can slipping onto the lid thereby completely shielding the coil unit.

Neutralization is accomplished with a stub



Back view of the high power mixer-amplifier.

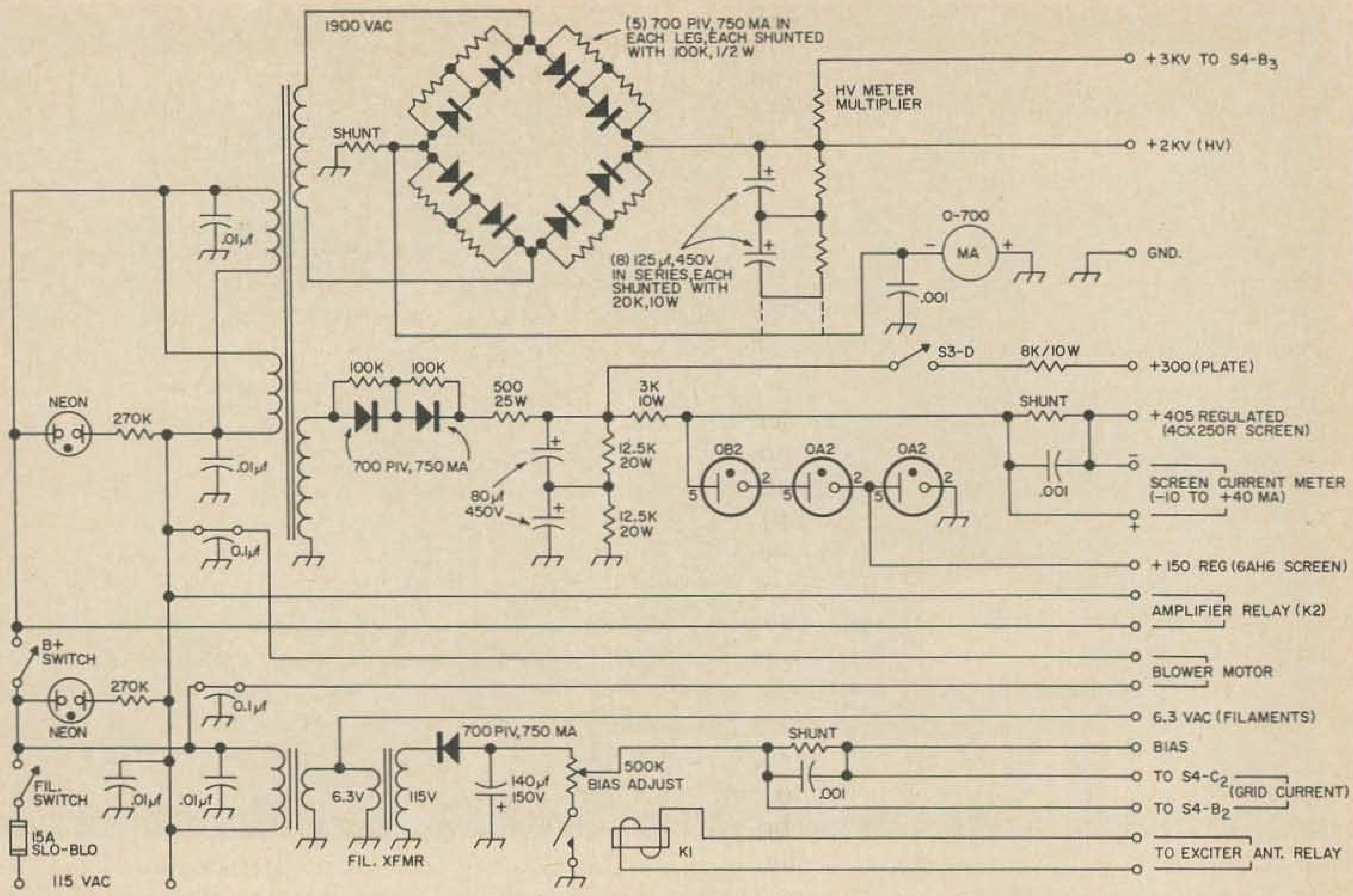


Fig. 4. Power supply for the mixer and high power amplifier. The bias pot marked 500 K should be 5K.

Output Frequency MHz	Crystal Frequency MHz	Exciter Frequency MHz
1.5— 2.1	12.5	14.0—14.6
2.0— 2.6	12.0	14.0—14.6
2.5— 3.1	11.5	14.0—14.6
3.0— 3.6	11.0	14.0—14.6
4.0— 4.6	10.0	14.0—14.6
4.5— 5.1	9.5	14.0—14.6
5.0— 5.6	9.0	14.0—14.6
5.5— 6.1	8.5	14.0—14.6
6.0— 6.6	10.0	3.4— 4.0
6.5— 7.1	10.5	3.4— 4.0
7.5— 8.1	11.5	3.4— 4.0
8.0— 8.6	12.0	3.4— 4.0
8.5— 9.1	12.5	21.0—21.6
9.0— 9.6	12.0	21.0—21.6
9.4—10.0	6.0	3.4— 4.0
9.9—10.5	6.5	3.4— 4.0
10.4—11.0	7.0	3.4— 4.0
10.9—11.5	7.5	3.4— 4.0
11.4—12.0	8.0	3.4— 4.0
11.9—12.5	8.5	3.4— 4.0
12.5—13.1	8.5	21.0—21.6
13.0—13.6	8.0	21.0—21.6
13.5—14.1	7.5	21.0—21.6
14.5—15.1	6.5	21.0—21.6
15.0—15.6	6.0	21.0—21.6
15.4—16.0	8.5	6.9— 7.5
15.9—16.5	9.0	6.9— 7.5
16.4—17.0	9.5	6.9— 7.5
16.9—17.5	10.0	6.9— 7.5
17.4—18.0	10.5	6.9— 7.5
17.9—18.5	11.0	6.9— 7.5
18.4—19.0	11.5	6.9— 7.5
18.9—19.5	12.0	6.9— 7.5
19.4—20.0	12.5	6.9— 7.5
19.5—20.7	9.0	28.5—29.7
20.5—21.7	8.0	28.5—29.7
21.5—22.7	7.0	28.5—29.7
22.5—23.7	6.0	28.5—29.7
23.5—24.1	9.5	14.0—14.6
24.0—24.6	10.0	14.0—14.6
24.5—25.1	10.5	14.0—14.6
25.0—25.6	11.0	14.0—14.6
25.5—26.1	11.5	14.0—14.6
26.0—26.6	12.0	14.0—14.6
26.5—27.1	12.5	14.0—14.6

of wire positioned near the plate of the 4CX-250R, but shielded from the base and screen grid of the tubes.

Coil dimensions are given only as a rough guide, as these will vary with builder's layout, parts placement, frequency requirements, etc. A grid dipper should be used for adjustment of all coils.

Selection of the crystal frequency will depend upon the exciter injection and the output frequency desired. In order to have unwanted mixer products attenuated as much as possible the oscillator and exciter frequencies must be as far as possible from the desired output frequency. The frequency table shows a list of crystal, exciter, and output frequencies that meet these requirements.

First, using a grid dipper adjust the oscillator coil to resonate at the crystal frequency. Then adjust the mixer tank to resonate at the desired output frequency. Apply power to the oscillator and mixer sections only. Check the oscillator for resonance and adjust the trimmer to drive the mixer to 20-25 ma. Next, inject the signal from the exciter until the mixer plate reads 40-50 ma. Then tune the mixer coil for maximum on the desired output frequency. NOTE: No dip in the mixer plate current will be found at the desired output frequency. Since there will be dips at other frequencies, some output indicating device must be used to tune for maximum, such as a pilot bulb and a loop of wire, or neon light.

Next, the grid circuit of the amplifier should be resonated for maximum output, WITHOUT PLATE OR SCREEN VOLTAGE TO THE FINAL. Now the amplifier must be neutralized. With a sensitive output indicator (RF probe and VTVM was used) tune the final to maximum output. Adjust the position and length of the neutralizing stub to obtain minimum feed-through, keeping the grid and final tanks at resonance.

After neutralizing is complete the screen and plate leads may be connected and power applied to the final without exciter input. At this time set the static plate current to 140 ma by adjusting the bias control pot. The amplifier may now be loaded into a 50 ohm dummy or antenna. Without drive from the exciter, the oscillator is adjusted to resonate by a peak on the mixer plate meter at 20-25 mils. Drive from the exciter is then adjusted to 40-50 mils on the mixer plate current. Using the grid tuning condenser load the 4CX250R's to 500 mils keeping the screen current at or below 0 ma. The screen current will read slightly below 0 ma until approaching maximum output. It will then drop to below −10 ma, then increase rapidly. Load to 0 ma screen current and to 500 ma plate current keeping the final at resonance with reference to the relative power output meter. When operating SSB, screen current should not be allowed to peak above +2 ma.

When using only the amplifier straight-through on ham bands, switch off the power to the oscillator and mixer sections. The exciter then provides the drive and tune up procedures remain the same for the final.

Using the parameters mentioned above the power output of this unit was measured at 650 watts into a 50 ohm antenna. Attenuation of unwanted signal products was found to be 25 db or better down.

Conclusion

This particular unit is the end result of three units designed and built using these mixer principles. The second unit could well be of interest in cases where a smaller low power unit may be desired. That particular unit is designed in the same manner except it has no provision for straight amplifier operation and it uses one 6DQ5 tube operating AB1 linear. Using essentially the same circuitry, the operating parameters for the 6DQ5 are: 700 VDC on the plate, 150 VRDC on the screen, 20 ma static plate current, load to 150 ma. This gives an input of about 150 watts PEP and a measured output of 60 watts into a 50 ohm antenna.

Both units are being operated on AM and SSB. The smaller unit is also being operated on RTTY and is used both bare foot and to drive a Heathkit SB-200 amplifier. These units both put out a beautiful clean, clear, and faithful reproduction of the exciter signal. The larger unit is dual purpose for those who do not already have a KW final. The smaller unit can be used where the station does not require high power. Either unit will make any amateur band transmitter truly all band. So pick a rock, sling an antenna, and we'll see you around the bands.

. . . WA4KIH, W4OPL

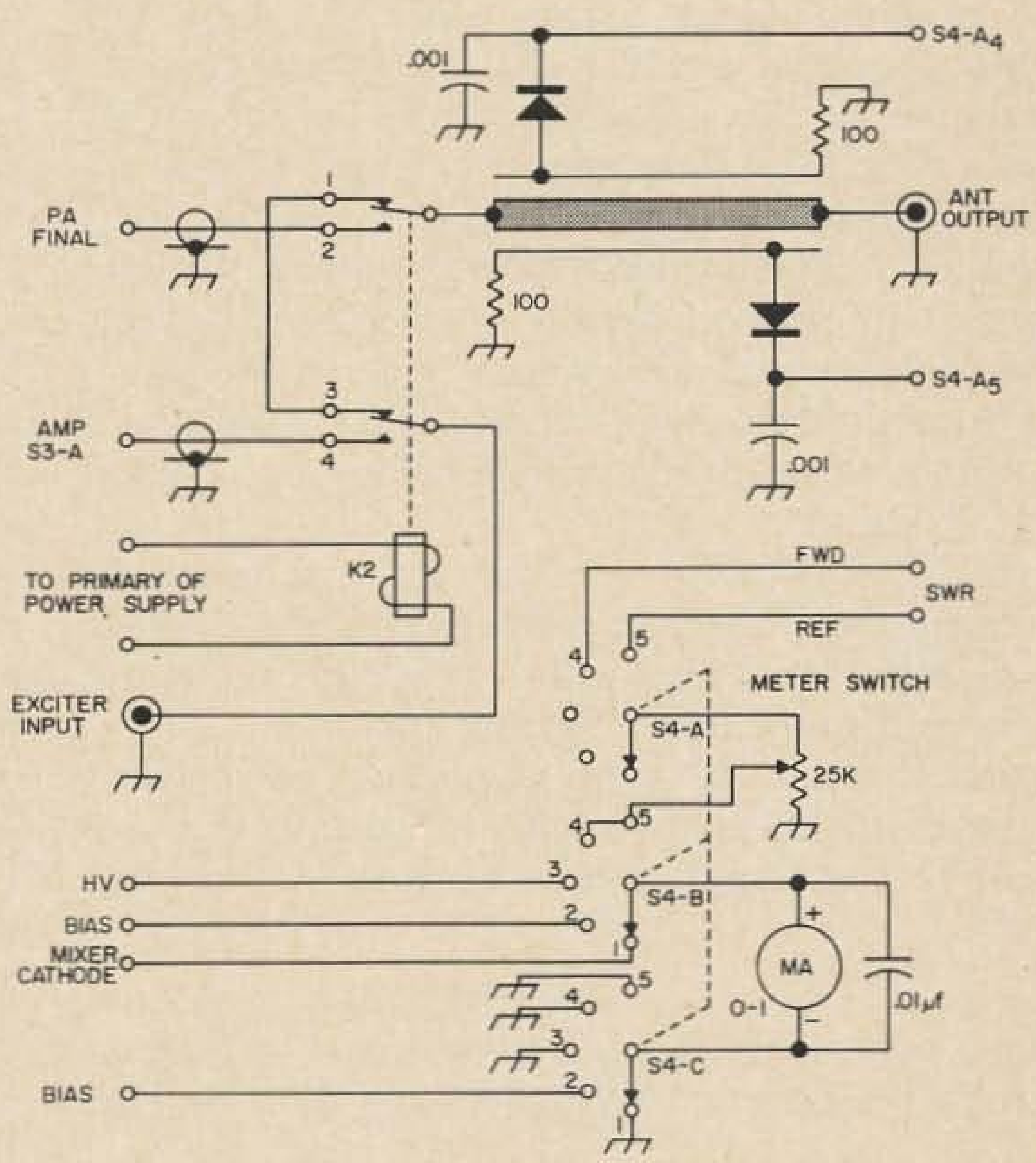


Fig. 5. SWR bridge and control circuits.

Build this shortened beam easily and inexpensively and get excellent results.

Terry Shankland WA8MVR
270 Fleming Rd.
Cincinnati, Ohio 45215

Simple Two Element Weeping Willow for Fifteen

What is a Weeping Willow? Just a yagi with bent elements, making it half as wide as it would normally be. Will it work? Well, the first time I put it on the air I got a new country, Ireland, 5X9 on 15 meters. Another Irish ham called me when I finished with the first, a situation to which I am not accustomed (he gave me 5X9, too). This was early in the morning, when the East dominates 15. Listening to a WB6, I found that his signal dropped about 3 S units off the side and nearly 4 units off the back. Satisfied? Read on.

I have a lousy location. In any direction, the antenna faces houses and fifty-foot tall trees. There is a hill peak about sixty yards to the west. My 40 meter dipole at forty feet did a fair job. However, I wished for something more. My two hundred watts PEP couldn't hold its own. The Weeping Willow, even at its present height of only twenty feet, gives me several advantages, among them:

1. Rotatability: Ever wished that you could rotate your dipole to get a lobe on a good DX station?
2. Unidirectionality: It sure is wonderful to cut down those Sixes when I want to hear Europe. And that gain! Less QRM coming in and more oomph going out.
3. Small size: If your mounting area is as small as mine, you will appreciate the size of this antenna. I have a hole in the trees that is barely big enough for a 6 meter beam, much less a 15 meter beam. This antenna has the width of a quad with one-half the height. The turning radius is only seven feet.
4. Low cost! Even if you must buy all the materials involved, the cost should be about fifteen dollars. This isn't bad for what you get.

Terry is a senior in high school and he'll enter Brown University in the Fall. He likes to DX.

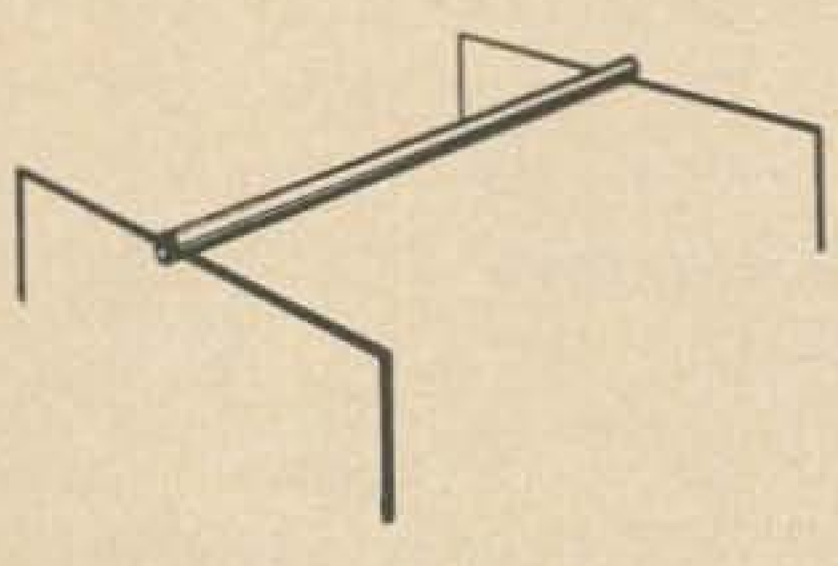


Fig. 1. Configuration of the elements of the weeping willow.

The Weeping Willow is formed as in **Fig. 1.** This antenna was mentioned in an article about a quad[1]. The elements are the same length as those of a yagi. However, one-fourth of the element's length on each end is bent downward 90°. Thus, my 15 meter version is approximately eleven feet across instead of twenty-two, and five and one half feet tall. Of course, this bending makes a 15 meter version a one band antenna. For those so inclined, a 20 and 10 meter antenna could be built with traps at the bends, a two band antenna the size of a 10 meter beam (how about a 40 and 20 version; it's only thirty-three feet across). Mine is two element because of the size and cost, but you might like three or more. I used .15 wavelength spacing between elements as recommended by the ARRL *Antenna Book.* The antenna in the picture cost me about $2.15 because I had almost all of the necessary materials on hand. There is only one big requirement to be met with my version: the elements must be above ground on the metal boom. This is not due to the antenna design, but to the matching section described later. A gamma or "T" match would not have this restriction. For anyone who does not have the materials I used, the possibility of a wooden boom might be investigated. A list of the dimensions for those who do not have a handbook:

$$\text{driven element (in feet)} = \frac{468}{\text{freq. in MHz}}$$

reflector (at .15 wavelength spacing)—

[1]David Morgan, K6DDO, "Three Elements on Three Bands," *73*, July, 1963, P. 62.

: 15 meter weeping willow over WA8MVR's ise.

$$\frac{501}{\text{freq. in MHz}} \text{ (length in feet)}$$

There shouldn't be much of a problem in ilding this antenna. All that is necessary is lay out the tubing, cut to length, bend in : proper places, fit together, mount, and run the mast. My antenna went together with major mishaps (very unusual) and only e mistake (the driven element is bent ghtly too far in). I hasten to add that this s the first antenna that I have ever built h the exception of my dipole. Anyone word about duplicating my feat, forget it; if I ı do it, you can too.

Now for that match. It is quite simple, costs le, radiates well, and needs only one adjustnt. I took this straight out of an old 73[2]. r those of you without that issue, here are : instructions (maybe **Fig. 2** will help):

Cut a length of RG8/U to the formula

$$\frac{234}{\text{freq. in MHz}} = \text{length in feet}$$

Determine exact center and cut off the outside cover for about an inch in each direction. Do *not* slice the coax in half. Now, cut the braid at the exact center (the braid only, please) and gather each side of the braid into a clump. To this you can solder the feedline (RG8/U) or an SO-239 female coax connector. I just soldered the feedline; you may not want so permanent an installation.

Now trim the insulation on the ends of the line. Solder the braid to the center conductor at each end.

Tape all exposed joints well so that they will not be affected by weather. You now have a ½ wavelength folded dipole.

Bill Driml, W6NAT, "Infinite Impedance Antenna ıtch," 73, March, 1963, PP. 20-21.

This match has several advantages, but also requires a few things of the builder. First, it would be best if you mounted this match inside the tubing of the driven element. W6NAT says that you can mount it on the outside of the tubing if it is larger than the i.d. of the tubing, but it is best to put the match inside. Second, the driven element must be cut into two halves. Just slice it in the middle and mount as two pieces a few inches apart (this also helps if you want to mount the match inside the tubing). The ends of the match will just about reach the bends in the elements. This requirement should not bother a person homebrewing the beam, anyway. Third, the elements must be mounted above ground or the metal boom as already mentioned. Last, a 100 pf variable capacitor must be mounted in series with the center conductor to tune out the reactance. I use a Matchbox and this does the job for me. The capacitor can be mounted at the antenna or the transmitter. Please consult the article by W6NAT if you become thoroughly confused.

By now, all the OT's with six element beams and eighty-foot towers must be howling at my misadventures. I wrote this article not for them, but for people like me. I had never built an antenna such as this one. Money does not flow in plentitude from my pockets (I did have a summer job which paid for an SSB transmitter, though). There is only one small hole in which I can mount an antenna. To tell the truth, I was afraid that my efforts would end with the world's biggest lemon (I'm only seventeen and not yet full of the confidence of years). However, the Weeping Willow went together easily, which was a miracle, and works fine. I must add that I have not tuned it at all. I just built it and put it up. Who knows what could happen if someone would really try to match it to perfection. I don't know the exact gain or front-to-back ratio, but the antenna fulfills all of my hopes. Right now it is only twenty feet above the ground, but it easily outperforms my forty-foot high dipole. I can't wait to get it up to forty feet.

. . . WA8MVR

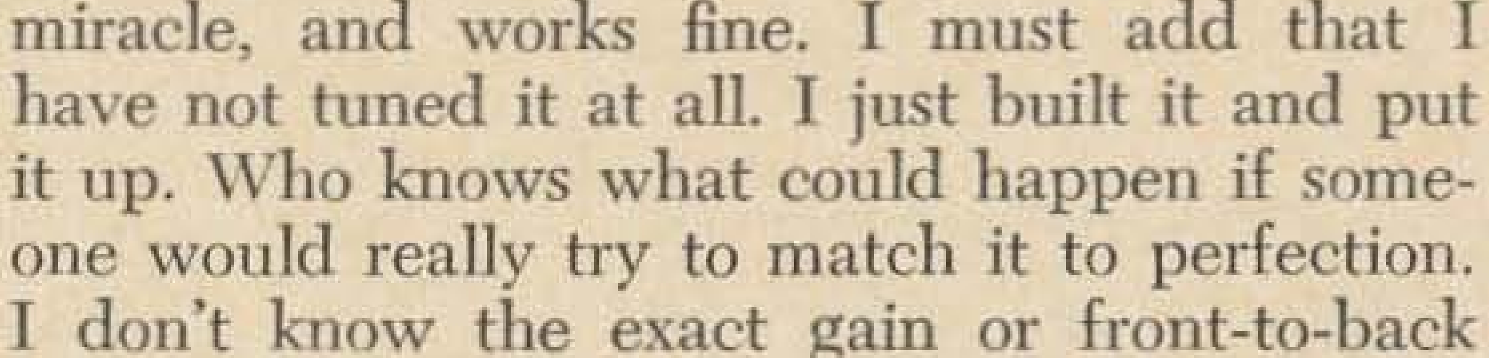


Fig. 2. W6NAT's infinite impedance match as used in the weeping willow.

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Precision Frequency Measurements for the Amateur

A general discussion of accurate frequency for hams with practical notes on reception of very low frequency transmissions.

The expanding uses of radio have forced tighter accuracy and stability tolerance on every radio service, including the amateur. Rigid frequency tolerance specifications have necessarily produced new components, systems and measurement techniques. It is now possible to measure frequency to a higher degree of accuracy than any other physical quantity.

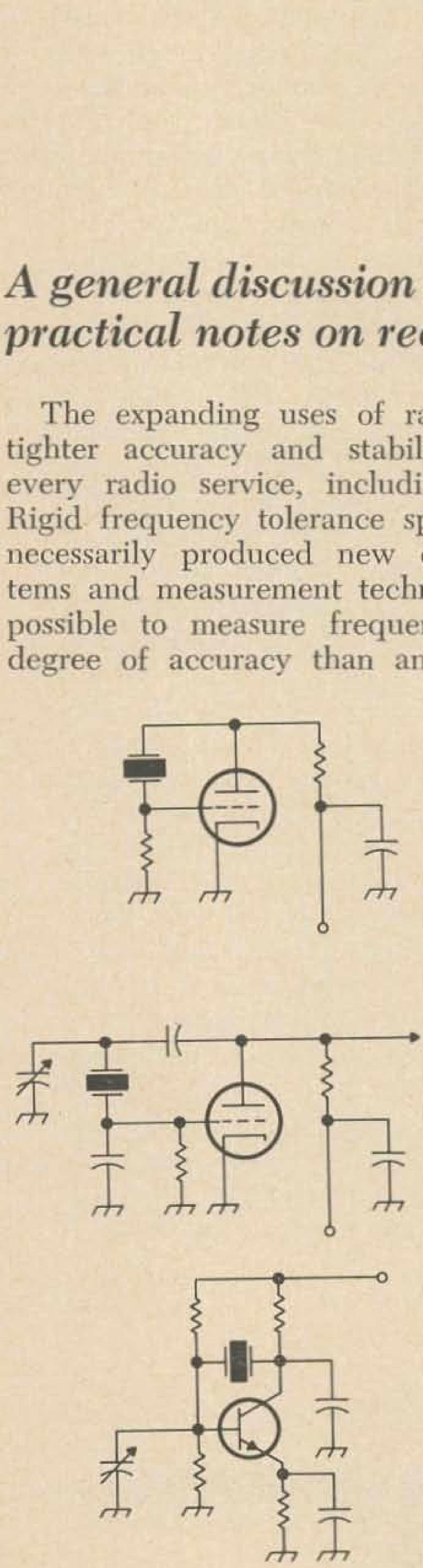


Fig. 1. Basic Pierce crystal oscillators. Values of resistors and capacitors will naturally depend on the individual tube or transistors used.

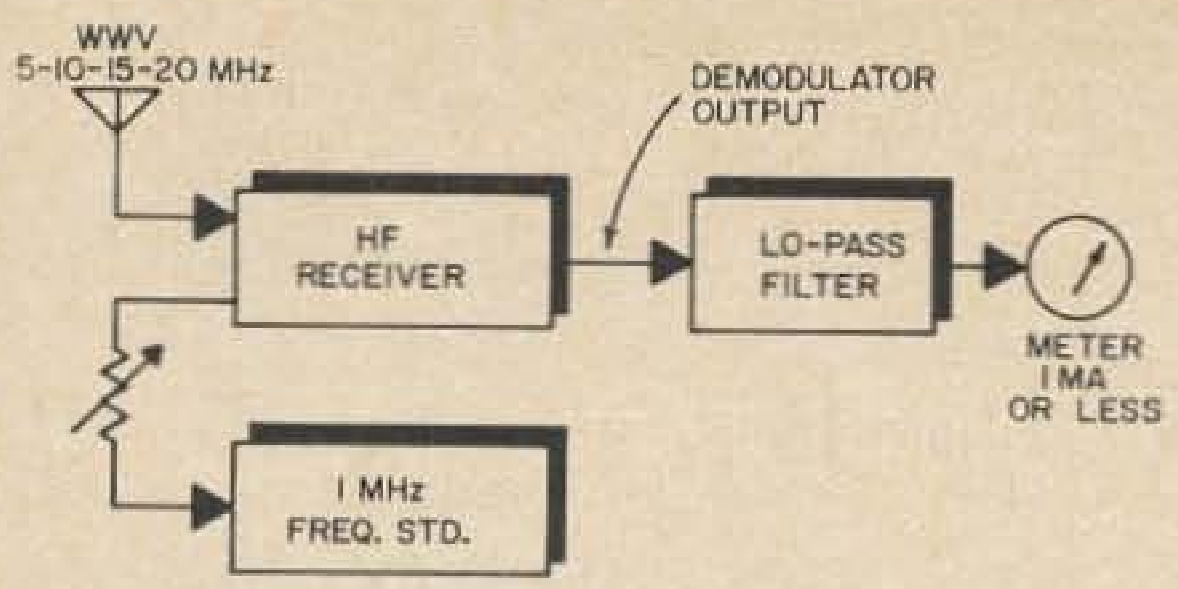
A logical question is: Does amateur radio need precise frequency measurements? This leads to: Just what does *precise* mean, as used here? Faced with questions like these, the measurements man on the receiving end of them invariably asks: What are the requirements?

Amateurs have often led in the development of communications techniques and have adapted complex systems to their needs. FCC regulations require that each amateur station maintain a means of measuring the transmiter frequency, independent of the transmitter frequency control. Depending upon the requirements this might be a temperature controlled quartz crystal, a calibrated receiver or even an absorption wavemeter. What are you using?

Accurate frequency measurements might be justified simply to protect the licensee against possible FCC citations. On the positive side they are useful for setting up nets and making them easy to operate, for schedules to put transmitters and receivers right on the spot for immediate CW, sideband, or teletype contact, or for making quick, accurate frequency changes to a hole in crowded bands. For the technical experimenter and builder they are especially useful.

A sideband carrier frequency may be operated within ten hertz of the band edge if it will stay there, and the reduced carrier ade-

Note: Hertz is now the "approved" term for cycles per second. Thus, Hz is equivalent to cps, kHz to kc, and MHz to mc.



g. 2. Frequency comparison using high frequency ansmissions from WWV.

uately suppressed. Unless the real stability of ɿe generated carrier is known with confi- ence such operation would be unwise. Ques- onable performance of a costly sideband ystem may result from frequency shifts that ıust be measured in hertz. Most owners of ıch equipment having such trouble would robably return it to the factory with instruc- ons to "make it work or send my money ack", or perhaps "no more payements".

The plus or minus 20 hertz stability re- uirement for good sideband performance and erfect duplexing is only one part in 100,000 tolerance 1 x 10^{-5}) at 2 MHz. In the 10 ıeter band it is 2/3 part in 10^6 or 6.7 parts ı 10^7. This accuracy can be accomplished by sing as a reference equipment made with urplus parts in modern circuits. It is so imple and easy to have a frequency standard nd accessories of this capability these days hat there is no reason to be without such seful gear.

Unfortunately, we can not buy apparatus vhich a manufacturer can guarantee unre- ervedly as producing a refrence frequency of his order, whether we buy it in one piece or ut it together. A reliable source of correct requency is needed to put the gear "on the ose" and keep it there. To maintain the toler- nces mentioned hams may use their old riend WWV.

Like everything else, WWV services have een improved, but radio propagation char- cteristics have not. Calibration instructions vhich usually read something like "adjust the eceiver for clear reception of WWV" suggest he recipe for rabbit stew which begins, "first atch your rabbit". In spite of the fact that he emmissions leave the transmitter accurate o a part in 10^{10}, and are maintained very tably, the average comparison against WWV s reliable only to a part or two in 10^7. By tudying the problem, choosing the best re- eived frequency and the best time of day, ccuracy of the order of a few parts in 10^8 nay be established–if the crystal oscillator lso has this order of stability. The ordinary everyday sort of beat comparison with WWV is suitable for most amateur crystal standards used for reference.

With a stable oscillator being compared at any of the WWV frequencies, except perhaps 20 or 25 MHz, an aural beat is not close enough. Under most conditions a zero beat is not reliable. Most ears are quite unselective below about 60 Hz; besides it is sometimes hard to decide between a slow beat and a fade. The simplest substitute is a sensitive milliammeter connected to the demodulator output through a filter with a cut-off fre- quency somewhere below about 10 Hz. Usually a resistor of about 47k ohms and a capacitor of about 0.5 μF will do the job.

Military communications, navigation sys- tems, timing systems for rocketry and space vehicles have need for better reference sources. Such activities often require controls that must be maintained within a part in a billion (1 p/10^9) or better. WWV high fre- quency broadcasts are useless for calibrating such precise systems because of the influence of propagation conditions. Means that have been developed for providing suitable refer- ences also provide the amateur with highly reliable, easy to use, standard frequency trans- missions.

A bit of history and a discussion of recent developments form a necessary prelude to the information to follow. So to proceed as briefly as possible. There was a time when all but a small portion of wireless communications was done with wave lengths of 30,000 to 10,000 meters. We now say 10 kHz to 30 kHz and call this band *very low frequency (VLF)*. The *low frequency (LF)* band is 30 to 300 kHz. The Navy has long used VLF and maintains several transmitters in the band below 30 kHz. They are able to communicate world wide when magnetic or ionospheric storms disable the higher frequencies. Because of the nature of those emissions modern equipment in sub- marines can receive them while submerged. Systems have been developed for stabilizing

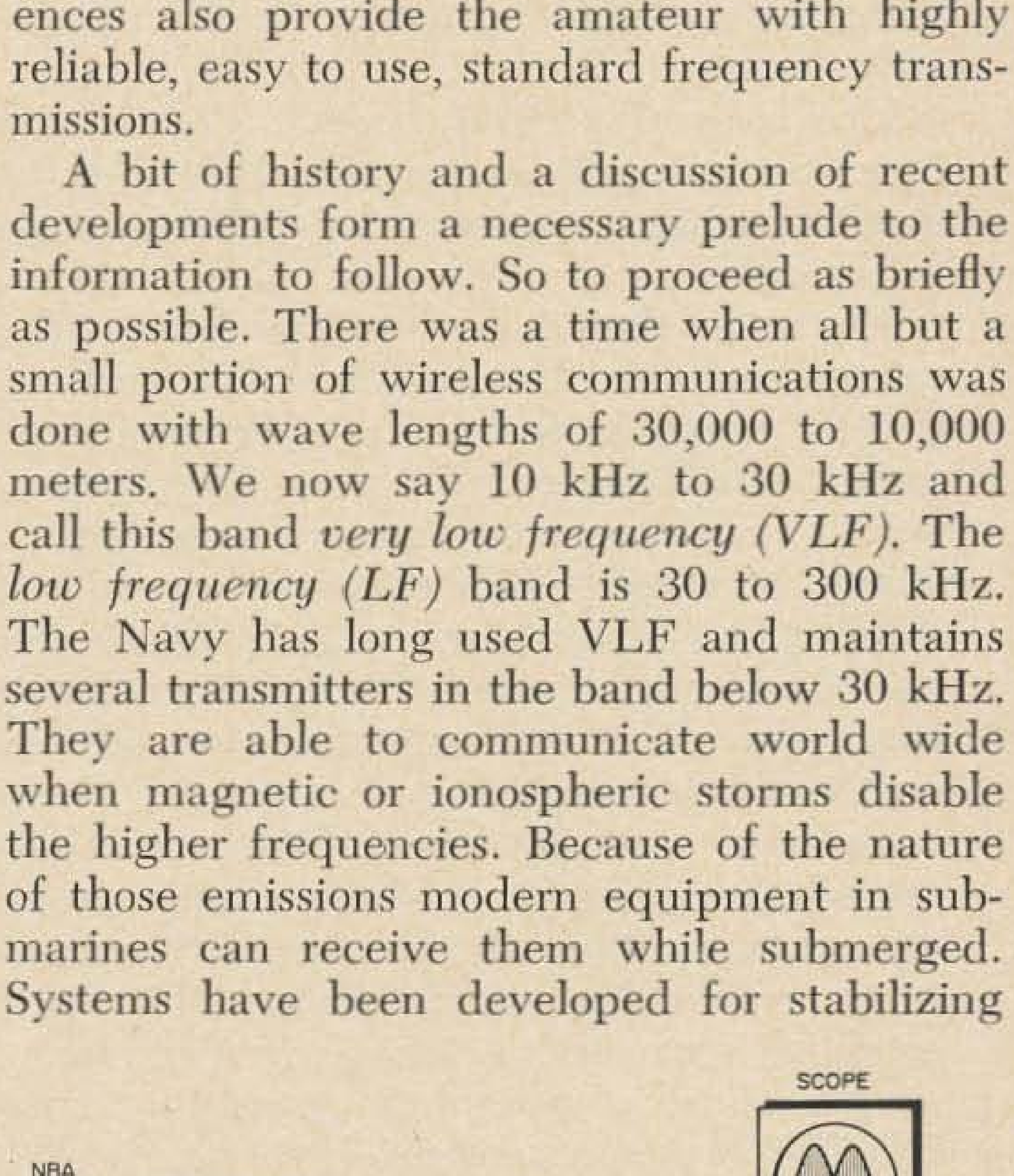


Fig. 3. Frequency comparison using very low fre- quency transmissions. See Figs. 4 and 5 for the notch filters and VLF receiver.

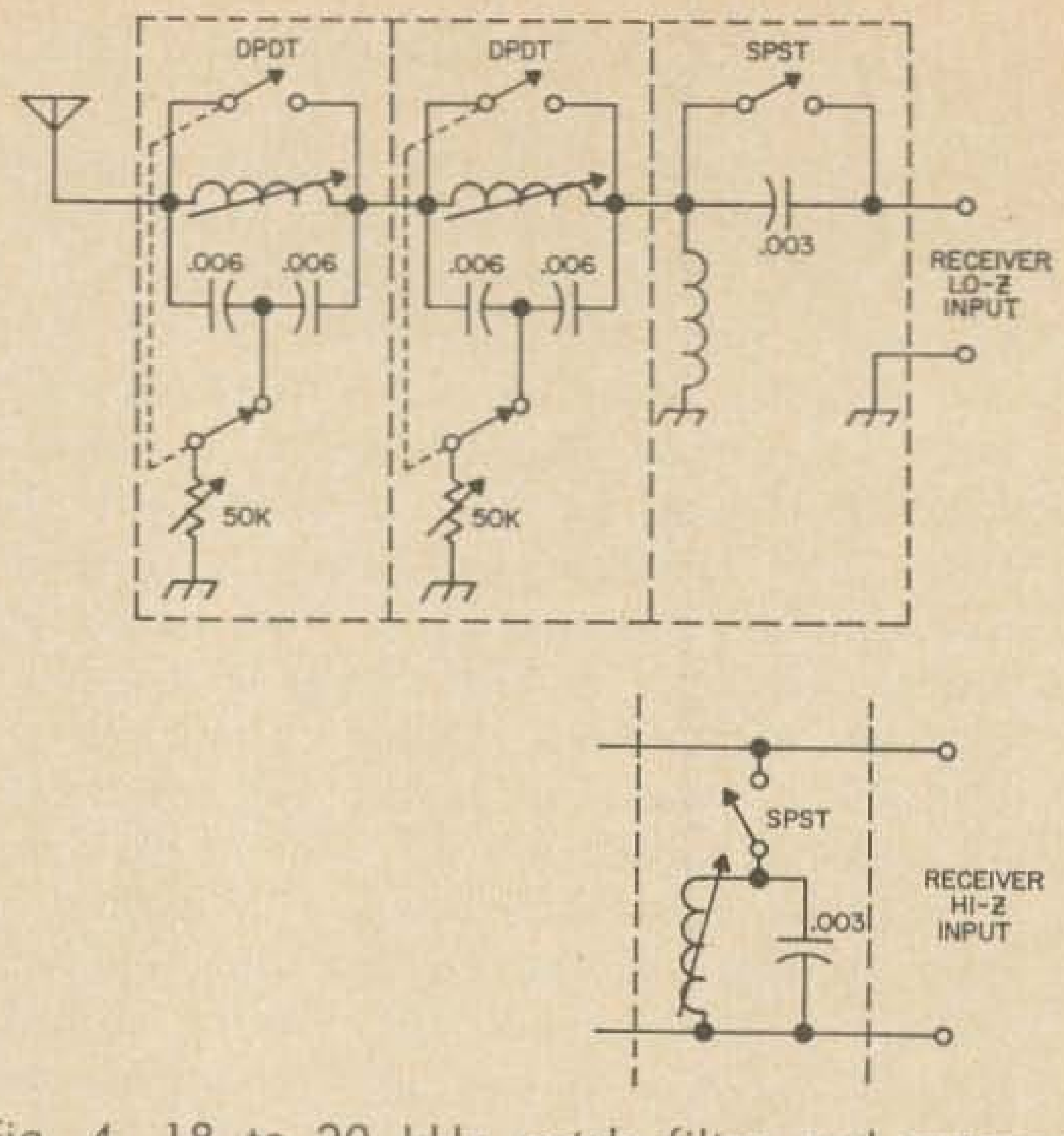


Fig. 4. 18 to 20 kHz notch filter and antenna tuner for high and low impedance receiver inputs. The coils are Miller 6315.

the frequencies of these stations so that they vary no more than 1 p/10^{10} per day about a nominal frequency known to a few parts in 10^{11}.

The basis of accurate frequency is a stable time reference. Frequency and unit of time are inseparable. One may be defined in terms of the other.

For more than a century the Naval Observatory has been the custodian of time for the United States. With the Naval Research Laboratory, the National Physical Laboratory of Britain, and private investigators like J.A. Pierce of Crufts Laboratory, Harvard, they conducted long distance tests by VLF over a period of several years. The results led to the establishment of the Ephemeris second, based on the earth's orbital motion, as the time interval for scientific work. They also determined the resonant frequency of a nuclear energy transistion of the element cesium in terms of the Ephemeris second. This led to establishment of an international system of atomic time in which the period of 9,192,631,770 cycles of cesium resonant oscillation is one second. No longer is the turning of the earth on its axis a suitable time reference. By comparison with the other references the earth wobbles along like a sprung buggy wheel rolling on a rutty road.

Station NBA in Panama and other Navy stations are continuously monitored by the Naval Observatory and the Naval Research Laboratory to maintain them accurately on frequency. Naval stations ashore and afloat have receiving systems which use these stations to maintain their frequency standards accu continuously to the least 1 p/10^9.

At mid-1965 the Navy stations using V all with power output from 100 kilowatts 1 megawatt. are as follows:

NAA Cutler, Maine 17.8 kHz*
NBA Summit, Panama 24.0 kHz
NPG Jim Creek, Wash 18.6 kHz
NPM Honolulu, Hawaii 26.1 kHz
NSS Annapolis, Md 21.4 kHz
*alternates hourly with FSK (or ot phase shifted emissions) and Morse t graph.

Now—the relationship to the amateur o ator. By the method described for HF rec tion, a quite ordinary VLF receiver is means to very accurate frequency comparis with these stations, almost any time, day night. The only restrictions on the amate accuracy of comparison are the stability his standard oscillator, and how long he willing to watch a meter or oscilloscope time a beat or note a change.

The oscillator will have to be used wit set of multivibrators or other frequency d ders to produce output at one hertz har nics which are used to beat with the V stations. Should one of them use 18 k (once used by NBA), a cycle on this f quency occurs in 55.5 microseconds. A mill cycles occur in 55.5 seconds. So, if the b meter pointer moves across the scale (or scope pattern moves), a half cycle in 56 s onds—and maintains this rate—the oscilla under comparison is accurate and stable to part in 10^6. A full beat in 9 minutes, seconds, or a half beat in 4 minutes, 38 s onds, represents 1 part in 10^7.

More versatile, though a bit more comp systems for amateur use are developed fr methods suggested by Hastings and Stone June 1961 NRL Report. These have be used to meet the needs of ship-yards, pend production of a military model of a V phase tracking system. They have proved be adequate as an interim method for c brating the most precise Navy Freque Standards.

Virgil Neher W6KT, has had a long ti interest in frequency measurement. A f

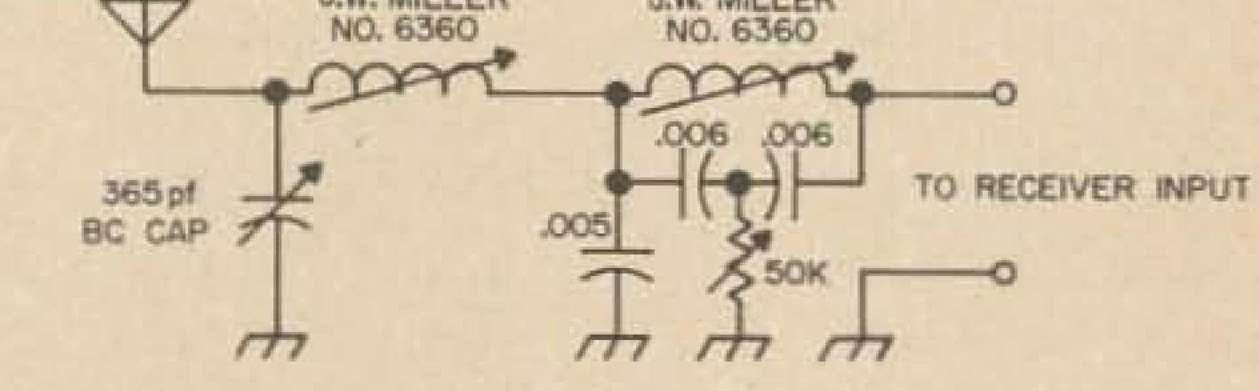


Fig. 5. Antenna tuner and notch filter for 14.5 25 kHz.

Home Station Performance

with a mobile rig?

LOOK INTO THE SWAN 350

The performance of the Swan 350 in your car may not quite equal your home station, but you will be amazed at how often the difference is very small. Many Swan mobile operators have established enviable DX records. QSL cards on file here at the factory verify solid contacts from all continents including stations in Antarctica.

Old timers who have fought QRM with old style AM equipment have discovered a new world of mobile communication thanks to the power and punch of the Swan 350 and 400 transceivers. The efficiency of the SSB mode coupled with the convenience of transceive operation and a powel level unmatched in the field, represent a combination well worth looking into. So, if you haven't heard a ZL, DU or JA say, "stand by, the mobile station," then, why not put a Swan in your car this summer!

SWAN SPEAKS YOUR LANGUAGE
ASK THE HAM WHO OWNS ONE

The 350 installs conveniently under the dash of most cars, and the power supply goes under the hood. The best location for a mobile rig is naturally up front under the dash, but if you have a car with a center console and a consequent space problem, you will be happy to learn that either the 350 or 400 can be installed in the trunk. The 406B external VFO was designed to permit trunk mounting of either transceiver, and thanks to its miniature size, the 406B can be mounted conveniently in any car, either under the dash or on top at eye level. Add an efficient 5 band mobile antenna such as the model 55 or 45 Swantenna, and you can enjoy mobile operation to the fullest. Home station performance? Well not quite, but nothing comes closer than a Swan Transceiver.

73, Dave Howard, WA6OQY

PRICE LIST

Model 350 Complete transceiver........	$420.00
Model 400 Deluxe transceiver, less VFO..	$420.00
Model 406B Mobile VFO...............	$ 75.00
12 volt Mobile Supply Model 14-117.....	$130.00
RC-2 Remote Control Kit...............	$ 25.00
Model 45 Swantenna..................	$ 65.00
Model 55 Remote Switching Antenna....	$ 95.00

For further information on Swan transceivers and accessories, see your Swan dealer—

SWAN

ELECTRONICS Oceanside, California

years ago, W6OC and W6KT had a session on the various methods of measurement, for the amateur. W6KT produced a progressive series of receiving devices for calibrating a precision oscillator, which was a product of the relationship. The stability performance of his oscillator approaches closely some of the better commercially available products. It seems that it may be very easily classed as a 1 p/^{10} per day unit, and since mid-1965 the ageing rate has decreased until it is not observable with the methods in use. A clock driven by such an oscillator would keep time within a second in three years or more.

Such a fine oscillator is not necessary for amateur requirements. A reasonably good quartz crystal in a good circuit, well constructed, will fill amateur radio needs. Most quality oscillators available today use what is known as a "Warner" crystal, in some variation of the well known "Pierce" circuit. The conformation of most of these has led to their being called "Crystal Colpitts". An article on this development with respect to self excited circuits is listed last in the bibliography.

The basic "Pierce" circuit and the simplest form of current tube and transistor modifications are shown in **Fig. 1.** Crystals operate series resonant in these circuits. Among common mass produced crystals for transmitter or receiving conrol, those operating very close to a specified frequency at parallel resonance, have been known to operate as much as 0.1% higher in a "Pierce" circuit. In general, shunt trimmers have very little effect on the frequency of oscillation, so may be used for very fine adjustment.

Surplus 1 MHz crystals of excellent quality for amateur purposes have been available for as little as 2 for $2.35. Several sources advertise such crystals for about $2 or $3. Some 100 kHz crystals have been available at slightly higher prices. A good check of the ads in the magazines will bring some worthwhile results when looking for bargain crystals.

To the good crystal oscillator just discussed, add some sort of divider string to come out with 1 kHz and if you want to go first class, 100 Hz. Also latch on to an oscilloscope which has provision for locking, driving, or triggering the sweep externally. The handbooks describe the latest versions of the old standby frequency divider, the multivibrator. Many amateurs today meet flip-flops, and phanyastron circuits in their daily work. These can hardly be kept from working if wired correctly. Just put them together and drive with the standard oscillator.

For NBA on 18 kHz Virgil W6KT, coupled the 17.5 kHz harmonic of a 2500 hertz output to the antenna of the receiver. The receiver has no audio detector (though one can be useful). The yield from the last rf (or *if*) stage is applied to the vertical plates of the oscilloscope. Adjustment of the injected signal level is made to effect 100% modulation of the incoming 18 kHz signal. A carrier with 500 Hz envelope is developed. The 500 Hz harmonic of one of the lower frequency dividers is applied to the horizontal drive or directly to the horizontal input of the scope. Adjustments are made to display one cycle of the envelope on the CRT.

If the oscillator is sufficiently stable and on frequency the pattern will appear stopped. Actually it will move across the screen at a rate which is a measure of the difference between the standard and the reference VLF station. Virgil sets the zero of the modulation envelope (or cross-over point of the pattern if you like) at a vertical line on the face of the scope. He then checks the time in minutes or seconds for movement of the pattern some definite fraction of a cycle. For NBA (when on 18 kHz), movement of 1/10 cycle in 30 minutes indicates a deviation of about 3 parts in 10^9. The same movement of the pattern in about 36 seconds shows a deviation of $1.5/10^7$, about as good as the normal HF comparison against WWV.

The VLF and LF services of the National Bureau of Standards are extremely accurate but are not so easily received by amateur methods because of the relatively low radiated power. On 20 kHz the output of WWVL

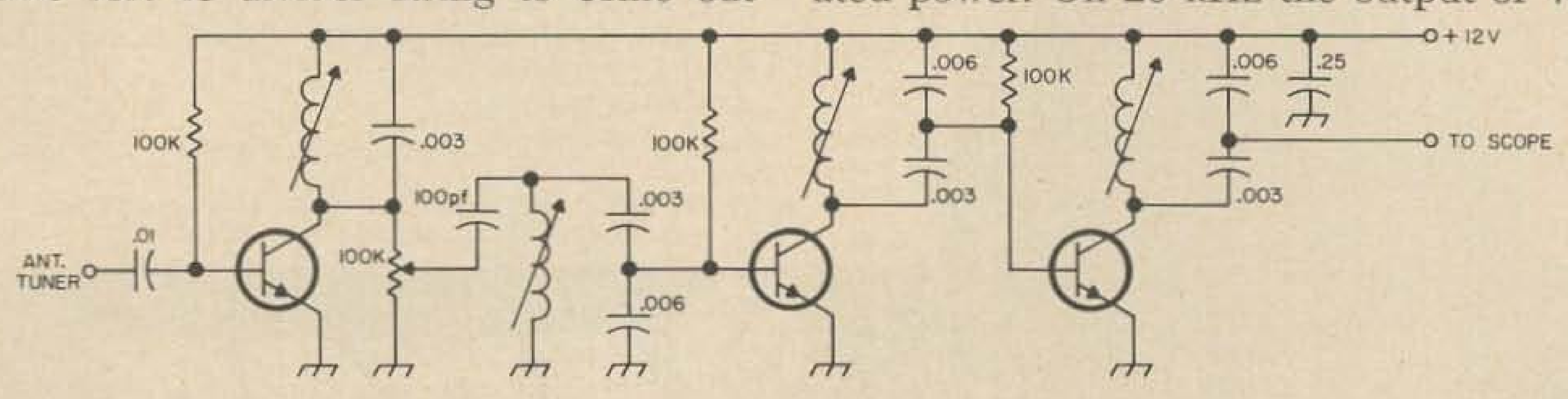


Fig. 6. Tuned amplifier for 18 or 20 kHz. The coils, which should be shielded, are Miller 6210 or Miller 6315. Transistors are 2N1149, etc. The 100 k resistors should be adjusted for about 1 ma collector current in each transistor.

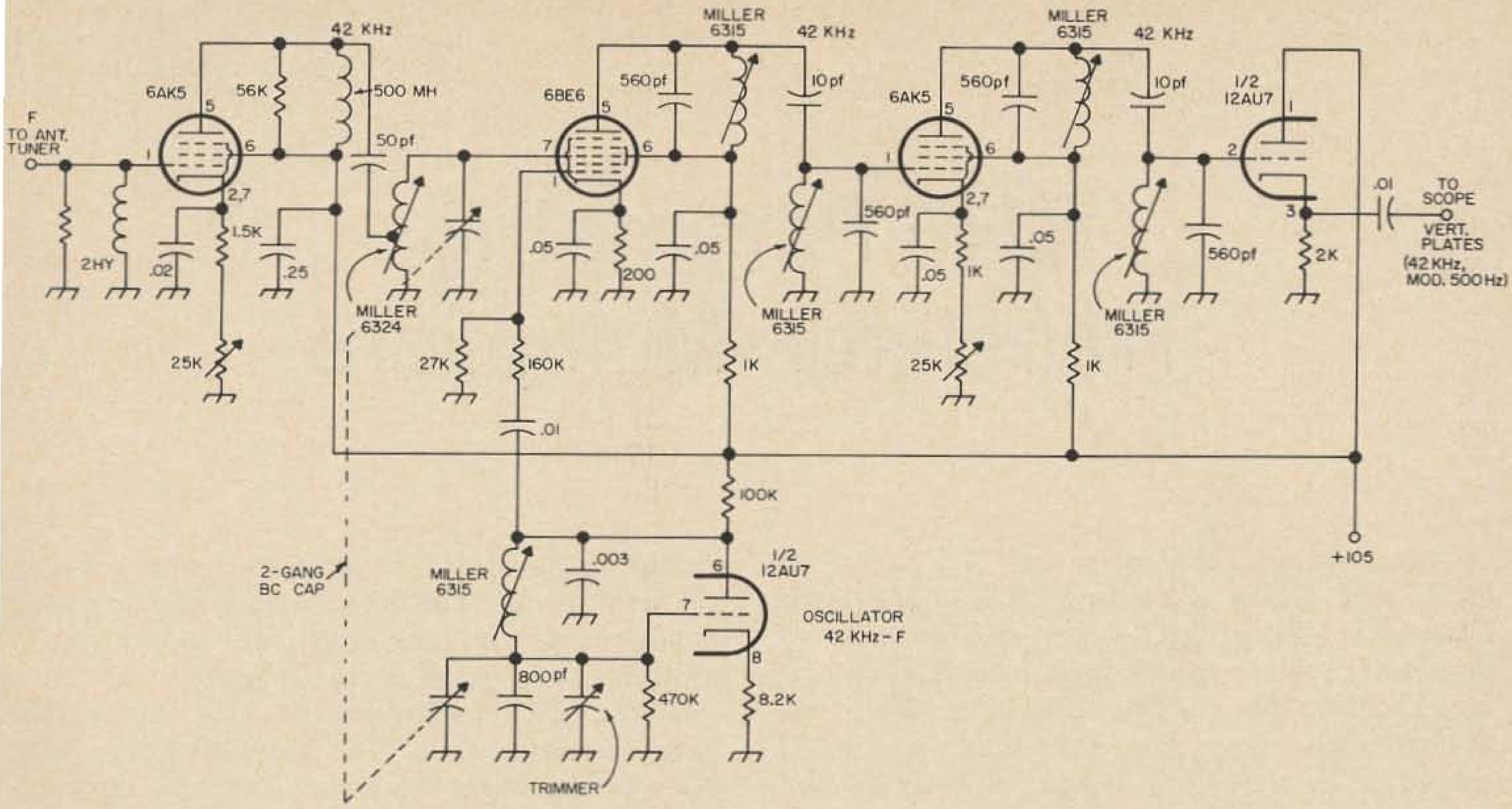


Fig. 7. VLF superhet receiver for 14.5 to 25 kHz. IF frequency is 42 kHz.

is about 1 kW; on 60 kHz WWVB radiates about 6 kW. Antennas and transmitting equipment are installed near Ft. Morgan, Colorado. Because of experimental and research work being conducted using special emissions using pulse, or phase or frequency shifted signals, it is not always possible to effect accurate frequency comparisons by simple methods. Subscription to the NBS bulletins relating to their standard frequency broadcasts may provide information in detail about the special emissions.

When the signal under control of the standard oscillator is injected into the antenna, the entire receiver must have band-width at least as great as the numerical value of the difference frequency. For NPG, 18.6 kHz, the injection may be 19 kHz and the pattern and scope deflection signals will be 400 Hz. For NPM, 26.1 kHz, 26 kHz injection makes the difference 100 Hz. Likewise, 18 kHz mixing with NAA, 17.8 kHz yields 200 Hz. VLF signals of even 1 kHz multiples like 18 or 24 kHz may be compared directly by applying the receiver rf output to the scope vertical plates and the divided standard frequency of the same value to the horizontal plates. Movement of the Lissajous pattern with time gives the deviation.

Since allocations in the VLF range are assigned at even 100 Hz intervals, interference can be a problem if the receiver is not sharp enough or filters of some sort are used. An antenna tuner sharpens the response and will improve the signal about 15 dB. If interference persists, one or more "Notch Filters" will usually clear it adequately.

For the serious "researching" amateur, a bibliography of reference material on precision frequency equipment and VLF transmission is provided at the end of this article.

. . . W6BLZ

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VHF Parametric Transistor Multipliers

In the March 1965 issue of "73", authors Firth and Olson described "The Parametric Transistor Multiplier,"—the combination of parametric diode multiplication and class "C" amplification in a single transistor. Now, co-author Olson shows how the technique can be extended to the VHF range, in a somewhat different mode that is more practical at the higher frequencies.

During the last year there has been considerable interest in the use of transistors as parametric multipliers. In fact, at least one semiconductor manufacturer has advertised a silicon power transistor that is specifically designed for parametric multiplication. R.C.A. has recently released its 2N4012 which, operating with 1 watt of 324 MHz drive, will produce 1.4 watts of 1296 MHz output.[1]

In a previous article in 73, a type of parametric multiplier was presented that utilized the emitter–base junction, of a transistor in a grounded-base, class–"C" amplifier.[2] The circuit was as in **Fig. 1**, a 3.5 MHz to 14 MHz quadrupler. This circuit is presented again for reference and to correctly show the idler frequencies—which were incorrectly labeled in the original figure. As can be seen, the amplification takes place *after* multiplication (at 14 MHz), since the idlers are across the emitter-base junction.

The original method of parametric transistor multiplication has in its favor: an easy-to-follow development from a circuit composed of a separate varactor multiplier and class "C" amplifier, and good load isolation.

In the VHF multiplier, we will reverse the order, letting class "C" amplification take place at the input frequency, and do the multiplication thereafter. This means that, now, the idlers will be across the base-collector junction, which acts as a non-linear capacitance.

The advantage of this configuration is that transistors can be used to produce output power that exceeds their input power, even though operating above their f_T. The disadvantage is that the idlers and output circuitry become one big network, which makes understanding more difficult and does not give load isolation.

An elementary VHF parametric multiplier is presented in **Fig 2**, showing the idler-output circuitry on the base-collector side of the transistor. Since the input impedance to a grounded-base stage of this type is low, one can actually use such an untuned input circuit during initial tests.

In designing a parametric multiplier, we ought to restrict ourselves to driving frequencies of lower than 1/3 the frequency at which the transistor has unity power gain, f_T. Also, only multiplication factors ("n") of two, three, four, and possibly five should be tried. Multipliers with "n" greater than five require too

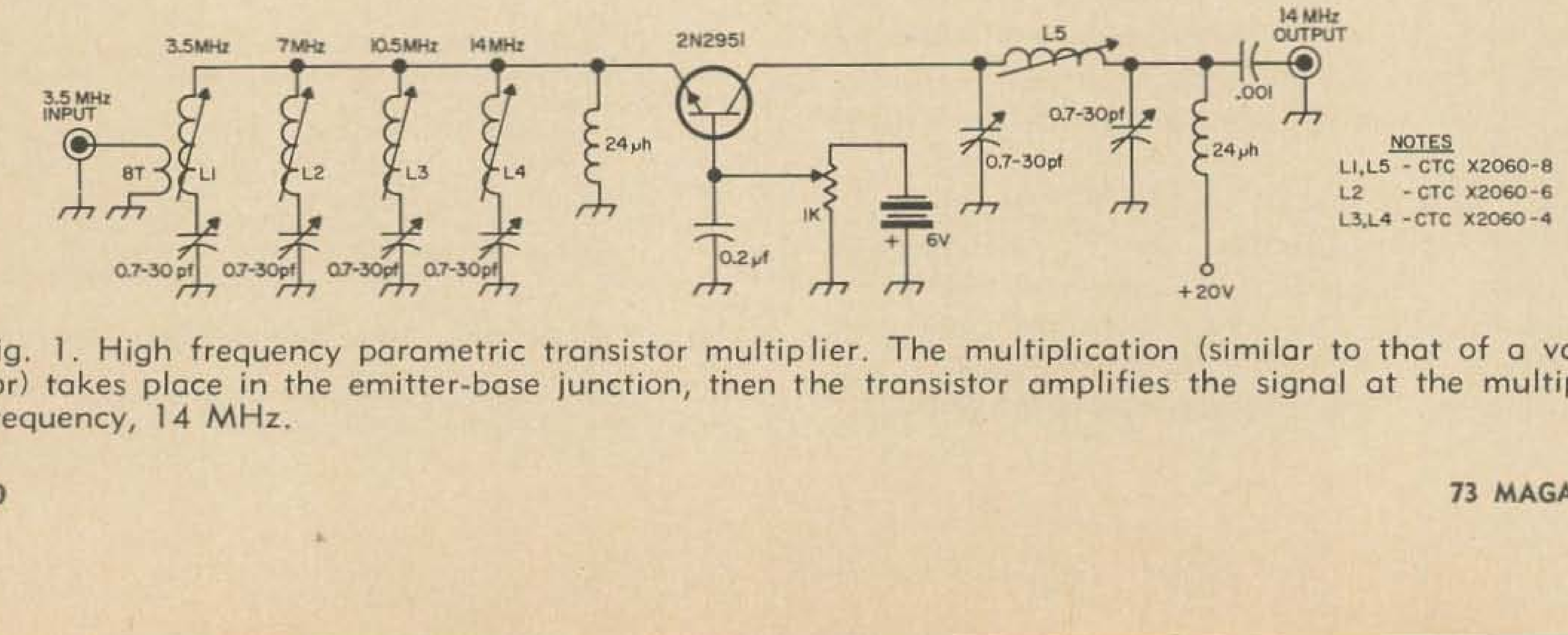


Fig. 1. High frequency parametric transistor multiplier. The multiplication (similar to that of a varactor) takes place in the emitter-base junction, then the transistor amplifies the signal at the multiplied frequency, 14 MHz.

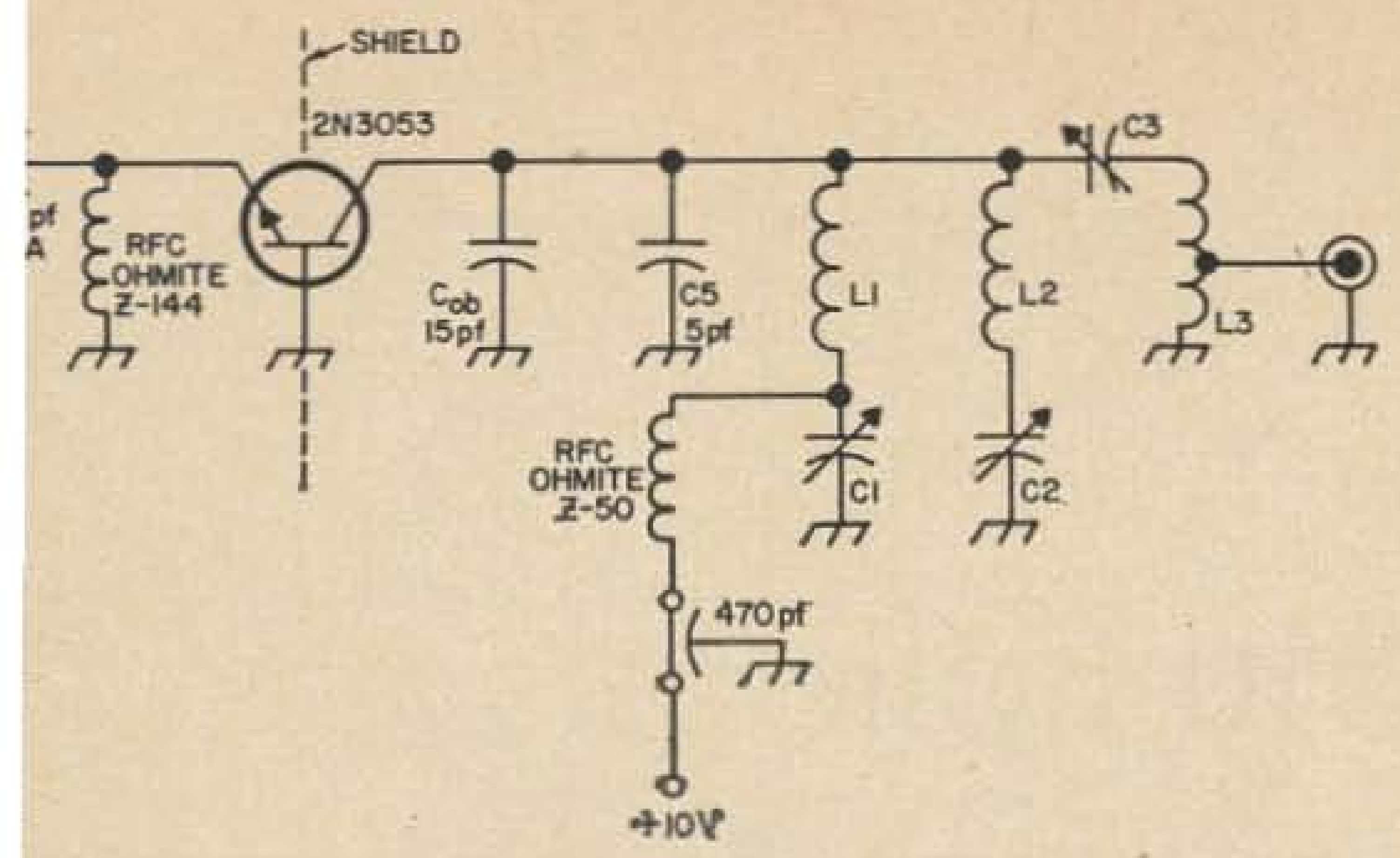


Fig. 2. 48 to 144 MHz parametric transistor multiplier. Note that this circuit is unlike the one in Fig. 1 in that the multiplication takes place in the base-collector junction. This is a preliminary circuit with untuned input. C5 is C_S, stray capacitance.

many idlers, and the calculation and implementation of such circuits gets out of hand. As an example, a transistor with an f_t of 120 MHz would best be driven with 36 MHz input and designed as a quadrupler, if 144 MHz output is desired.

Bear in mind that *the transistor must be operated at an input frequency where it has some power gain,* since all amplification goes on at the fundamental frequency. This fact is clearly shown in a recent R.C.A. application note (SMA-40), wherein a 2N4012 will typically put out less than 1 watt at 1296 MHz as tripler (with 1 watt of 432 MHz drive) but will put out 1.4 watts at 1296 MHz as a quadrupler (with 1 watt of 324 MHz drive)! This relation is shown in **Fig. 3.**

As a start, let's design (and gain experience with) a circuit which is inexpensive and forgiving, yet which will demonstrate all the little subtleties of VHF parametric multipliers. A transistor costing less than a dollar is used; it is *normally* used "in small signal applications up to 20 MHz." We will use a 2N3053 as a 48 MHz to 144 MHz tripler, and if there are any "semiconductor tragedies," at least we are not out much.

Looking at the 2N3053 spec. sheet, we find that it has a maximum gain-bandwidth product of 200 MHz, see **Fig. 4A.** The second fact that is apparent is that, unlike some of the "overlay" transistors, no curve of collector-base capacitance versus voltage is given. Since the collector-base capacitance (Cob) is a depletion-region capacitance, it should follow the same (exponential) curve as that for varactor diodes. We then can take the normalized capacitance-voltage curve from any varicap data sheet, plug in the one data point as given by our particular transistor spec. sheet for Cob; (15 pF at 10 volts for the 2N3053), and get the values of capacitance for any other voltage.

However, to simplify matters, suppose we make our first attempt at a collector of +10 volts, where Cob is known. This, also, gives an operation point that falls on the published Ec-Ic curves of the 2N3053, see **Fig. 4B.** If we decide on an average collector current of 30 mA, this puts our operating point approximately a third of the way between the 175 MHz and 200 MHz gain-bandwidth contours of figure 4a. This point is marked by an X, and gives us a gain-bandwidth product of approximately 180 MHz.

A 48 MHz to 144 MHz tripler easily fits within our criterion of 1/3 the f_T for a drive frequency. **Fig. 2** is such a tripler, simplified to make it easy to adjust initially. The effective output capacitance of the transistor is Cob plus Cs (a stray wiring capacitance of 5 pF), for a total of 20 pF.

L_1 and C_1, the 48 MHz idler, must be series resonant in combination with the 20 pf output capacitance. That is, **Fig. 5A** must resonate at 48 MHz. Similarly, **Fig. 5B** must resonate at 96 MHz, and **Fig. 5C** must resonate at 144 MHz. Or, at least, this is *nearly* true, since each idler's impedance at the other two frequencies modifies the design aim somewhat. Since we know that $Cob+C_s$ is 20 pF, L_1 must be at least 0.6 μH to resonate at 48 MHz. Let's take L_1 to be 1.2 μH and make C_1=20 pF (a 3 to 30 pF trimmer in the actual case). In a similar way we make L_2=0.3 μH and C_2=20 pF. Then with the output series-circuit we must use a bit more caution, making L_3 relatively large in order that C_3 be small, so as not couple too much of the funda-

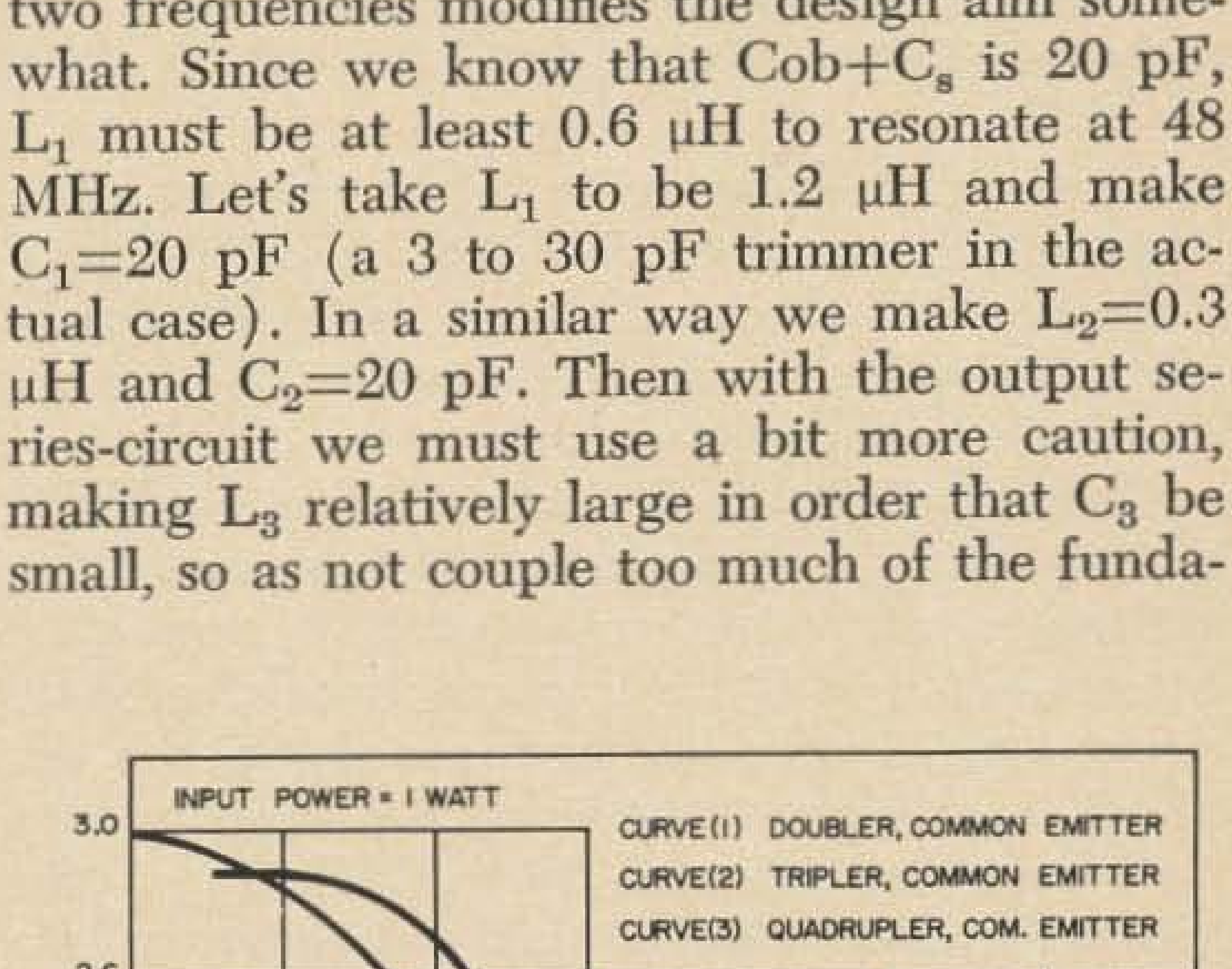


Fig. 3. Output of an RCA 2N4012 operated as a parametric transistor multiplier. Note that the 2N4012 will pu out more power at 1296 MHz as a quadrupler than as a tripler. The text explains this.

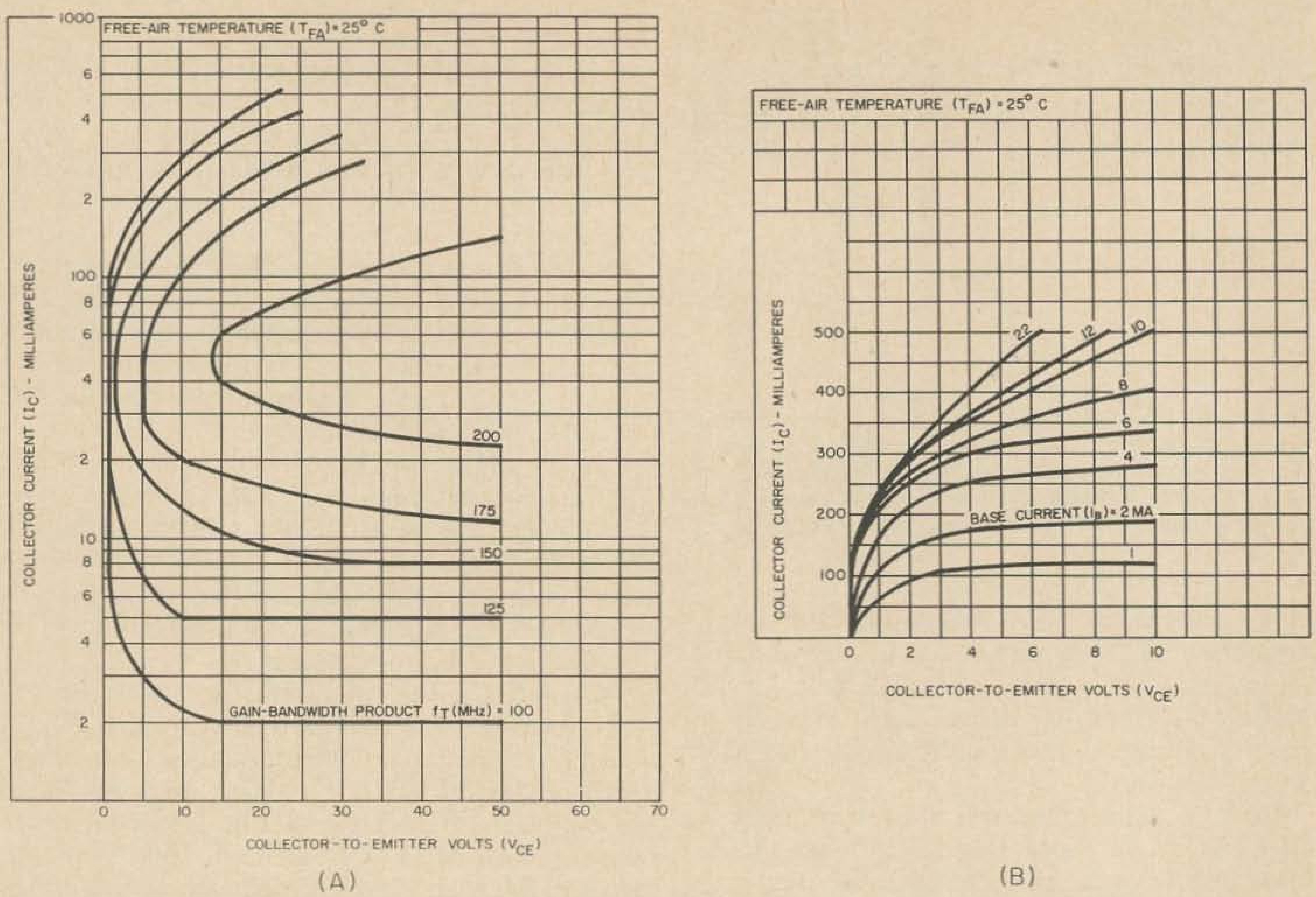


Fig. 4A. Gain-bandwidth curves for the RCA 2N3053 (a 96¢ transistor). Fig. 4B. Collector current (I_C) versus collector-emitter voltage (V_{CE}) for the 2N3053. Add an "X" at the junction of 10 on V_{CE} and 30 on I_C in A.

mental and 2nd harmonic to the output. L_3 is made 0.4 μH and C_3 is 3 pF, (a 3 to 12 pF trimmer). The output tap is deliberately placed very low on L_3, to cause small loading, during initial adjustment.

The 48 MHz, 50Ω output of a small (6 meter) exiter is coupled to the input of the multiplier, after the output of the multiplier is terminated in 50Ω. Increase the drive to no more than 10 volts rms and one should see the 2N3053 collector current climb from zero to our operating point of 30 mA. Using a grid dip meter as an absorbtion wave meter, couple it to L_3 and tune C_3 for the maximum 144 MHz output. Then tune C_2 for maximum 144 MHz output with the grid dip meter still coupled to L_3. And, similarly peak up C_1. The drive level will need readjusting (reducing) during this process. C_1, C_2, and C_3, should then be readjusted several more times for maximum 144 MHz output, until readjustment has a small effect.

At this point we will go back and put a matching transformer in the input, to optimize transfer of drive from the 50Ω driver to the 2N3053 emitter. Also, various taps on L_3 for optimum output loading are tried, each time retuning C_1, C_2 and C_3. Now, finally, that we've "juggled" and "tweaked" the whole thing up, the reader will begin to understand what he has in store if *large* multiplication ratios are involved.

As to the performance of the unit, it required 1.5 volts rms of 48 MHz drive at 50Ω. The 144 MHz output was 2.25 volts rms across 50Ω. The collector efficiency, then, is 33% (300 mW dc power input, 100 mW of 144 MHz output). To asure ourselves that the RF output voltage that was being measured is really predominantly 144 MHz, a look at it was taken with a highly specialized oscilloscope. The oscilloscope used was a "storage" scope with "sampling" plug-ins. Such a device allows one to look at repetitive waveforms up to 1,000 MHz and "store" that waveform image on the 'scope face, for leisurely examination and

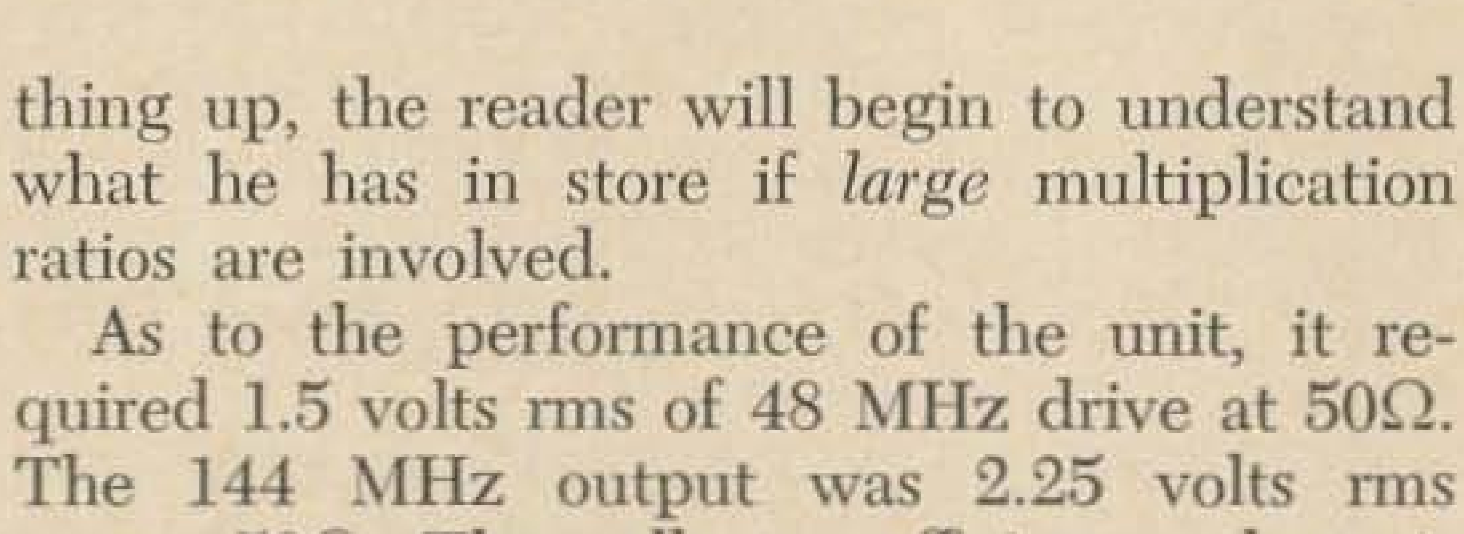
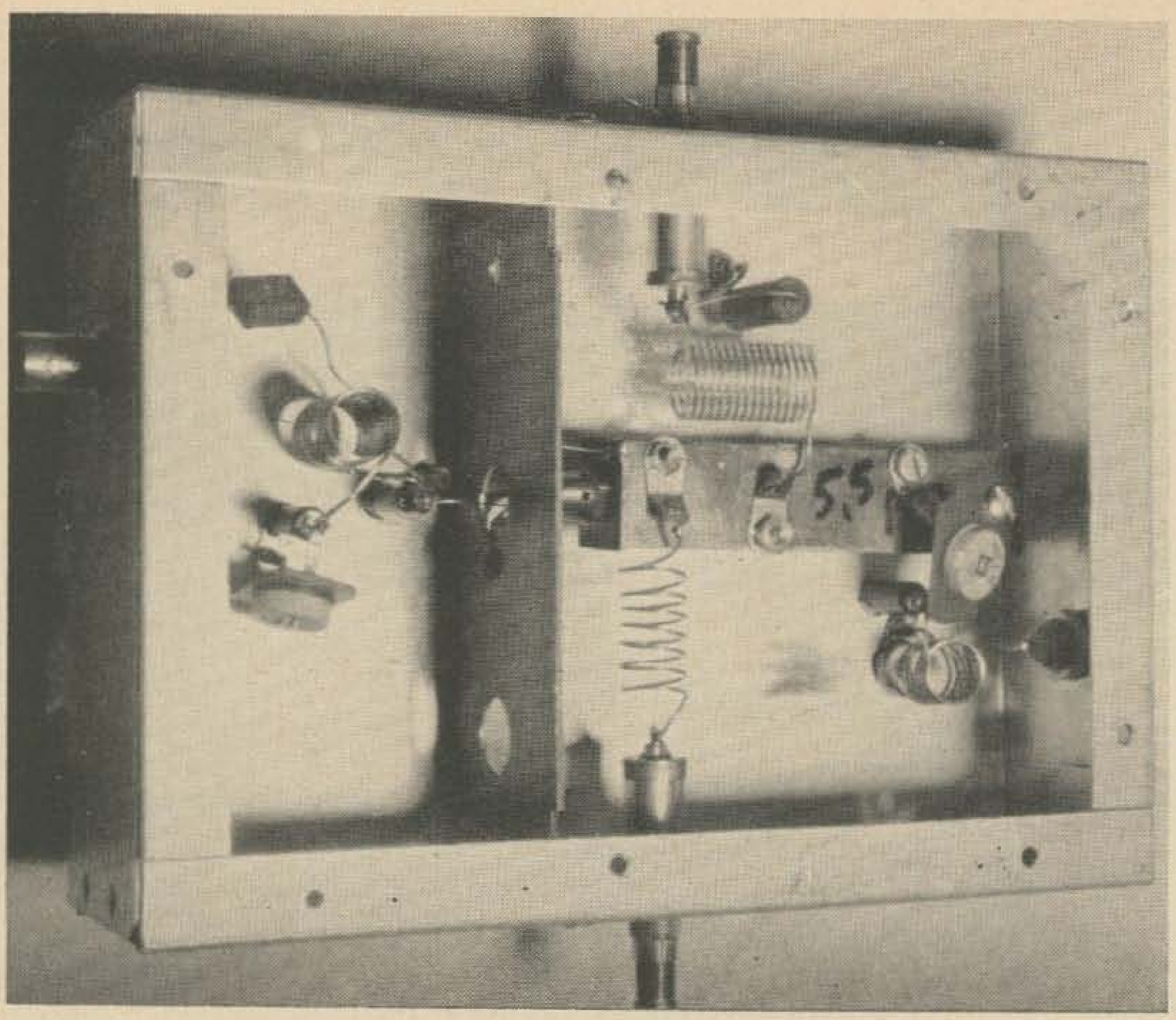


Fig. 5. Output circuit of the parametric transistor multiplier. In A, the resonance is at 48 MHz, in B, at 96 MHz, and in C, at 144 MHz.



Bottom view of the 48 to 144 MHz tripler in Fig. 7.

sketching. The waveform of the above unit is shown in **Fig. 6**, as it was sketched, from storage 'scope face. Three cycles of 144 MHz RF are displayed so that the amount of 48 MHz present can be observed. The fact that a rather special 'scope was used for making **Fig. 6** does not mean that it was essential, but its use only confirmed our other measurements. The grid dip meter was the only necessary piece of test equipment.

The final circuit is shown in **Fig. 7**. It was built inside a 5 X 7 X 2 aluminum chassis as shown in the photo. Note that the input circuit occupies occupies the 2½" compartment at one end of the chassis. The transistor is mechanically and electrically attached with an IERC TX 0507-1B heat sink to a 3 inch long piece of ¾" wide copper strap (the collector of a 2N3053 is connected to the case). This strap serves to dissipate heat, and also serves as a low inductance connection to the idlers. Note that the three coils for 48, 96, and 144 MHz are all spaced from each other and all at right angles to each other, to avoid inductive coupling. A bottom plate is used which completes the shielding of the input and output compartments. It has a ⅜" hole in it for adjustment of C_3 and a 1⅛" hole immediately above L_3, so that the grid dip meter can be coupled to that coil during adjustments.

A second unit was constructed to try the principle as a 144 MHz to 432 MHz tripler (**Fig. 8**). The transistor used in this case was a 2N3553 (R.C.A.) which was about $8.00 when purchased. The newer 2N3866 should

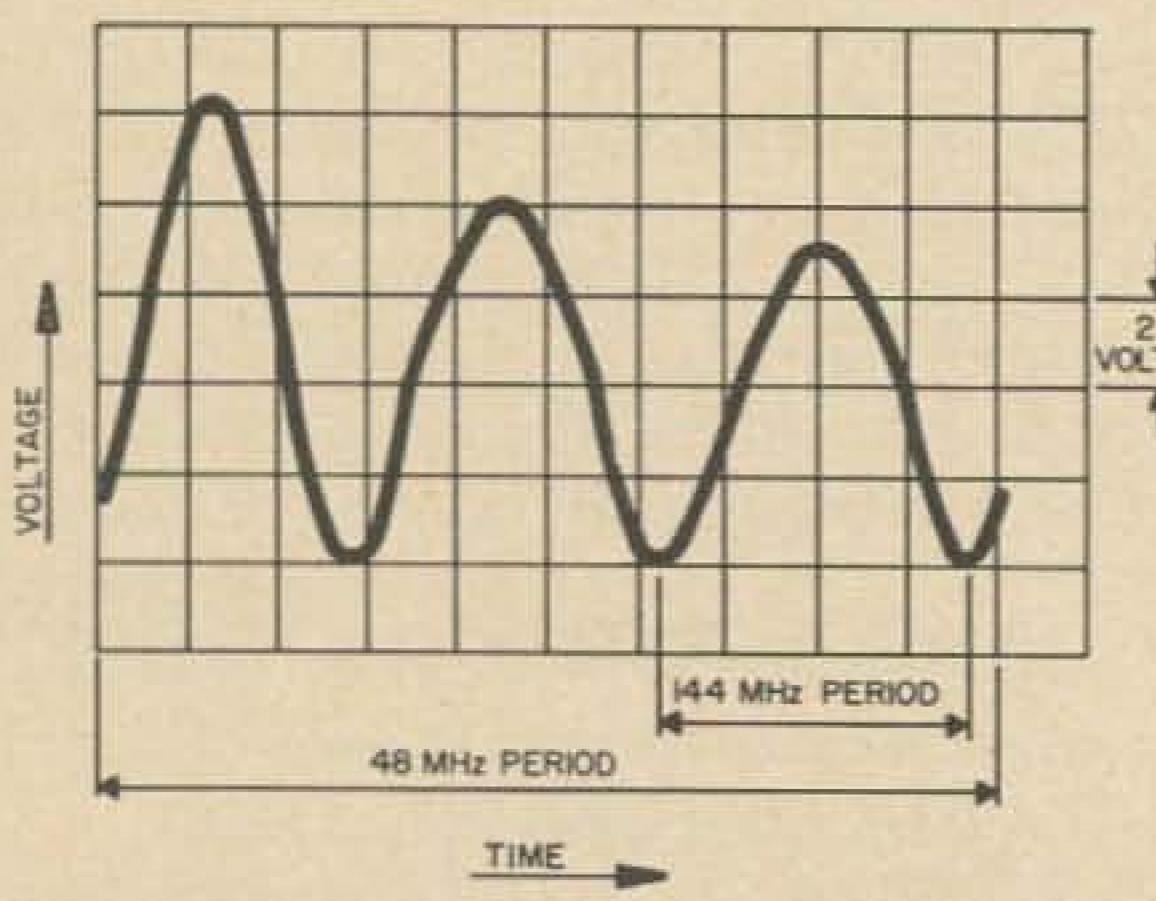


Fig. 6. Output waveform of the tripler in Fig. 7.

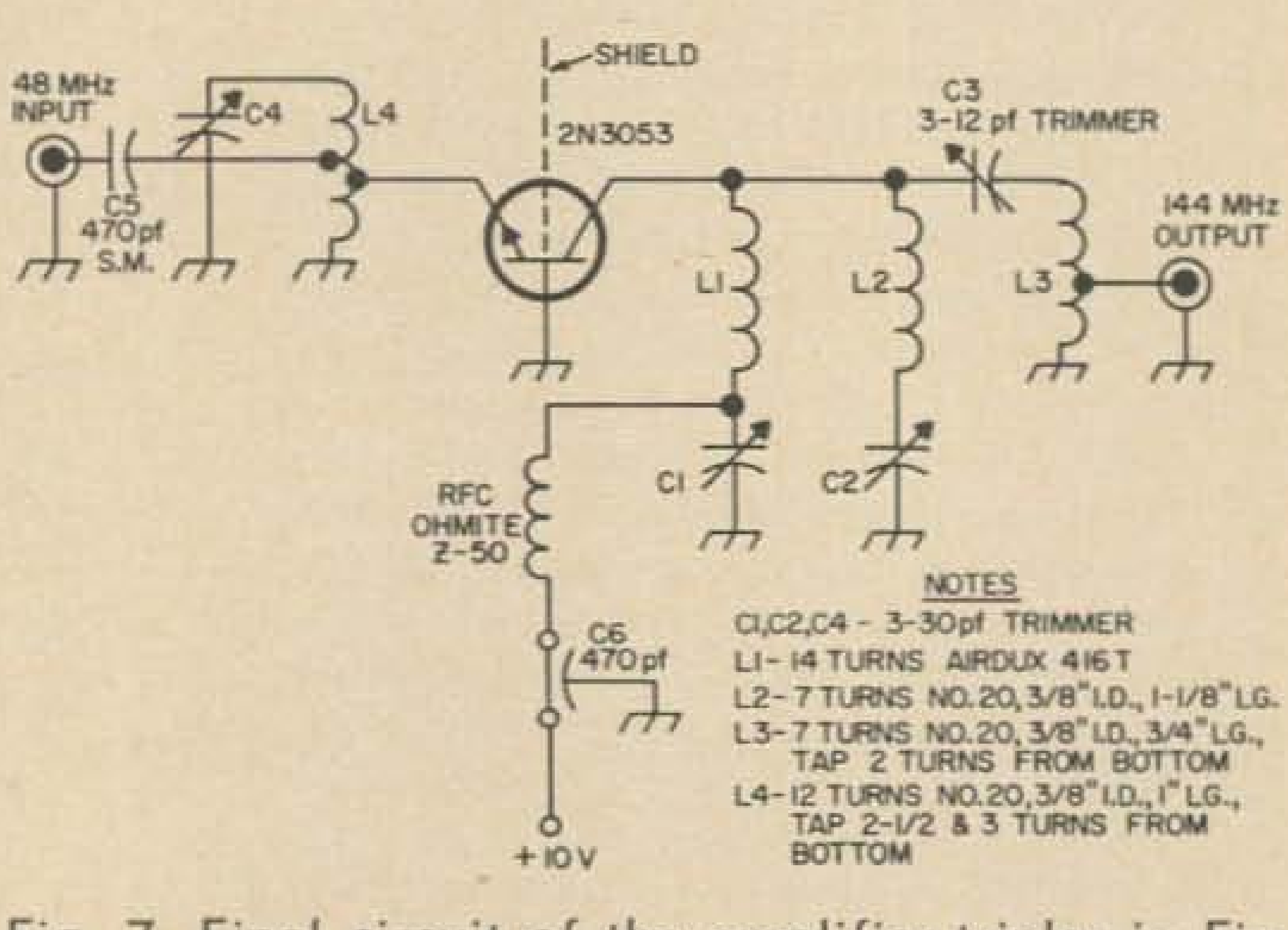


Fig. 7. Final circuit of the amplifier-tripler in Fig. 2. It puts out 100mW on two with 45 mW of 48 MHz drive and 300 mW dc input.

work as well and is only about $5.00. (the 2N3866 is now being manufactured by two other firms, which will tend to bring the price down).

The 432 MHz tripler was constructed in a smaller chassis, a Bud AC-431, measuring 4X6X2. It was partitioned, as before, and one will note the "wavelength scaling" throughout (ie: smaller inductances and smaller capacitances) in the photo of it. Note, also, that the copper heat sink tab had to be cut shorter than previously to reduce its inductance.

The output of the unit is 320 mW at 432 MHz with 180 mW of 144 MHz input. The DC input power was 12 volts at 50 mA, or 600 mW.

While the two parametric multipliers herein described are perhaps not pushing the state of the art, they do represent working models of a relatively new technique. No doubt the units shown can be driven harder, modified, etc.; but the experimentation and "smoke-testing" will be left to those interested in further work. As they stand, the circuits may be useful in handytalkies, or (offset a bit in frequency) as local oscillator chains.

What has been attempted above is to present an approximate method of designing a parametric-transistor-multiplier. The resultant circuits *do* work, though they are almost certain not to be optimum circuits. Since we can change drive level, operating voltage, C_1, L_1, C_2, L_2, C_3, L_3, and the tap on L_3; we can be said to be dealing with nine variables. The optimization of such an array is nearly hopeless theoretically, unless a digital computer is handy and you can set the nine equations in nine unknowns up for it.

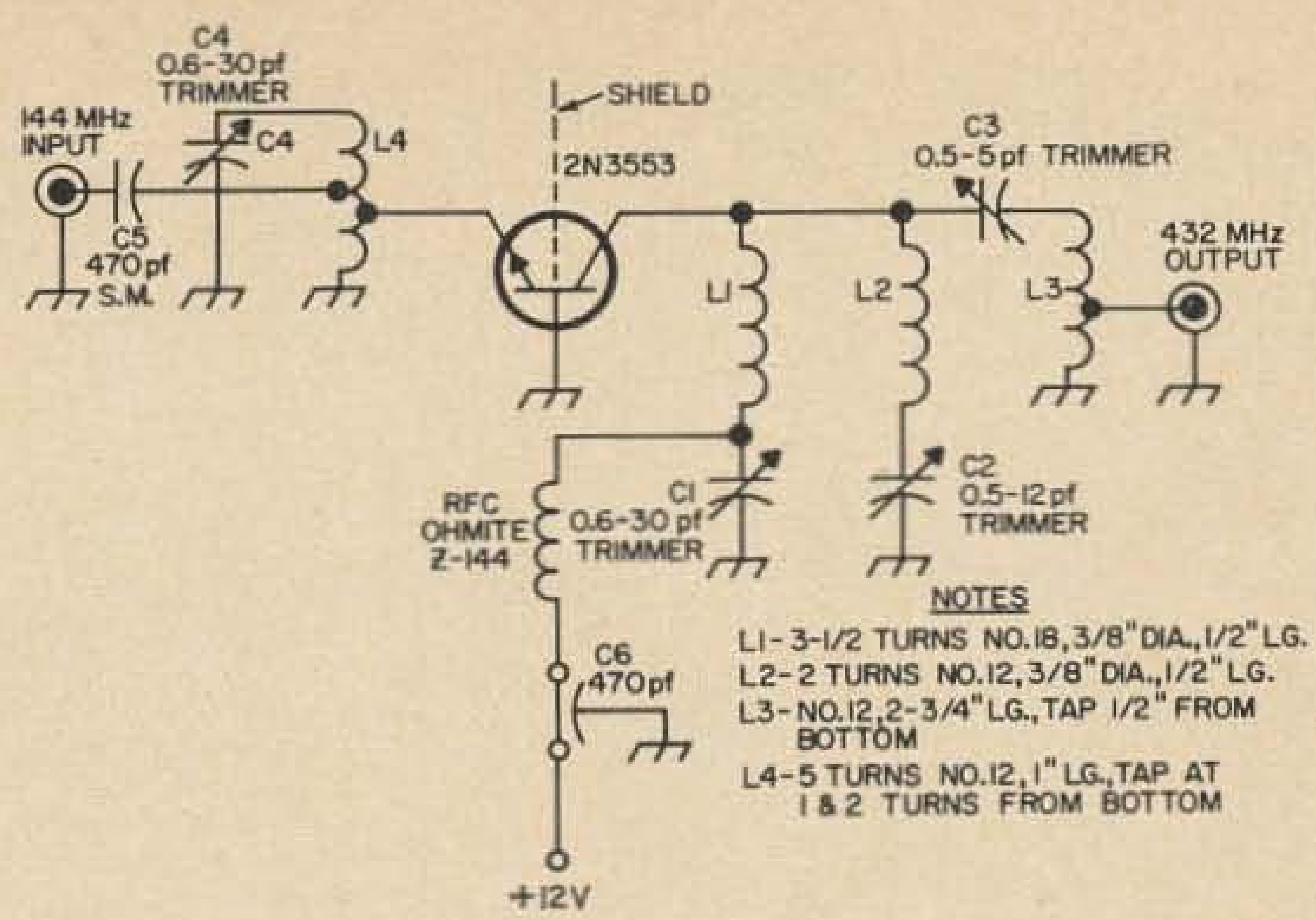


Fig. 8. Parametric transistor multiplier from 144 to 432 MHz. Output is 320 mW with 180 mW input on 144, with DC input of 600 mW (12 volts at 50 mA).

However, this approximation method does work—give it a try!

The author wishes to thank Radio Corporation of America for permission to use **Figs. 3** and **4.**

. . . W6GXN

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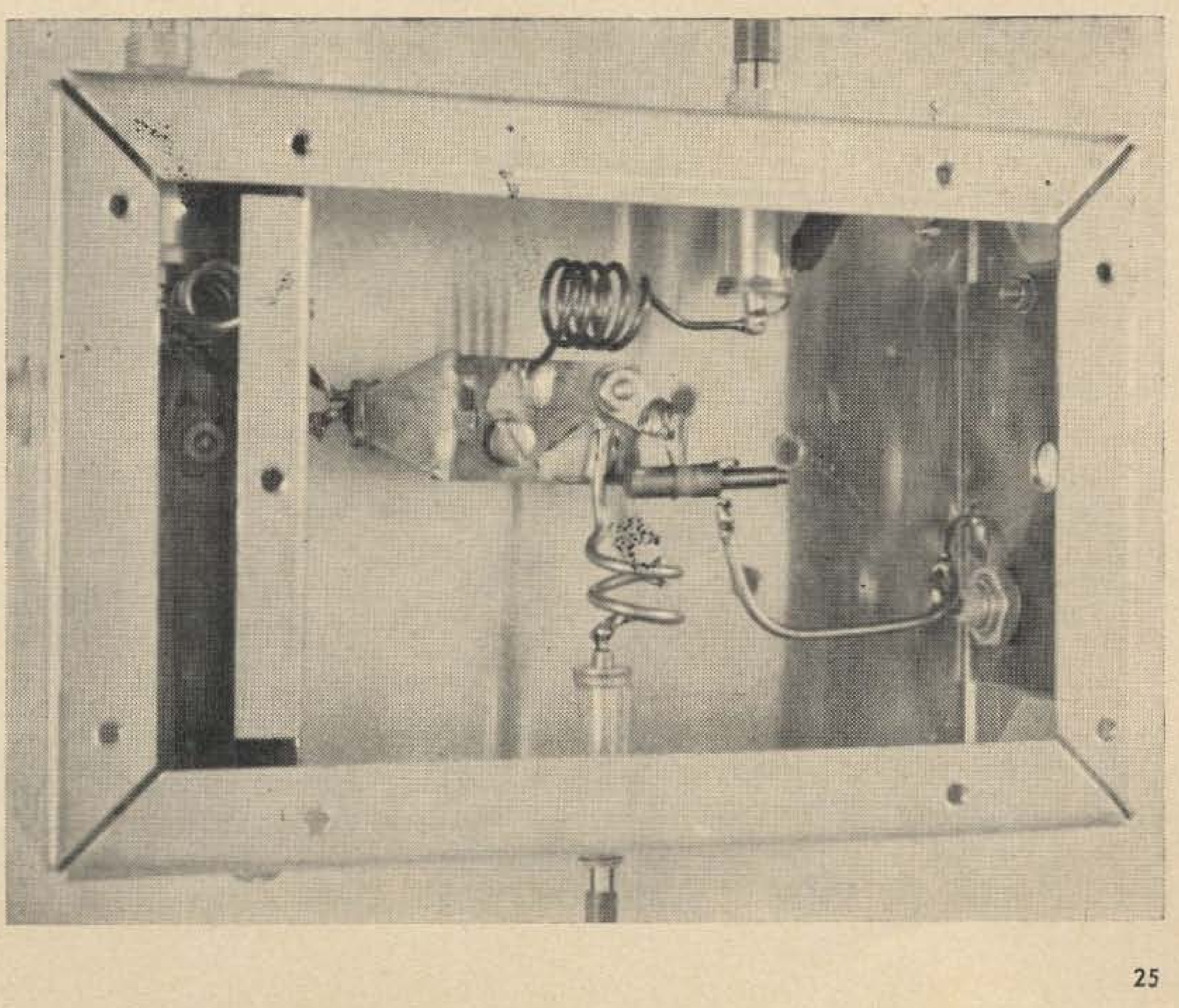
1. Minton, R. and H. Lee. "Frequency Multiplication Using Overlay Transistors," RCA Application Note SMA-40. September 1965.

2. Firth, F. and H. Olson. "The Parametric Transistor Multiplier," 73, March 1965.



Bottom view of the 144 to 432 MHz tripler in Fig. 8.

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How To Get Your Extra Class License

With all the controversy about incentive licensing going around and the good possibility of the FCC making an extra class license necessary to enjoy full ham privileges, I guess many of us have given serious consideration lately to getting that extra class ticket. Any ham would be proud to have one of these licenses simply because of its prestige and the feeling of self-accomplishment that it gives. But until now, who has needed it? A general class license gives us full operating privileges now, so why go to a lot of trouble? This I'm sure is the attitude that most of us have taken, but now our thinking perhaps has changed in view of the recent developments. The thought of getting out the code practice oscillator and the theory books is not too pleasant to many of you, but let's say that you've told yourself that this is the thing to do and you've resigned yourself to getting that extra class ticket. Just what do we have to do to get it and where do we start? Well, we know that we will have to get our code speed up to 20 wpm and that we will have to bone up on some theory. Let's take a look at several ways that you might be able to do this.

Louis is an electronic engineer at Gulf Aerospace (BAS, Houston). He has a second class telegraph and first phone license as well as his extra class ham license, and has written many articles for many periodicals.

Code speed

If you are a regular CW man you are probably capable of about 20 wpm already, or you can't be too far away from it. Most of us don't really know exactly what speed we are capable of, so don't jump to any conclusions. Find out just where you stand and then do something about it if you have to. I guess the best way to check your speed is to use a commercial code machine set to 20 wpm. If there is none available to you, check in with ARRL station W1AW in the evenings. (See a recent issue of QST for times and frequencies.) They regularly transmit code at various speeds and make it easy for you to check your capability. You may be surprised to find that you can already receive 20 wpm or very close to it. If you're not quite there, start practicing.

If you're a phone man, then you've got another problem. The thought of having to copy code at 20 wpm is probably enough to make you throw up. But don't panic. If you once copied 13 wpm for your general class ticket, then you should be able to work back up to and beyond that now. Before you go telling yourself how rusty you are, check your speed by a code machine or W1AW to be sure. Then get to work on improving it. If you're a regular phone man and hardly ever work CW, then the best thing you can do is to put the mike away for a while and get out the key. The best (and most painless) way to up your code speed is to do some regular CW hamming. Nothing will get it up faster—and you'll be getting up to the speed you need to renew your ticket (if you fail the extra class exam).

I was away from ham radio for about four years at one time before I finally realized that to renew my ticket I was going to need some CW operating time. I rented some gear and put in a couple of good weeks on 40cw and got the needed time. But what surprised me was that I remembered the code at all. I not only had remembered it, but I was good for about 10 wpm when I started and was doing 15 to 18 when I quit. So don't start thinking pessimistic things about your code abilities. They are probably better than you think and with a little effort you can improve tremendously. After a couple of weeks of CW operation, check your speed again and do what's necessary to get it up to 20 wpm if you still need it. Practice is the key to it all.

Getting our code speed up to 20 wpm is probably the toughest requirement of the whole project. I personally feel that the 20 wpm requirement is dumb. That is a little too fast for comfort. Oh, I believe that the FCC exam should require a code capability, but why so fast? Is there really a reason for this other than trying to screen out as many persons as possible? If we could average the speeds of all CW stations on 40 meters some Saturday night, I bet it would fall in the 10 to 15 wpm range. That's not too fast or too slow. It's just comfortable and why shouldn't we be comfortable. This is our hobby isn't it and why should our hobby require us to be so uncomfortable? But we are stuck with this requirement so we ought to get used to the idea and start practicing.

Theory

The extra class exam is quite a bit tougher in the technical department than the general class, but with a little study we should be able to do it. I guess most guys will immediately rush out and buy a copy of the ARRL, CQ or Sam's license manual and will start memorizing it just like they did when they got their general class ticket. Well, believe it or not, this is not the quickest and easiest way that it seems to be. And if you do it this way, you are really cheating yourself. I'm not just saying this to offend some of you, and I'm not knocking license manuals. What I am trying to say is that too many of us get our tickets by memorizing, and the license manuals have made it too easy. It should not be this way but it is. The license manuals are written as a guide to the material covered on the FCC exams. They tell you what you can expect on the test and you really should have one. They are *NOT* written to teach you electronics, however, and this is what you need to do—learn electronics. Why? Let me give you a few reasons. First, by knowing electronics you will really understand the license manual questions. Most of them are basic theory and you will be able to answer from this basic knowledge alone. The more specialized questions, their answers and the explanations will be clear to you. All this means is that regardless of how they ask the question on the test, you will be able to answer it because you understand it and not because you memorized it. And your chances of passing the test will be much greater.

Second, a knowledge of electronics will make your hobby more enjoyable. You will understand how your equipment works, you will be more likely to fix your own gear when it breaks down instead of spending a lot of

1. Time constant is the time that it takes a capacitor to charge to 63.7% of the applied voltage through the accompanying resistor.

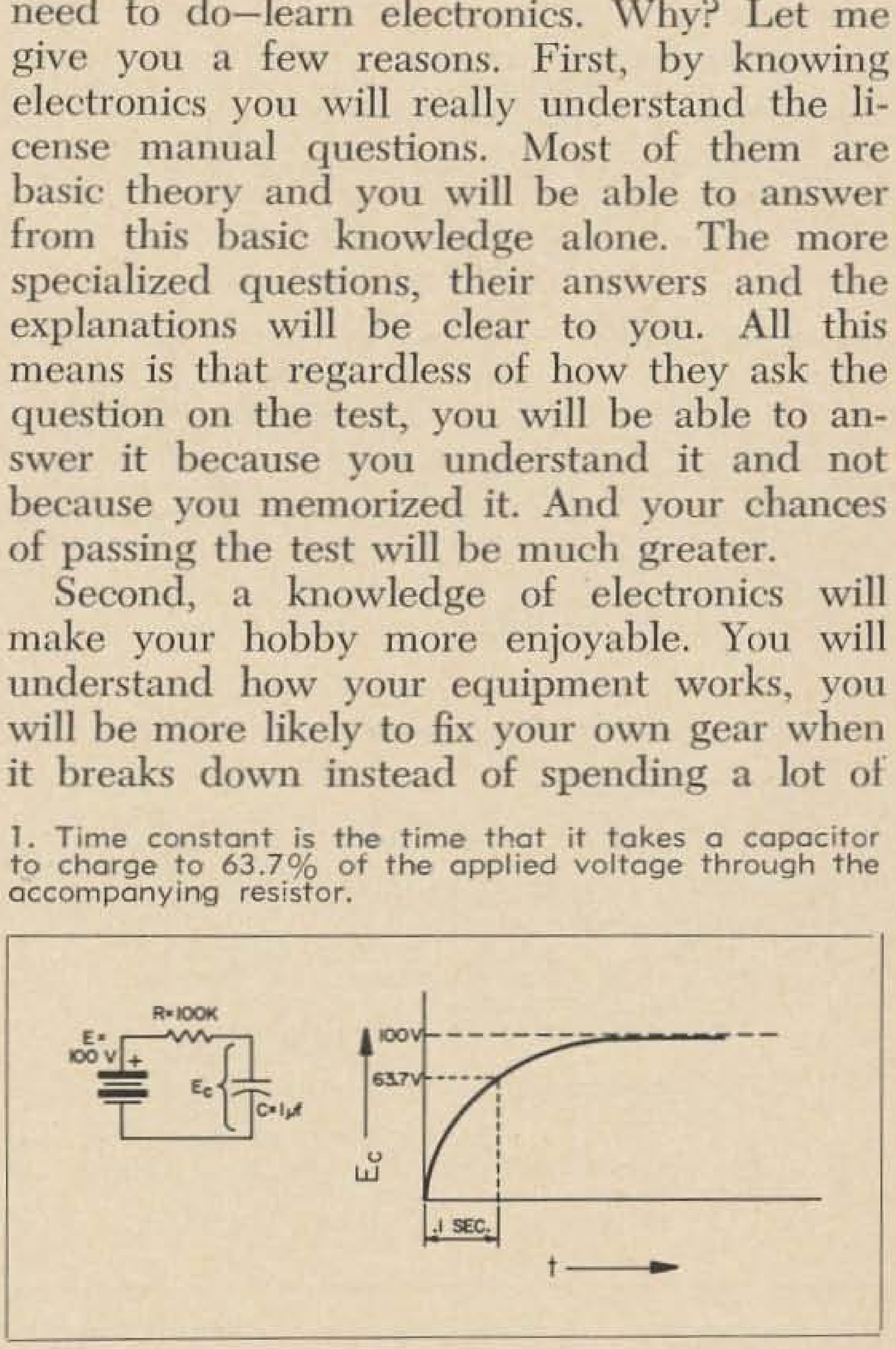


Fig. 1. Paragraph-sentence completion programmed text.

The time constant T in seconds is equal to the capacity multiplied by the resistance (T=RC), where R is in ohms and C is in farads. For example, with the values shown in the figure above, the time constant $T=RC=(10^5)(1\times10^{-6})=.1$ second. This means that the capacitor will charge up to 63.7% of 100 volts, 63.7 volts, in one-tenth of a second. (See graph) If the applied voltage in the circuit above was 25 volts, in one tenth of a second the capacitor would charge up to __________ volts.

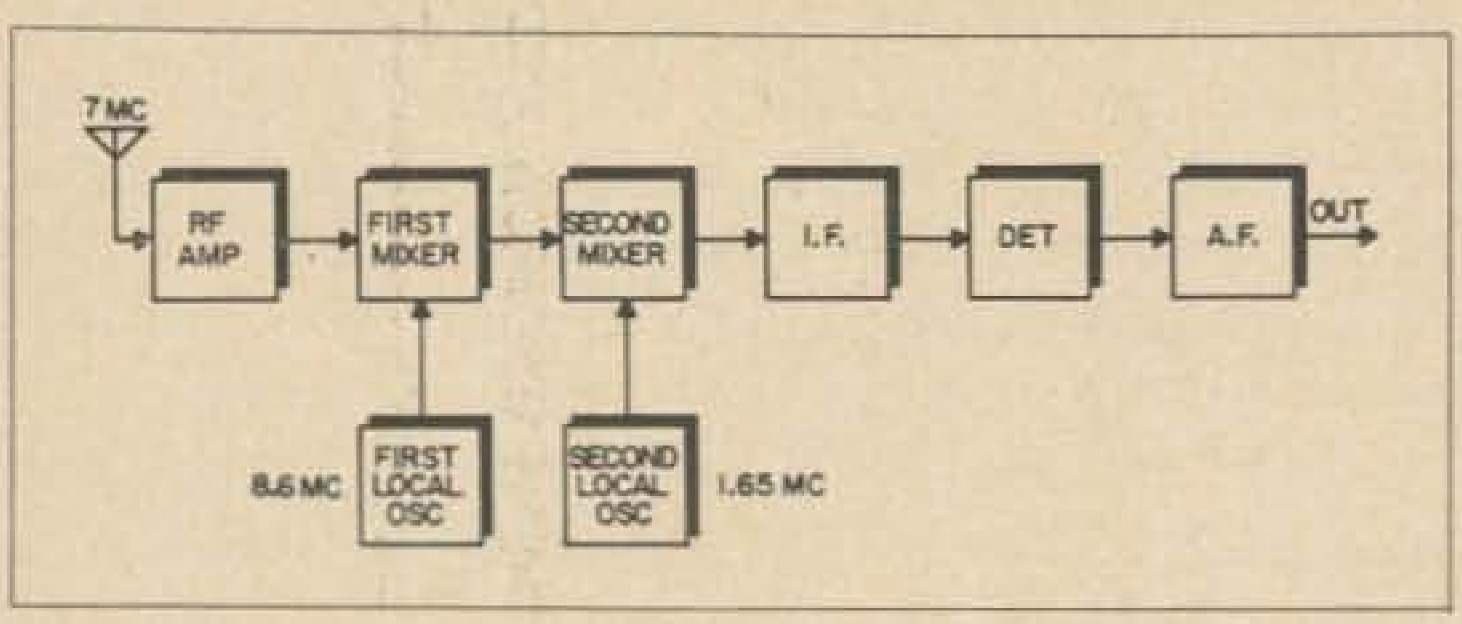
---

2. (15.925 volts) It takes approximately 5 time constants for the capacitor to charge up to full applied voltage. In the example of the previous frame, it would take $(.1)5 = .5$ seconds for the 1 μf capacitor to charge up to 100 volts. If the resistor value is 4 megohms, the capacitor is .05 μf and the applied voltage is 40 volts, it would take __________ seconds for the capacitor to charge to this value.

---

3. (1 second) Time constant also means the time it takes a capacitor to discharge to 36.3% of the value it was charged to. Etc.

1. Another form of the superhetrodyne receiver uses double conversion. In this type of receiver the incoming signal is converted to an intermediate frequency and then this IF signal is again converted to an even lower IF value. A block diagram of this kind of receiver is shown below.



The big advantage of double conversion receivers is the improved image rejection over conventional superhets. Also, selectivity can be improved since lower second IF's can be used.

Assuming that we are using difference frequency mixers, what is the second IF frequency shown?

3250 kc. . .go to frame 10
50 kc. . .go to frame 17
1600 kc. . .go to frame 26

---

10. Your answer, the second IF frequency is 3250 kc, is incorrect. The first IF is the difference between the oscillator frequency 8.6 mc and the incoming signal 7 mc. 8.6 − 7 = 1.6 mc = 1600 kc. The second IF is the difference between the second local oscillator frequency 1650 kc and the first IF. You apparently determined the sum rather than the difference. While the second mixer will generate both the sum and the difference frequencies, we are interested in the difference only. Return to frame 1 and select the correct answer.

---

17. Your answer, 50 kc, is correct. The first IF is 8.6 mc − 7 mc = 1.6 mc = 1600 kc. The second IF is 1650 kc − 1600 kc = 50 kc.

The double conversion receiver is tuned like other superhets. The tuned circuits of the RF amplifier and local oscillator are gauged together and are adjusted simultaneously so they track. Now answer this question about double conversion receivers.

Which of the statements below is correct?

The second local oscillator is ganged and tuned simultaneously with the first local oscillator so that it tracks properly.
GO TO FRAME 8

The second local oscillator is usually tuned separately.
GO TO FRAME 11

The second local oscillator does not have to be tuned.
GO TO FRAME 13

---

26. Your answer, 1600 kc, is incorrect. This is the first IF derived by taking the difference between the local oscillator and the incoming signal in the mixer. 8.6 − 7 = 1.6 mc = 1600 kc. Now determine the second IF the same way using 1600 kc as the input to the second mixer, then return to frame 1 and select the correct answer.

Fig. 2. Another form of programmed text.

money to have it fixed, and you may even get the urge to build that gadget you want—the one that's not made commercially. All these things are a little hard to appreciate if you're not already knowledgeable in electronics. Once you get that way though you will see what I mean. I got my general class ticket when I was 13 and I did it like many of you did—memorizing the license manual. Oh yes, I understood Ohm's law and had a fair idea how a tube works, but I really couldn't analyze circuits, fix my own gear or talk theory very well. Nevertheless, I had a good time with my commercial gear. But now I have a college degree, and I've been employed as an electronic engineer for several years. I really know theory, and I have learned to appreciate those things I mentioned earlier. It's a satisfying and secure feeling to know how my transceiver works and that I can probably fix it myself if it goes out. I've even designed and built an exotic electronic keyer that I wanted and couldn't buy.

Well, assuming that you're now sold on the idea of learning electronics, let's see how you can go about it. The first thing that probably comes into your mind is to rush in and get out your old Handbook and start reading. Well, basically there is nothing wrong with this, but it is probably the hardest and most boring way to do it. I don't have to tell you that reading theory out of a Handbook is not like reading a good story in Playboy or a James Bond book. After about an hour, if you last this long, you will be so bored that you may give up and chances are you won't be able to recall what you did read. What you need is a brief reading period followed by some practice in answering questions or working problems to test yourself. The handbook won't give you these and you won't get too far making up your own questions or problems. The license manuals help some here but they really do not have the practice material that you need. What you need is a planned and scheduled study and learning program. How do we get it? Well, if you are really gung-ho and don't mind spending a little money and putting in a little time, I recommend a correspondence course. There are several good schools offering home study courses in electronics with a communications slant. Many of them are designed to help a person get a commercial FCC license. Such courses are quite effective. They provide a planned curriculum and will give you plenty of practice problems and tests. They will be more than sufficient. The biggest problem is their cost and the time it takes to complete them. A good course costs somewhere in the $100 to $300 range and may take as long as a year or two to complete. This is the real Cadillac way to go and you certainly won't regret it. Besides, you will probably end up with a commercial FCC license as well as a nice diploma. If you're interested in this approach, drop a post card to one of the schools listed in **Table I.**

Another approach to the problem is a night school vocational course in electronics. Again cost and time are the main factors against it.

There is another way to accomplish your

objective. It is a rather new method and you'll probably enjoy it. It's effective, and it is truly a do-it-yourself technique. I recommend it highly. Have you ever heard of teaching machines or programmed instruction? These are relatively new ways to teach. The material to be learned is presented to you either by a machine or a special book in small, short doses and then you are immediately tested on this small bit of information by a question to answer or a problem to work. If you work the problem correctly, you are given another bit of information to read and then another test and so on. **Fig. 1** and **2** show examples of two different types of programmed instruction. In the first type, (**Fig. 1**) you read a short paragraph containing a fact or two and then you are tested by having to complete a statement involving the facts by filling in a blank. Each block of information is called a frame. In the next frame you are given the correct answer and then go on to some new material.

In the other type of programmed instruction, you are given a frame of information and a question or problem to answer. The question is usually the multiple choice type. If you answer correctly you are sent to a new frame of information. If you choose the wrong answer, you are sent to a special frame that tells you that you are wrong and explains why. It then sends you back to the previous frame to select the correct answer. **Fig. 2** is a typical example. As you will discover, this type of self instruction is infinitely better than reading your Handbook—it's more effective since you take an active part, and you won't get nearly as bored.

There are a good many of these programmed books on electronics available today and for a modest amount of cash you can pick up several of these. A list of titles and publishers is given in **Table II.** If you can't get these through your local bookstore, write the publisher directly. With some of these books and a promise to yourself to set aside an hour every night to work on it, you will learn electronics in no time and will be quite well prepared to study and understand the extra class license manual questions. The theory exam will be a snap.

The exam

Once you have gotten your code speed up and you are really hot on theory (don't forget to learn the FCC rules and regulations) run, don't walk, to your nearest FCC office. Take the exam while you are at your peak. The human mind won't retain all this unless you continually review or use this information, so use it while you've got it. Once you get the extra class ticket you can forget it all and go back to enjoying the non-technical aspect of your hobby if you want.

While you are boning up for the extra class license, you just might chip in a few bucks and buy a study guide for the FCC commercial licenses. (Your local library probably has a copy if you don't want to buy one.) These make good references and the study material on the 1st and 2nd class radiotelephone licenses is so close to being the same as that for the extra class license, you'll really be surprised. This commercial study guide will give you a different slant on the same material and will broaden your knowledge. Then when you go for the extra class exam, you might as well get your commerical license as well even though you don't need it. If you're going to impress your friends with a higher grade license, you might as well go all the way. Happy studying, and good luck! . . . W5TOM

Table I. Home study schools offering training in electronics with a communications or FCC license preparation slant.

National Radio Institute
3939 Wisconsin Avenue
Washington, D. C. 20016

National Schools
400 S. Figueroa Street
Los Angeles, Calif. 90037

Grantham School of Electronics
818 18th Street, N.W.
Washington, D. C. 20006

Cleveland Institute of Electronics
1776 East 17th Street
Cleveland, Ohio 44114

RCA Institutes Inc.
350 West 4th Street
"A Programmed Course in Basic Electronics"
New York, New York 10014

Table II. Programmed lesson material and books on electronics.

"A Programmed Course in Basic Electricity"

"A Programmed Course in Basic Transistors" by New York Institute of Technology, $6.95 each. Publisher: McGraw-Hill Book Company, 330 West 42nd Street, New York, New York.

"Basic Electronics: Autotext," A Programmed Course in Circuits by RCA Institutes Inc. $13.00. Publisher: Prentice-Hall Inc., Englewood Cliffs, New Jersey.

"Basic Electricity Electronics" (5 volumes) $19.95 (soft cover). Publisher: Howard W. Sams & Company Inc., 4300 West 62nd Street, Indianapolis, Indiana 46206.

"Applied Electricity" $12.50
"Introduction to Transistors" $9.50
"Basic Transistor Circuits" $9.50. Publisher: Basic Systems Inc., (Write directly) 880 Third Avenue, New York, New York.

International Educational Services, Inc., Scranton, Pennsylvania 18515. 16 lessons on basic electronic subjects: $4.95 each or all 16 for $65. Write direct for information.

"Basic Electronics" Tutor Text, Publisher: Doubleday and Company, Inc., Garden City, New York.

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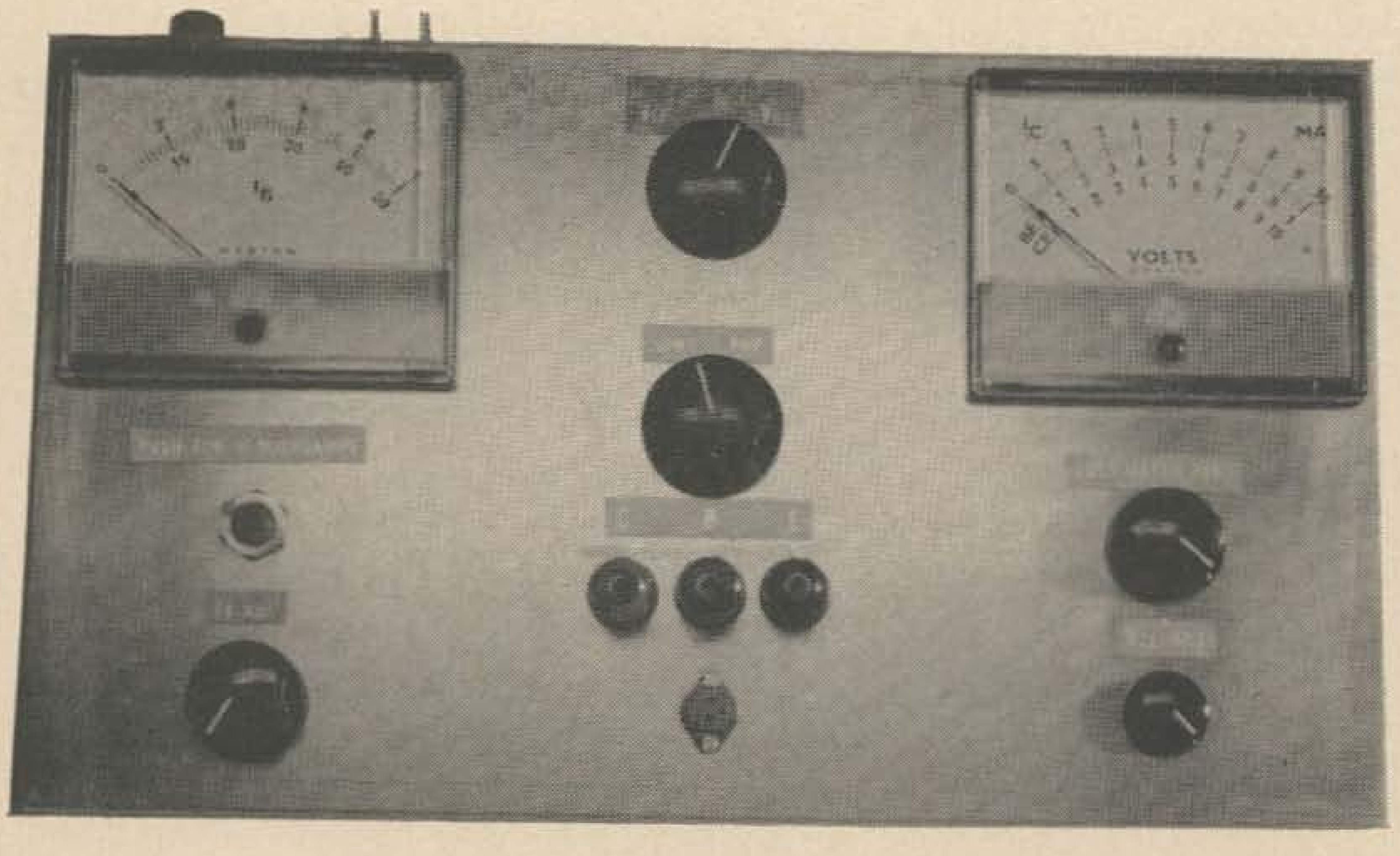
Transistor Analyzer

Build this analyzer for checks on transistor input resistance, voltage feedback ratio, forward current gain and output admittance

Some of you will probably look at the title of this article and remark, "Here comes another transistor tester, but with a fancy name." Well this is not so, and if you really want to learn to design with transistors the professional way, read on. Good cheap transistors are readily available to the amateur, but locating their specifications is another story. Oh sure, you can look in one of the many parts catalogues available and come up with such things as current gain, polarity, breakdown voltage, plus a few other parameters and use these to design a few circuits by the seat of your pants. But chances are you don't know what you have. Do you know what the input and output resistances are, or what the current gain and voltage gains are, what is the bandpass at the 3 dB points, is the load matched to the output stage? Well this instrument won't tell you all this, but it will give you the necessary data on your bargain basement transistors so that you can calculate with good accuracy how it will behave in a circuit. This transistor analyzer will give you the "h" or hybrid parameters for the common emitter connection; these being "h_{11}" or "h_{ie}" the input



Front of the transistor analyzer. The left meter is for base current. It normally reads 0-1 mA, but the button below it can be pushed for a scale of 0-50 µA. The right meter is for collector current, and voltage between base and emitter or collector and emitter. These functions are selected by the switch between the meters.

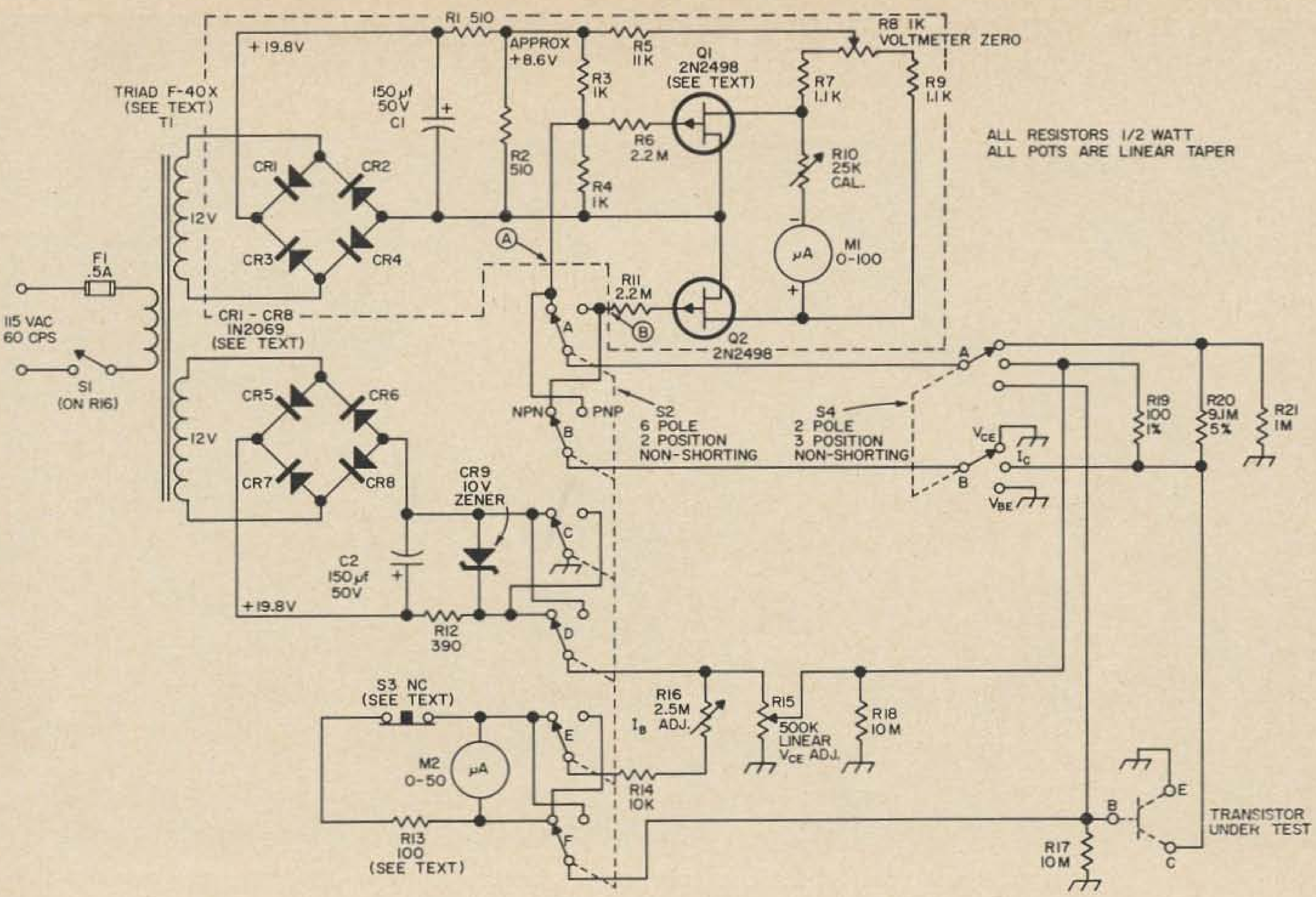
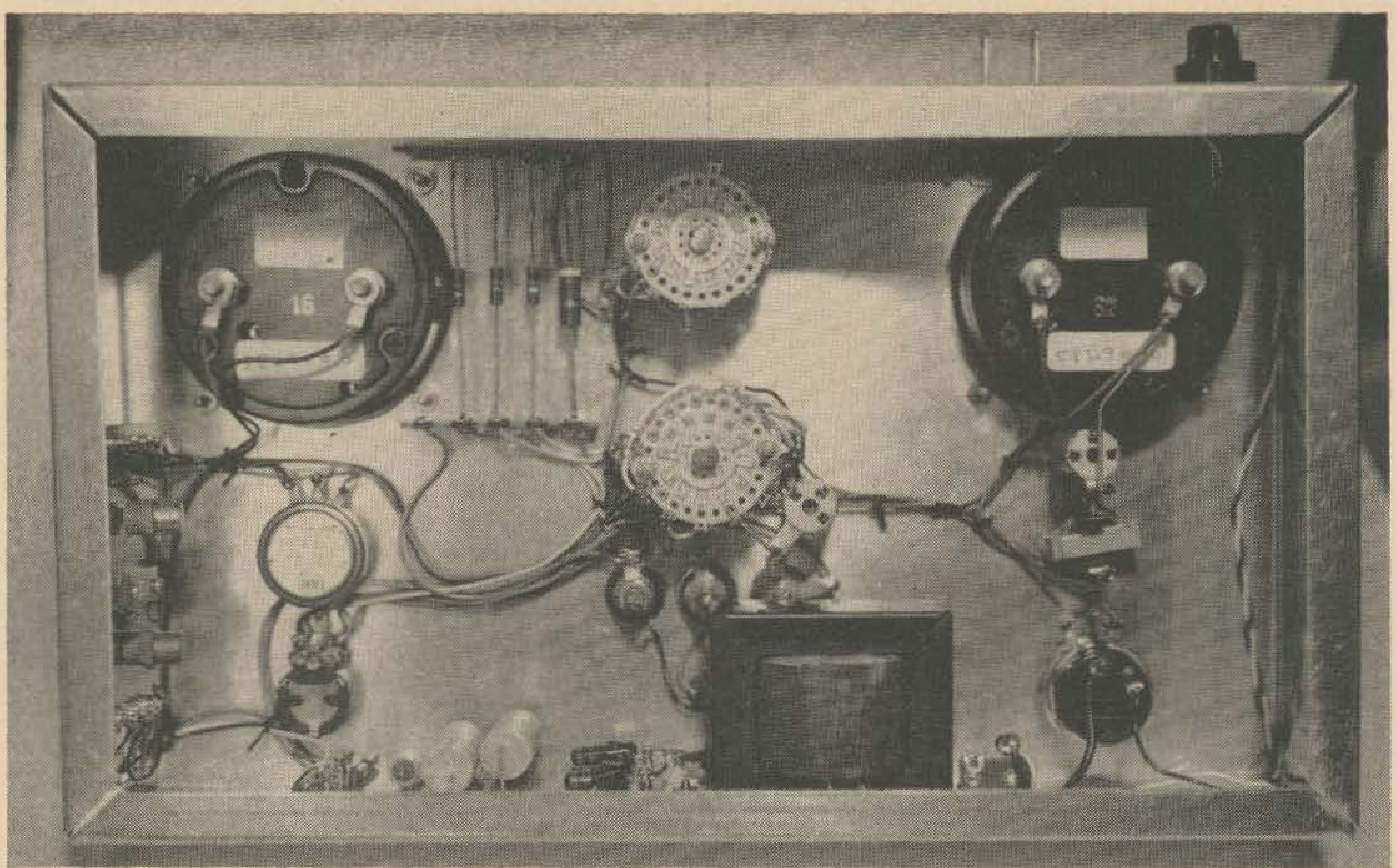


Fig. 1. Schematic of the transistor analyzer described in the text. It measures the hybrid parameters, h_{12}, h_{21}, h_{11}, and h_{22}, necessary for accurate checks on transistor capabilities.

resistance, "h_{12}" or "h_{re}" the voltage feedback ratio, "h_{21}" or "h_{fe}" the forward current gain, and "h_{22}" or "h_{oe}" the output admittance. These are the only "h" parameters needed, and by plugging these numbers into suitable equations, circuits can be designed and analyzed. More on this later; let's get to the hardware.

A look at the schematic diagram will reveal two separate power supplies. The power supply associated with CR1-CR4 and the remaining circuitry comprise a field effect voltmeter. This is the solid state equivalent of the vacuum tube voltmeter and has an input impedance of about 10 megohms. The high input impedance is necessary to avoid loading down the test transistor when measuring V_{BE}, the voltage from base to emitter. The basic sensitivity of the voltmeter is 1 volt full scale. In the V_{ce}, or volts collector to emitter position of S_4, the voltage divider consisting of R_{20} and R_{21} extends the range to 10 volts full scale. In the I_c, collector current and V_{BE}, volts to emitter position of S_4, full scale is 1 volt. For the I_c position the meter scale is calibrated 0 to 10 milliamperes since we are reading the voltage drop across a precision 100-ohm resistor. Potentiometer R_8 is the voltmeter zero and R_{10} is the calibration pot.

Power supply 2 serves to furnish the necessary voltages and currents to the transistor under test. R_{15} is the V_{ce} adjust and allows placing 0 to 10 volts approximately across the collector emitter of the test transistor and R_{16} is the base current adjust. Meter M_2 is used to monitor base current continuously during tests. This meter, a 50 microampere unit, is shunted by R_{13} to read a full scale of 1 milliampere. S_3, a normally closed push button switch, is used to remove R_{13} from the circuit so that a full scale reading of 50 microamperes can be obtained. This is a big help in reading small currents. Hindsight tells me that a 100 microampere unit would be more practical, since on some tests it doesn't take much to go off scale on a 50 microampere unit. However, mine is installed and calibrated and I will have to be content with it. A value of 100 ohms was a suitable shunt for my particular meter and others will no doubt have to determine the proper value for theirs. This is not hard, and the necessary information for doing so is available in any radio handbook. Switch S_2 is the polarity reversing switch and is shown schematically in the NPN position. Its function is to reverse the voltmeter, collector voltage supply, and base current supply so that both NPN and PNP devices can be tested. Q_1 and Q_2 are field effect devices man-



Rear view of K3LCV's transistor analyzer. The cabinet is open and uncrowded for easy construction.

ufactured by Texas Instruments. They are not cheap, and carry a price tag of about $12 each. If you buy the exact field effect, the voltmeter will work. I cannot say how other devices by other manufacturers will work in this circuit, but you can try. A little playing around on the bench with resistors R_5, R_7 and R_9 should get the circuit going with just about any field effect. If you feel you don't want to experiment with the circuit, then you can leave out the circuitry in the dashed block and bring points A and B out to test jacks. You can then connect any 10 megohm input impedance or better VTVM externally and realize a savings in parts and assembly time.

For construction I mounted all parts on a 7" x 12" x 3" chassis with meters and controls laid out as symmetrically as possible. Wiring is in no way critical as the voltages and currents are quite small. On my unit, two rather crude homemade printed circuit boards hold most of the small parts. For diodes CR1 through CR8 just about any cheap diode will do. Something around 100 PIV at about 50 milliamperes would be satisfactory, so check your junk box. T_1 is just a little special in that it has to undergo a little surgery to serve our purpose. Basically T_1 is a 24-volt center tapped filament transformer in which we will split the center tap and end up with two 12-volt windings. On the side that the three wires of the secondary come out, slit the outside protective paper vertically and peel both halves out of the way. The center tap connection is made up of two wires twisted together and spot welded to the single wire. Untwist these wires and solder leads to both of them. Slip some small tubing over the exposed joint, and glue the protective paper back in place with epoxy or what have you. Do this properly and all that will show is a thin scar line.

Calibration involves only the voltmeter and takes but a few minutes. Open the circuit at points A and B and connect a 10 megohm resistor between these points. Turn power on and zero the meter. Connect a 1-volt source across the 10 megohm resistor with plus at A and minus at B. Adjust R_{10} for a full scale reading on meter M_1. That's it; with the parts specified the voltmeter will read properly. If other field effects are used, first get the voltmeter working properly on the bench; then install and calibrate it.

Now that our analyzer is working properly, let's use it. If you built it as a Beta tester, it will give you two valuable pieces of information. It will give Beta, which everyone likes to know, and also the voltage needed on the base of the transistor to get a specified amount of collector current to flow. As an example, let's see what kind of data we can get from a transistor. Turn the analyzer on and set I_B and V_{ce} to minimum. Set the polarity switch to

NPN or PNP depending on the transistor being tested. Set the function switch S_4 to V_{ce} position and advance the V_{ce} adjust pot for 5 volts. Set function switch to I_c and advance I_B adjust for 1 mA of current. Beta is $\frac{\Delta I_c}{\Delta I_B} | V_c |$ which means: A small change in collector current (I_c) divided by a small change in base current (I_B) with the voltage on the collector held constant. Therefore, read base current for 1 mA and write it down. Now advance I_B adjust for 2 mA of collector current and again read the base current. Subtract the first base current reading from the second and divide the result into the change in collector current, which was 1 mA. This then is the Beta at about 1.5 mA. Always use the same terms when dividing; i.e., milliamperes into milliamperes, microamperes into microamperes, etc. Back off now on the I_B; adjust pot till I_c reads 1.5 mA. Switch to the V_{Be} position and read this voltage. You now know what voltage and current to apply to the base of your transistor to get 1.5 mA to flow. The above operations can be performed at various voltages and currents within the range of the instrument and are quite easy to do after a few practice tries.

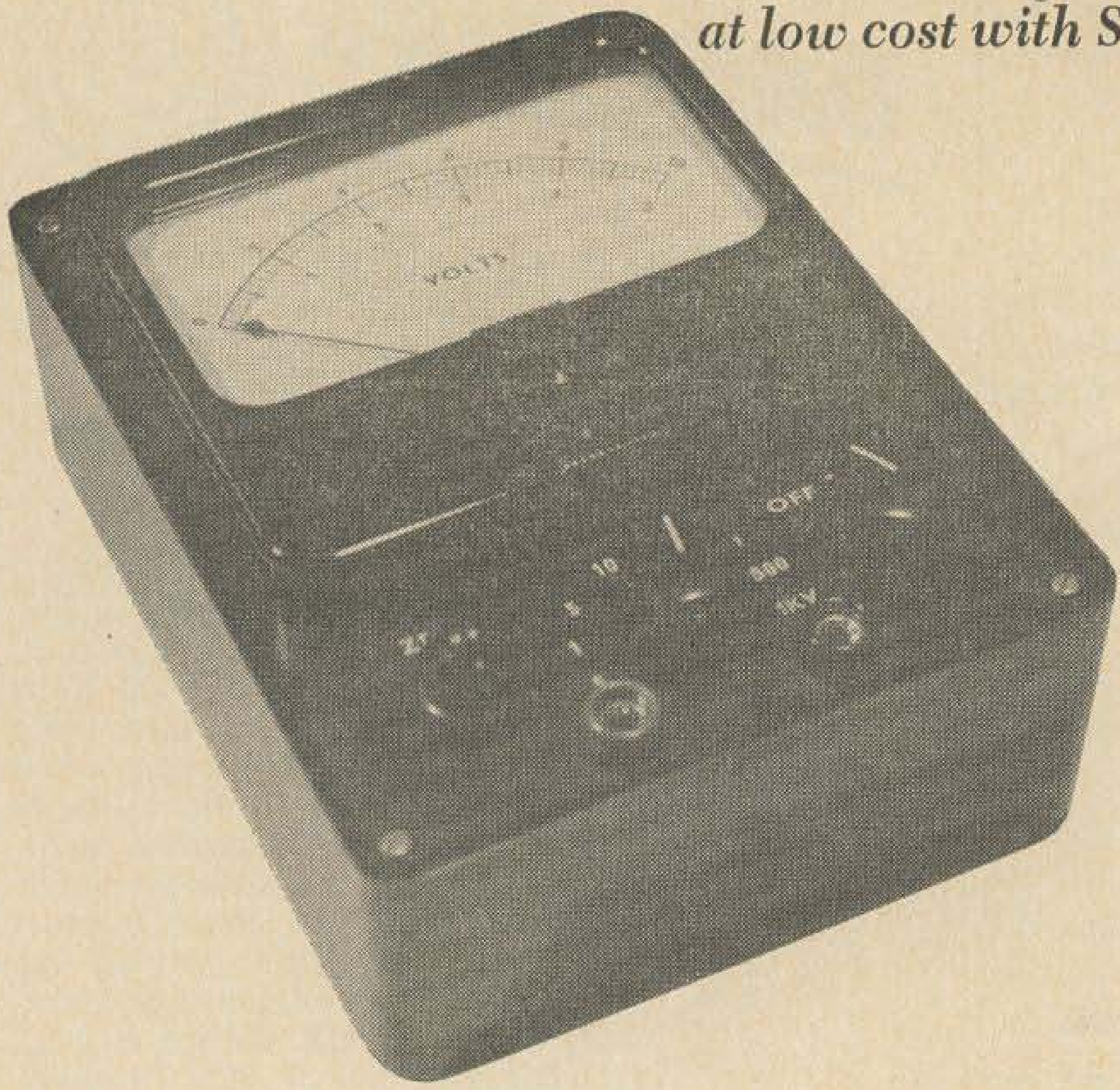
The other 3 "h" parameters are h_{oe} or h_{22}, the output admittance which is $\frac{\Delta I_c}{\Delta V_c} | I_B |$, h_{ie} or h_{11} the input resistance, $\frac{\Delta V_B}{\Delta I_B} | V_c |$, and h_{re} or h_{12} the voltage feedback ratio $\frac{\Delta V_B}{\Delta V_c} | I_B |$. Calculate these the same as for Beta and remember to use volts and amperes in your division. Some representative values are $h_{fe} = 66$; $h_{oe} = 2 \times 10^{-5}$ mhos; $h_{ie} = 2000$ ohms; and $h_{re} = 1.2 \times 10^{-3}$.

If you have gone this far with me, let me explain that space does not permit me to give the equations needed to take advantage of this instrument. But let me hasten to recommend to you a fine book for those of you who want to know more. High school alegbra is all the math needed to understand this book. It is called: **Transistor Physics and Circuits,** by Robert L. Riddle and Marlin P. Ristenblatt and is published by Prentice-Hall. The authors do a good job taking you in nice easy steps from fundamentals through to actual circuit design.

Well, that's it; and I hope you can get as much out of this instrument as I have.

. . . K3LCV

Build this very high impedance (22 M) voltmeter at low cost with Siliconix field effect transistors.



Field Effec

Richard Palace K3LCU
4402 Clearfield Road
Wheaton, Maryland

Here is a handy piece of test equipment for the ham shack. It features low power drain, instant warm-up, portability, and an extremely high input impedance. All this is accomplished by using field effect transistors which behave like screen grid vacuum tubes, but without the heater and high plate voltages normally associated with tubes.

This voltmeter will measure from .5 to 1000 volts with an input impedance of 22 megohms as compared to most commercial voltmeters which have input impedances of about 11

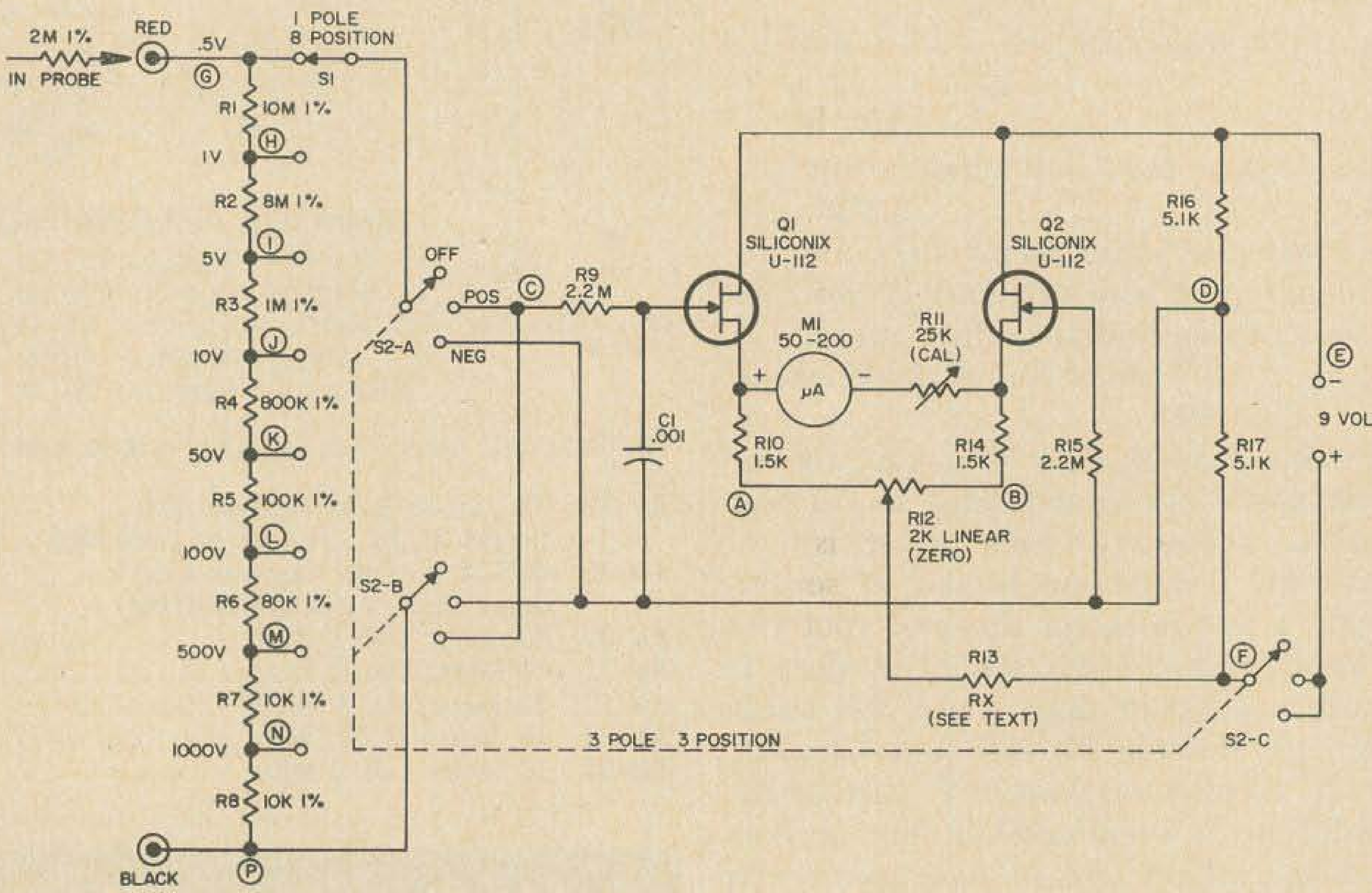
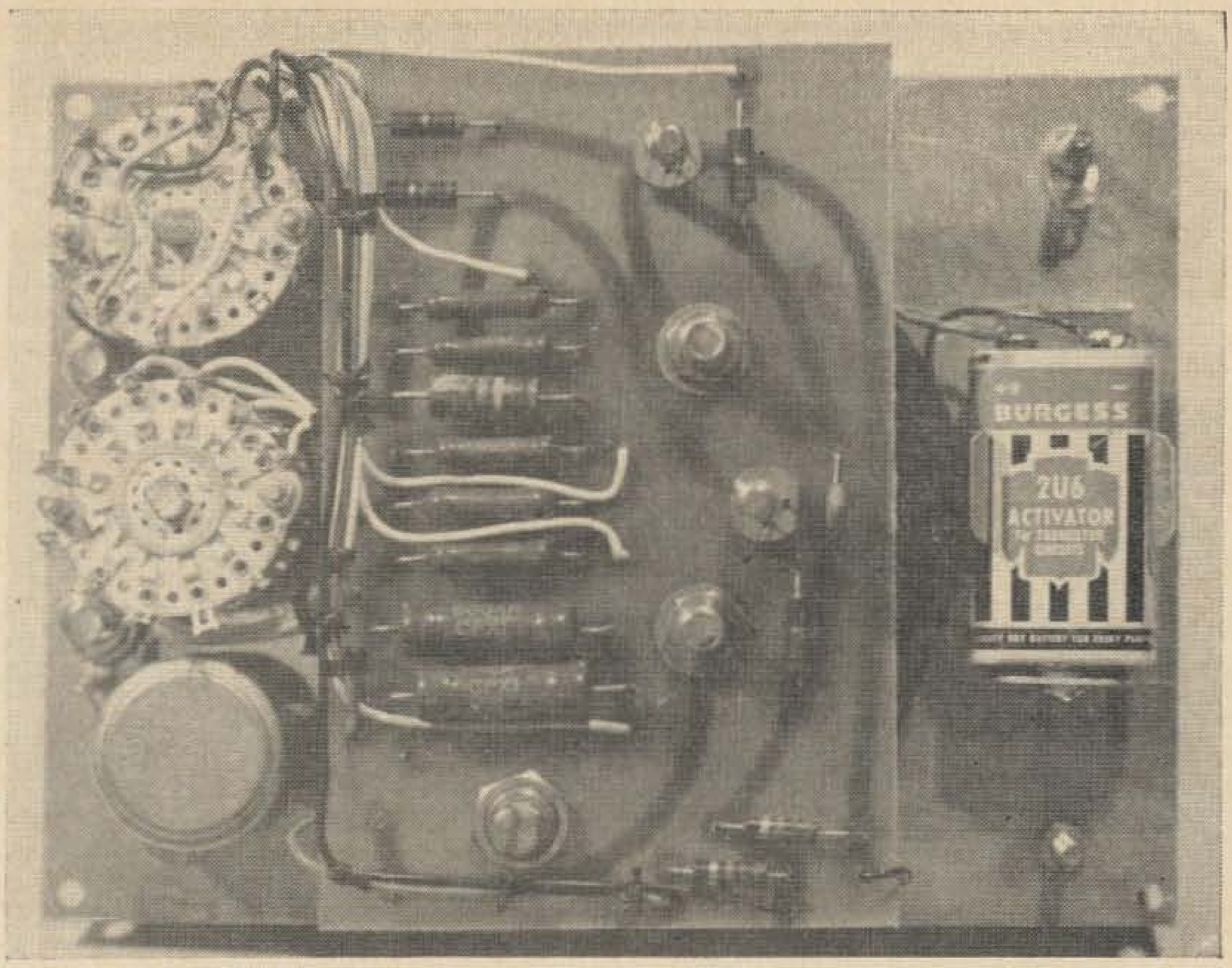


Fig. 1. Simple-to-build high impedance voltmeter using field effect transistors (FET's). Input impedance is 22 megohms. You can build the circuit on an etched circuit board using the plan in Fig. 2, or buy a low leakage, fiber glass board from the Harris Company, 56 E. Main St., Torrington, Connecticut, for only $2. Although these FET's are drawn as N-Channel devices the U-112 is a P-Channel field effect and the gate arrow should point in the other direction.

/oltmeter



Inside of the FET voltmeter showing the etched circuit board mounted on the meter terminals. The ceramic switches are recommended for low leakage since the input impedance is 22,000,000 ohms.

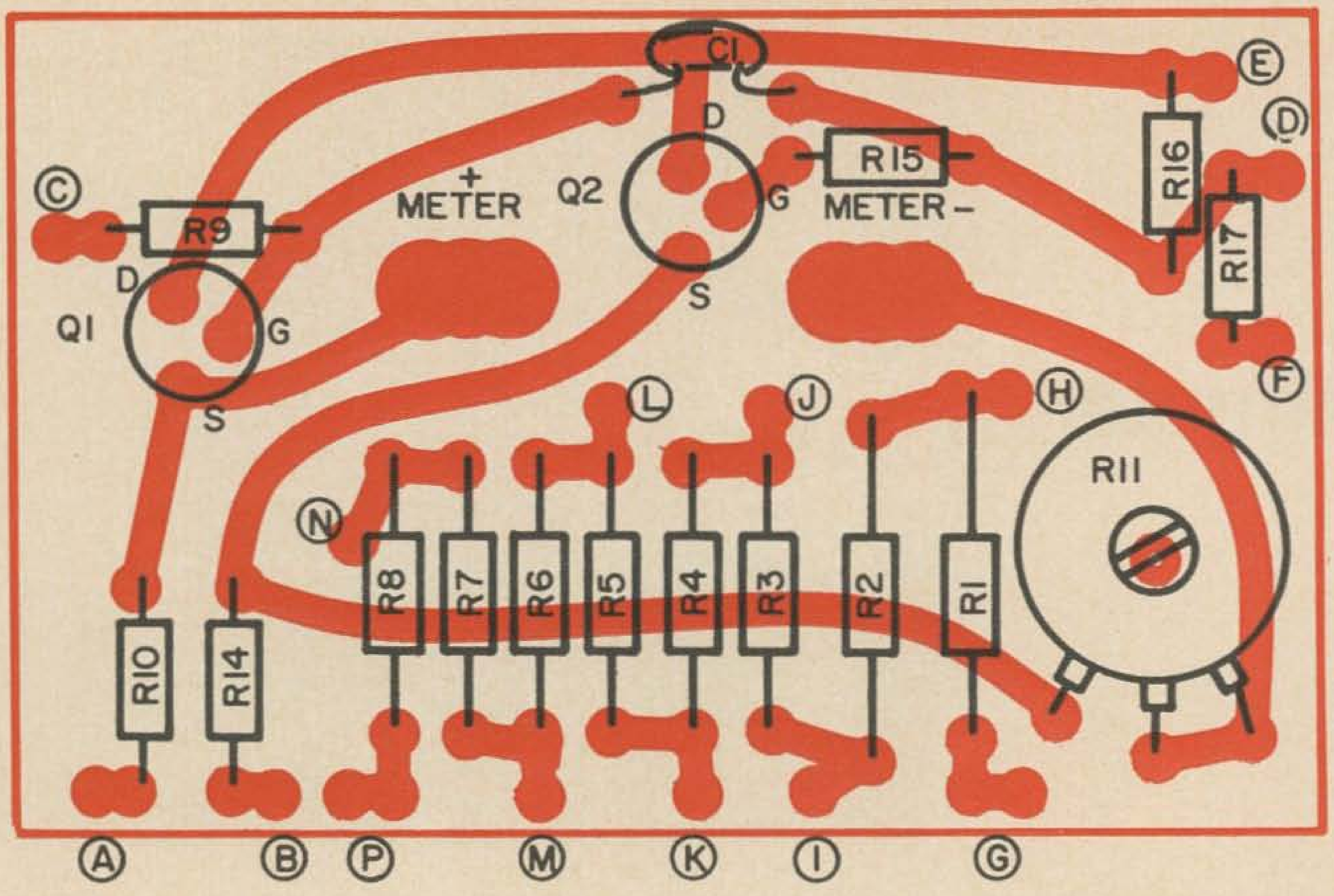
megohms. All this of course means that the FET voltmeter gives a truer reading because it loads the circuit under test less.

The circuit works as follows. FET Q2 is referenced to common or floating ground by R15. When the meter is zeroed by R12, the voltage drops across R10 and R14 are equal so no meter current flows. Effectively then, the gate of Q1 is also at ground, but biased at the correct operating point with respect to its source. Any signal introduced onto the gate of Q1 will change the operating point with respect to Q2 and the voltage drop will change across R10. Since a voltage difference now occurs across the meter a current proportional to the applied voltage will flow. Full scale deflection of the meter occurs with .5 volts input. The voltage divider string, R1 through R8 plus the 2 M. in the probe, is used so that full scale deflection occurs at several different voltages. R11 is the calibrate pot and serves to adjust the meter so that with .5 volts on the gate of Q1 the meter reads full scale. R13, although not needed on my unit, may be required with other FET's. It is used to set the linearity of the voltmeter so that .5 volts occurs at full scale and .25 volts at exactly half scale. R13's function is to slide the operating point up or down the FET's characteristic curve to utilize the most linear portion. Try a 10 k pot at R13 if you have difficulty finding a linear portion of the curve. When a linear scale is achieved measure the resistance required and permanently wire that value into the circuit. Interchanging Q1 and Q2 may help if they are not matched too closely. The meter M1 can be of any sensitivity from 50 μA to 200 μA. But bear in mind that the final accuracy of your voltmeter depends on the use of precision resistors in the voltage divider and also in the basic accuracy of the meter used. Buy the best meter that you can afford. I would also recommend using ceramic switches for S1 and S2 to keep leakage paths to a minimum. All other resistors in the circuit may be half watt 5% carbon.

I won't go too deeply into construction as the photos are self explanatory. Use good construction techniques and if you use a printed board as I have—do by all means clean the board of excess resin after all the parts have been mounted. The resin comes off quite easily with alcohol (not the drinking type), and besides looking professional, it eliminates a source of leakage on your board.

A matched pair of Siliconix U-112 field effect transistors is available from Siliconix, Inc., 1140 West Evelyn Avenue, Sunnyvale, California 94086 for only $6.00. This is a tremendous bargain for these excellent FET's that normally sell for $16.50 in matched pairs.

After you've tried this FET voltmeter, you'll never want to use a vacuum tube voltmeter again. . . . K3LCU



BODY OF R11 MOUNTED ON FOIL SIDE

LETTERS IN CIRCLES CORRESPOND TO POINTS ON SCHEMATIC

Fig. 2. Full size layout of the etched circuit board for the FET voltmeter. Notice that this view is of the component side of the board, so if you make your own board, you'll want a mirror image of it for the copper pattern. Glass board is recommended for low leakage.

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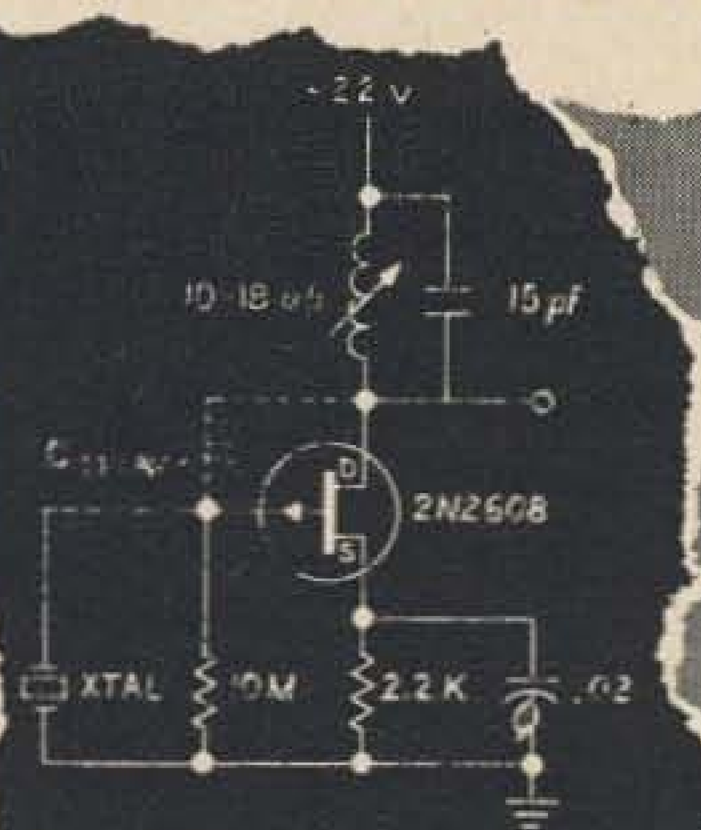
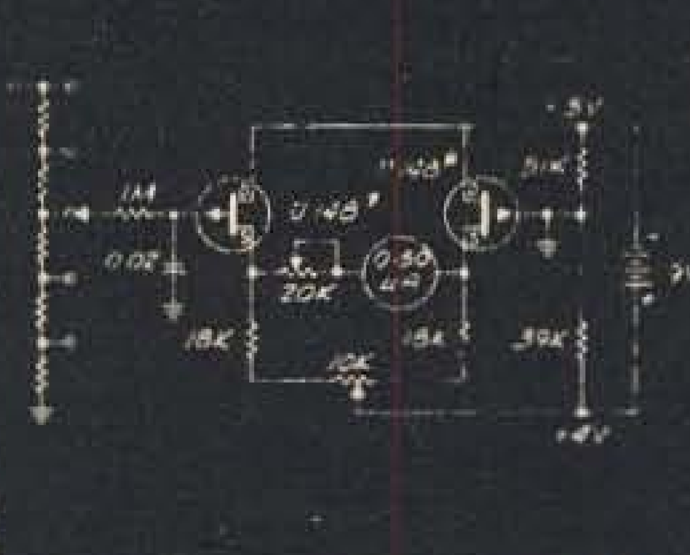
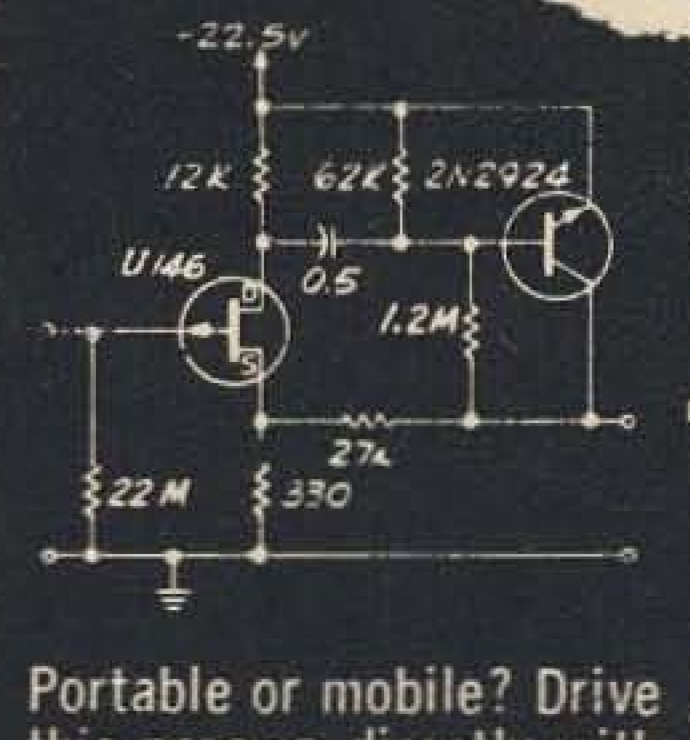


Crystal oscillators are a natural for the high-Z FET. This one is for 10 mc.


This highly sensitive FET voltmeter can have the entire circuit mounted on the meter terminals.



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FET Parameter	I_{DSS}	V_P	BV_{GDS}	g_{fs} (Min.)
Approximate Tube Equivalent	Zero Bias Plate Current	Grid Cutoff Voltage	Max. Plate Voltage	Minimum Transconductance
U110	0.1–1.0 ma	1–6 V	20 V	110 μmho
U112	0.9–9.0 ma	1–6 V	20 V	1000 μmho

Get your FETs now . . . clip this coupon, send with check or money order, and be the first in your block to fool with FETs!

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Bernard Ring, K3VNR
6619 Powhatan Street
Riverdale, Md. 20840

An FET Audio Compressor

Build this simple compressor for higher average modulation from your transmitter. It uses two inexpensive field effect transistors for high input impedance.

Presented here is an audio compressor circuit which makes use of two field effect transistors in conjunction with two conventional (bipolar) type transistors. Simplified circuitry has been employed in order to keep costs at a minimum, but without sacrificing the necessary requirements for good speech compression.

This compressor has a compression range greater than 20 dB, and is capable of handling up to 300 mV input before distortion occurs due to overload. After exceeding the compression threshold, an output change of less than 1 dB will take place for each 6 dB change in input. The high (2.2 megohm) input impedance allows the use of either crystal, ceramic, or high impedance dynamic microphones without the use of additional transformers.

A brief review of compressor circuits

Since this is primarily a construction article and not a treatise on audio compressors no attempt will be made here to analyze the numerous compressor circuits now available and in popular use. However, a brief review of compressor circuits in general may be of some help in understanding why some compressors work better than others. It may also explain why judicious substitution of components will sometimes improve the circuit, but indiscriminate substitution often results in the compressor being relegated to the junk box.

Audio compressor circuits, whether vacuum tube or transistor, make use of a dc control voltage, (either positive or negative) to control either the amplifier gain, or to attenuate the input or output signal of the amplifier by applying the voltage to a control element.

Transistorized compressor circuits can usually be classified into two types. Each type can further be classified into several methods.

In one type the control voltage varies the forward transfer characteristics of the controlled stage by either reducing the emitter current, or by reducing the collector voltage. While these two methods require only simple circuitry, and only a few components, they are subject to some serious disadvantages. For instance, large input signals will result in distortion because the transistor is driven into a non-linear portion of its characteristic curve in an effort to reduce stage gain.

In the second type the circuitry is usually a little more complex, but the results are also usually more rewarding. Here again, any one of several methods may be used.

In this type of compressor the dynamic resistance of a diode or a transistor is varied by the control voltage and made to act as a variable resistor. The voltage-variable resistor may be placed across the amplifier input circuit to shunt a portion of the input signal to ground, or it may be placed across the output circuit to shunt the output voltage to ground. The voltage-variable resistance element may also be connected either in series or parallel with other circuit components carrying signal voltages to either attenuate the signal, or to "switch" the component in or out of the circuit to reduce the stage gain.

Since in this type of compressor the variable-resistance element is usually isolated from the

Bernard, former W2GRK and W2HPO, has been licensed since 1933. He's a research analyst with the Department of Defense in Washington.

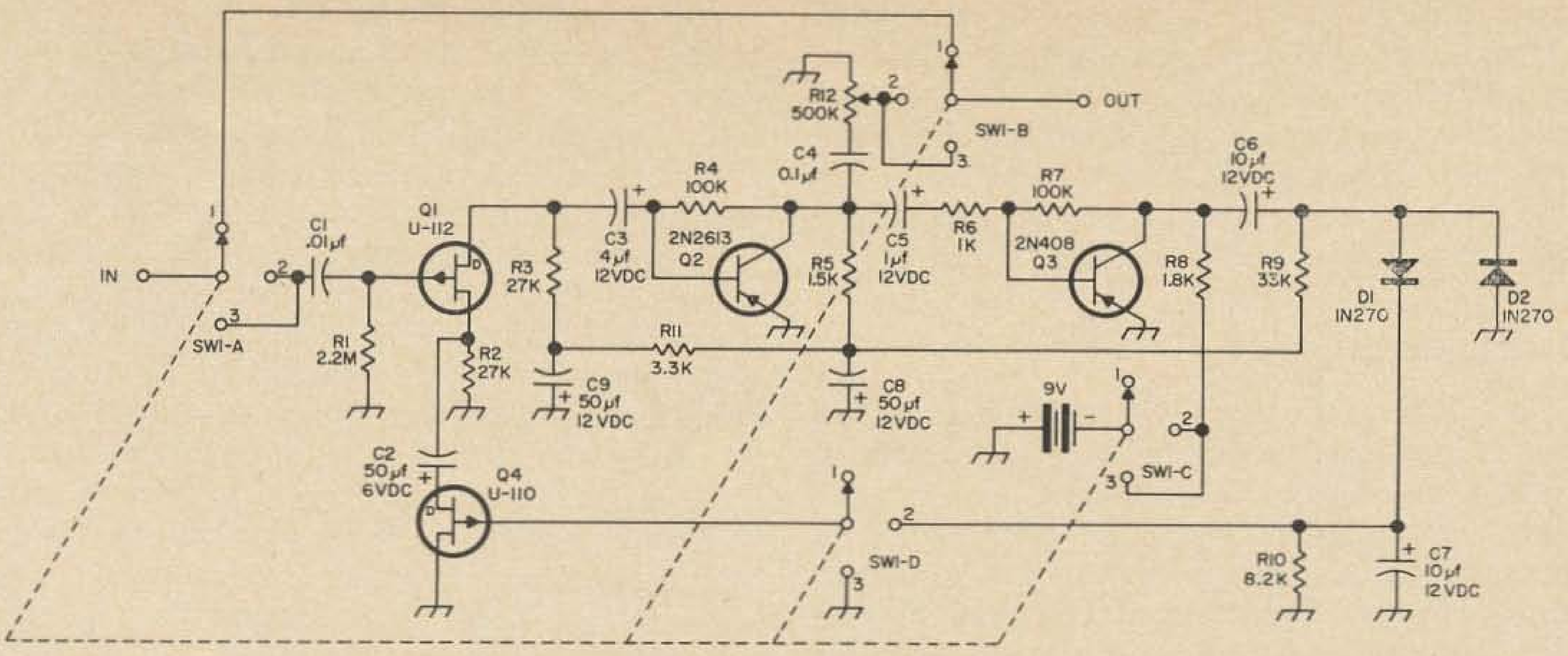


Fig. 1. Schematic of the FET compressor. There should be a dot indicating a connection at the cross-over between R8 and SW1-C.

dc circuits, the operating voltages and currents are not effected by the application of the control voltage. However, there is a possibility that with some methods noise produced by the control element may be introduced into the signal path.

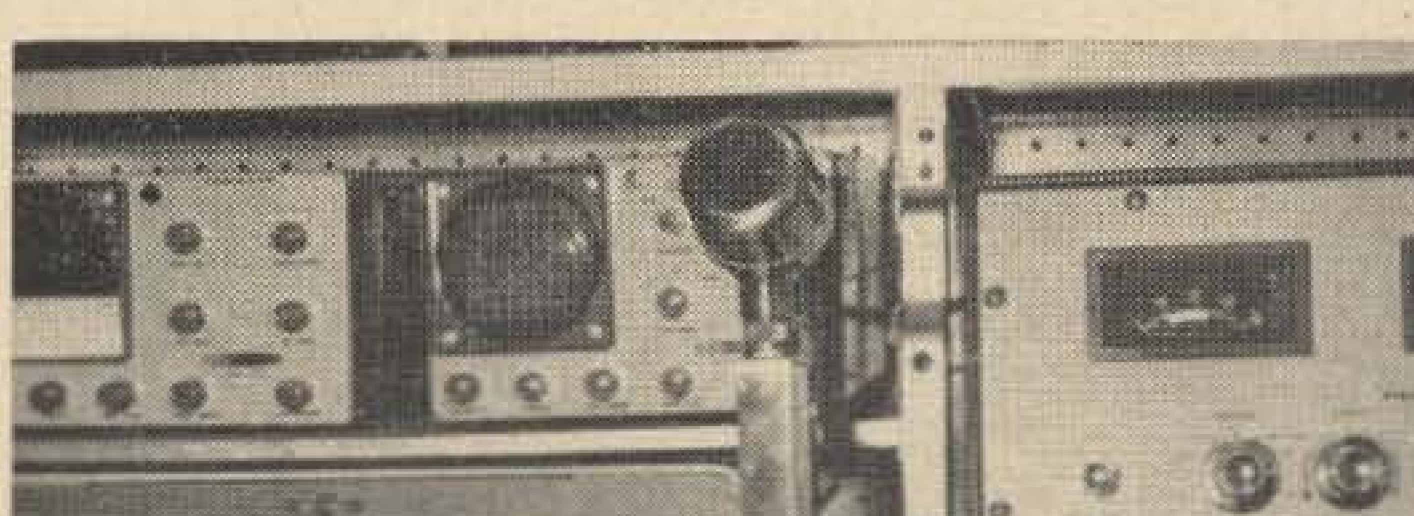
Of great importance to the proper operation of any compressor is the time constant circuit of the control voltage loop. Not only does this circuit determine the attack and release times of the controlled stage, but it must also filter the rectified ac voltage so that the control voltage will be reasonably free from ripple.

The attack and release times of some compressors may differ by as much as several hundred percent from the ideal. The ideal attack time should be about 1 msec or faster to prevent overshoot on steep wave front signals. In some circuits such a fast attack time could cause transient "thump" due to the inability of the amplifier to follow rapid changes in current or voltage.

Release times are usually made longer than the ideal time of 10 msec. If the release time is too fast the amplifier will recover before the lower audio frequencies have been filtered out. On the other hand, if the release time is too slow a weak syllable following a strong one will be compressed just as much as the strong one.

The compression range will depend on the circuit used and may vary from only a few dB to as much as 60 dB. The choice of compression range will depend upon the application of the compressor. A small amount of compression will limit audio peaks but will add little to the improvement in "talk power." Too much compression on the other hand will make the signal sound harsh. For speech compression a range of about 15 to 21 dB has been found to give the best results.

At this time perhaps one of the more popular misconceptions about audio compressors should be clarified. There seems to exist among many people the idea that the audio compressor will increase the peak power output of a transmitter. This is not quite true. Compression will improve the peak power output only if the low level audio stages of the transmitter have been deficient, or the microphone output level had been too low to supply sufficient audio to the transmitter, and then only because most compressors also act as audio preamplifiers. The primary purpose of the compressor however, is to improve the average power, or "talk power" of the transmitter by providing additional amplification to soft spoken syllables, and by reducing the amplification of loud syllables so that peak power



The FET compressor in use at K3VNR's shack.

output is attained over a greater percentage of the time. This higher average output will show up in SSB in on-the-air reports that the receiver S-meter appears to "hang" close to the peak with only a slight variation between syllables. It will also show up on the transmitter plate current as a higher average reading.

Circuit description

The heart of the audio compressor described here consists of a pair of field effect transistors, the Siliconix U-110, and U-112, which were recently made available for the price of $2.75. Replacing these FET's with bipolar transistors would require sophisticated circuitry to perform the same functions, and at a considerably greater cost. By using the U-112 as the controlled amplifier stage it was possible to achieve a high impedance input, (2.2 megohms) without the use of an input transformer or an additional emitter follower stage. The U-110 in this case functions as the voltage-variable resistor to control the amplifier stage gain through the application of negative feedback to the source of the controlled stage. In addition to the 20 dB of compression previously mentioned, the result is a low noise, low distortion preamplifier with high gain.

No noise measurements were made, but scores of on-the-air tests proved to be very gratifying in this area. Also, although no extensive distortion measurements were conducted, cyclogram tests indicated negligible distortion.

The signal after being amplified by Q1 is further amplified by Q2, a 2N2613. This is a low noise transistor especially suitable for preamplifier circuits. The forward bias resistor R4 of this stage is connected between the base and collector in order to reduce the number of circuit components and still achieve some measure of stability.

This photo shows the small size of the compressor board (1½" x 2½"). The RF filter mentioned in the text is mounted at the left.

After amplification by Q2 the audio signal to the transmitter is taken off through the level control R12. Since even after compression the output voltage will still show a gain of 6 to 9 dB the level control is used to reduce the output to a suitable level for the transmitter.

A portion of the signal from Q2 is also amplified by Q3 to a higher level which is then rectified by D1 and D2 to become the dc control voltage. No attempt should be made to take the audio signal from the output of Q3 since the signal at this point is in the form of a square wave and will sound highly distorted.

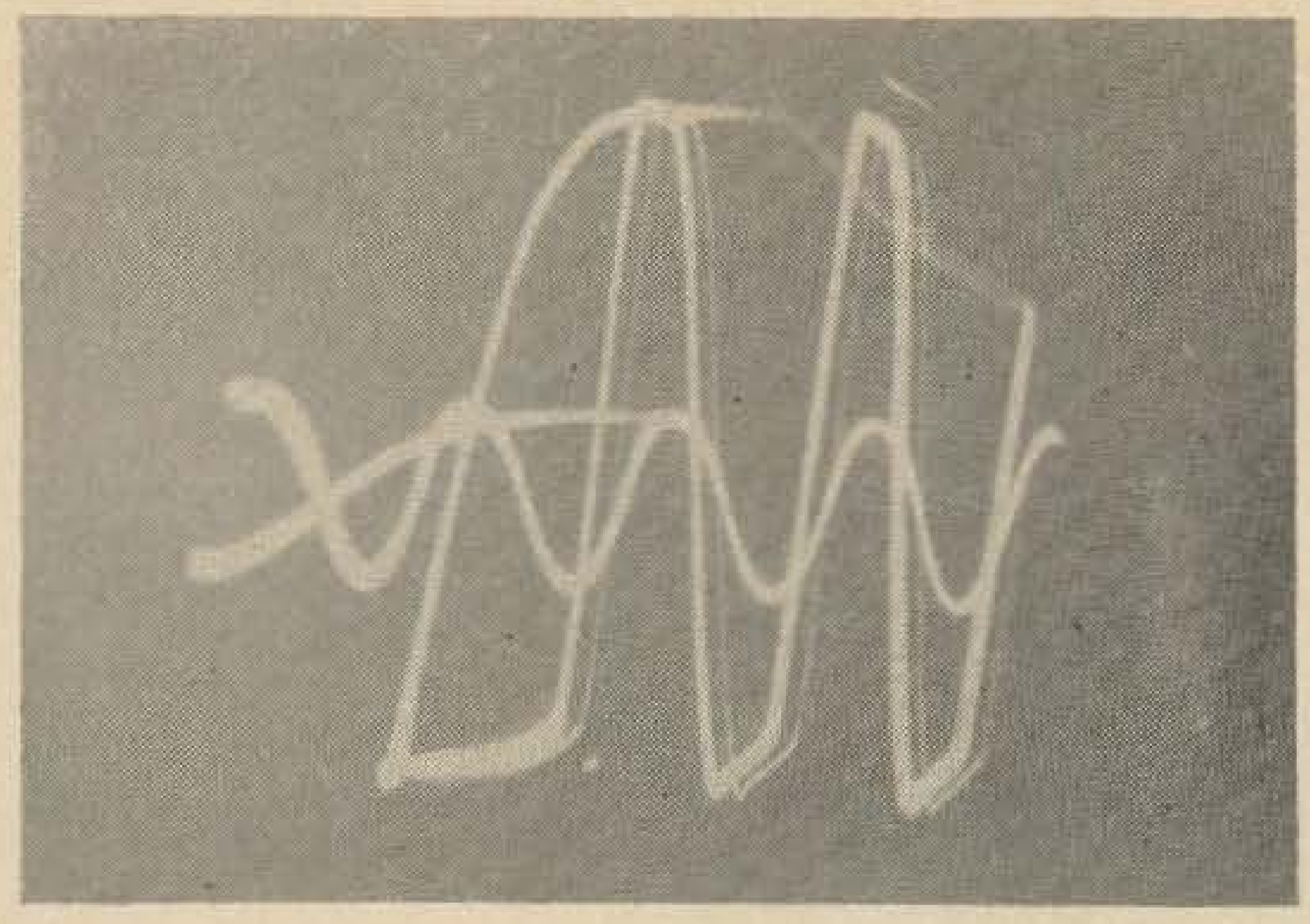
Notice that the forward bias resistor for this stage, like that of Q2, is also connected from collector to base. This means that a small amount of ac voltage will be fed back from the collector to the base and will also appear at R6. R6 will isolate this small amount of feedback so that it will not appear at the audio output as distortion. If the audio output is viewed on an oscilloscope, this distortion, if present, will appear as a bright spot at the baseline cross-over in mild cases, and in severe cases the baseline will actually show. Increasing the value of R6 will prevent this type of distortion but will also lower the available ac voltage at the base of Q3.

The output from Q3 is rectified by D1 and D2 and the resultant dc voltage is filtered by C7. This dc voltage is the control voltage which varies the drain-source resistance of Q4. Besides acting as the dc filter, C7 in combination with R10 sets the time constant of the control loop.

When a positive potential is applied to the gate of Q4 the drain-source resistance is increased, effectively switching off C2 which is the source bypass capacitor of Q1. When R2, the source resistor, is unbypassed an ac voltage drop is developed across the resistor and the gain of Q1 is reduced. With R2 in an unbypassed state negative feedback occurs and the percentage of harmonic distortion is reduced by an amount which is almost equal to the amount of compression.

When the amplifier gain is reduced the control voltage is also reduced and C7 discharges through R10. The bypass capacitor C2 is now "switched" back into the circuit and the amplifier recovers. Recovery time is determined by C7, R10 which has a time constant of approximately 82 msec.

In reality C2 is not switched in and out of the circuit by Q4 since Q4 has an irreducible amount of internal resistance between the source and the drain. However, since a switch is characterized by low resistance when it is closed, and high resistance when it is open, then for all practical purposes Q4 with its rise



This oscillogram was made by driving the amplifier to overload distortion, then switching in compression. Note the lack of distortion when compression is applied to the signal. What appears to be phase shift is a result of the method used to get this photo and is not caused by the compressor.

and fall in drain-source resistance is switching C2 on and off.

One of the advantages of this circuit is, that because Q4 is capacitor-coupled to the source of Q1 there is no change in bias current and therefore no distortion due to driving Q1 into the nonlinear region. Another advantage is that the sudden application of control voltage will not cause an objectionable transient thump.

The circuit does have a minor fault, but one which will have no effect on normal operations. As the input voltage is increased the control voltage will approach pinchoff, and "remoting" will take place .This is because Q4 will be operating in the "remote" region of the characteristic curve. In this region, as the positive potential to the gate is increased there will be no increase in the compression range since the FET does not follow square law behavior at low drain currents and there is no sharp cutoff. This, incidentally, may illustrate the difference between "pinchoff" as applied to the FET, and "cutoff" as applied to a triode vacuum tube when the grid bias is increased. This small fault should cause no trouble when the compressor is used with a microphone input since the voltage developed by the microphone will never reach a level where "remoting" can take place, and is only mentioned here as a point of interest.

Construction And Testing

No difficulties should be encountered in constructing this unit. With the exception of the switch and output level control, all components, including an RF filter not shown in the circuit diagram, were mounted on a piece of perf-board measuring 1½ x 2½ inches. An RF filter was included in the final construction as an added precaution against stray RF being picked up and rectified, but this filter may not be necessary in all cases.

Wherever possible the components were mounted in a vertical position in order to conserve space. With double-ended components, such as resistors, and some capacitors, the technique is to bend one lead back towards the body of the component so that both leads will face in the same direction, thus forming a single-ended component. The two leads are then placed in adjacent holes in the perf-board.

Although the unit is compact enough to be mounted in a small Minibox, one measuring 4 x 5 x 6 inches was used. This large size Minibox allows the controls to be mounted conveniently on the front panel without crowding, and also allows the use of a larger sized battery. Instead of chassis type of connectors, cable type connectors attached to short pieces of shielded mike cable were used. This eliminates the use of a patch-cord between the compressor and the transmitter, and permits easy changes to be made in the future in the event that a new transmitter might use a different type of mike connector.

The test procedure is quite simple. A VTVM, and oscilloscope (if available) is connected to the output. A 400 Hz audio signal is fed to the input. If a signal generator is not available a microphone picking up a beat note from a receiver will suffice.

The compressor switch is turned to position three and the audio input level is adjusted to give an output reading of 100 mV with the output level control turned full up. With the switch in this position no compression is being applied to the signal. Note the waveform and amplitude of the signal on the oscilloscope; the display should show a pure sine wave.

Without further adjustment of the input signal, turn the compressor switch to position two. With the switch in this position compression is now being applied to the signal. The output reading should drop to 18 mV for 15 dB of compression. The oscilloscope display should also indicate this drop in output, and waveform should remain a pure sine wave but lower in amplitude.

Switch the compressor back to position three and increase the input signal so that the output now reads 200 mV. This is an increase of 6 dB in output which also roughly corresponds to a 6 dB increase in input since at these signal levels the amplifier gain is quite linear. Again note the oscilloscope display.

Without changing the input signal switch the compressor to position two to apply compression. The output reading should now be about 20 mV indicating 20 dB of compression.

Except for a lower amplitude the oscilloscope pattern should remain the same. Note that although the input signal had been increased by about 6 db with no compression, under compression the output signal change was about 1 dB.

This completes the testing, but an interesting little experiment can be conducted here by carrying these tests to the point where "remoting" takes place. It is also interesting to see that when the input is increased to a point where overload distortion takes place with no compression, by switching in compression the overload distortion will disappear. This is because negative feedback is now applied and a new input level is set for overload distortion.

Operation

Because there is only one control to adjust, the output level control, operation is virtually self-explanatory.

With the compression switch in position one, speak into the mike and adjust the transmitter audio gain control for proper operation. Since the mike is feeding straight through to the transmitter the audio gain control should be at the usual setting.

Turn down the compressor output level control and turn the switch to position two. Speak into the mike and slowly turn up the output control. Proper setting for this control will be indicated on the transmitter when full modulation is reached. If VOX is used, and if it had been marginal before, back off a little on the transmitter audio gain control as the compressor output level control is advanced. A few minutes of adjusting should show the proper settings for the audio gain control and VOX controls of the transmitter, and the output level control of audio compressor.

Note that when the compressor is first turned on an initial transient surge will render the compressor momentarily inoperative, but the amplifier will recover rapidly. Also note that position three of SW1 is not used during operation.

Conclusion

Although a 9 volt battery supply was used in the design of this compressor, voltages ranging from 6 to 12 volts have been used successfully. An ac pack could be used providing it is well filtered. The power source could also come from the transmitter filament transformer by using a pair of diodes in a voltage doubler circuit, and a proper filter. Bear in mind though, that any additional leads brought into the Minibox could introduce ac hum, and stray RF pickup.

If compressor is to be operated directly from a 12 volt car battery in a mobile installation, all 12 volt capacitors should be changed to 15 volt units. Also observe proper ground polarity; since the circuit as shown in the diagram has a positive ground.

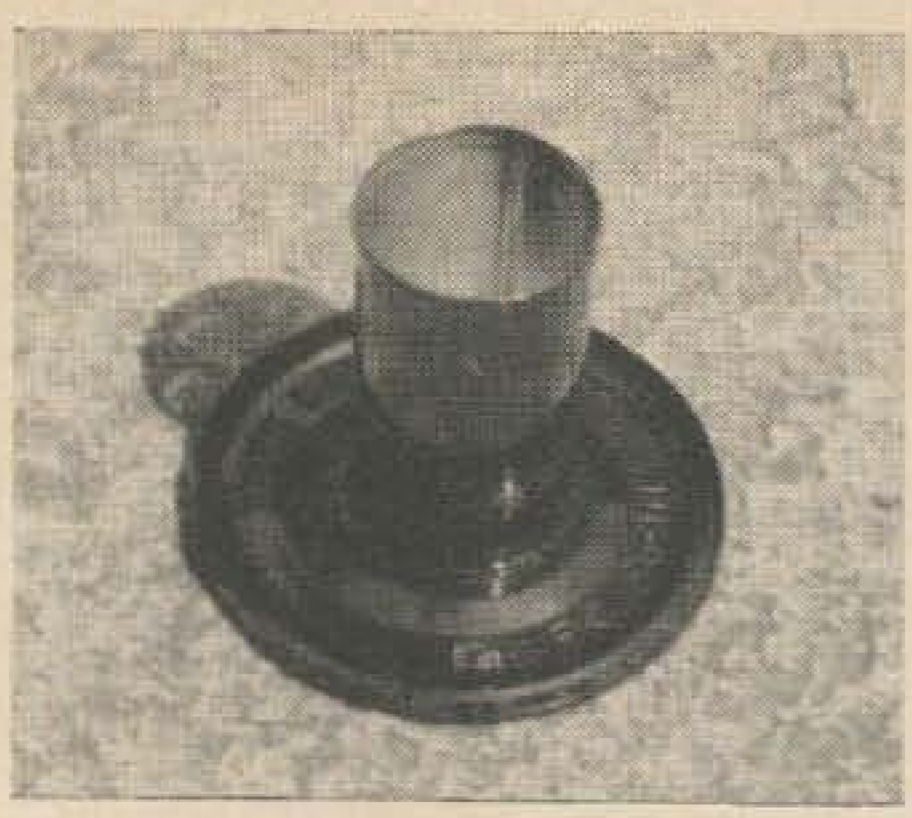
Only the U-110, and U-112 FET's were tried in this circuit. Undoubtedly with minor component changes other FET's will work just as well. In any case Q4 should have a low pinchoff.

The diodes D1, D2 have been specified as 1N274's, but other diodes, including the "dollar a dozen" variety, were tried with satisfactory results.

Resistor R9 sets the compression threshold. A higher resistance will lower the threshold. Replacing R9 with a combination fixed and variable resistor will allow the threshold to be adjusted.

Several other refinements, such as a meter to read compression, could be made, but the additional cost would defeat one of the primary aims, a low cost audio compressor.

. . . K3VNR



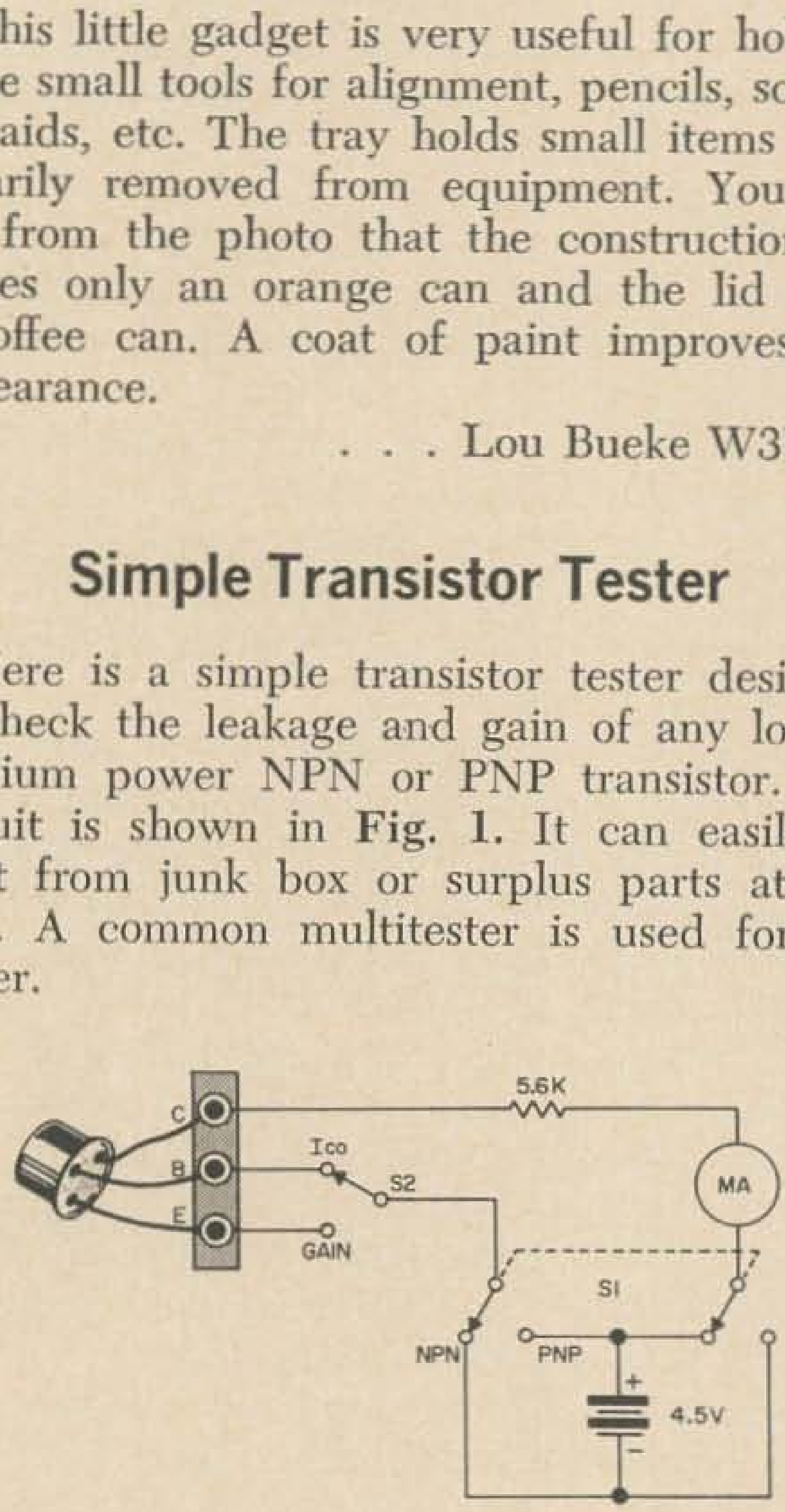
Tool Holder

This little gadget is very useful for holding those small tools for alignment, pencils, soldering aids, etc. The tray holds small items temporarily removed from equipment. You can see from the photo that the construction requires only an orange can and the lid from a coffee can. A coat of paint improves the appearance.

. . . Lou Bueke W3UGR

Simple Transistor Tester

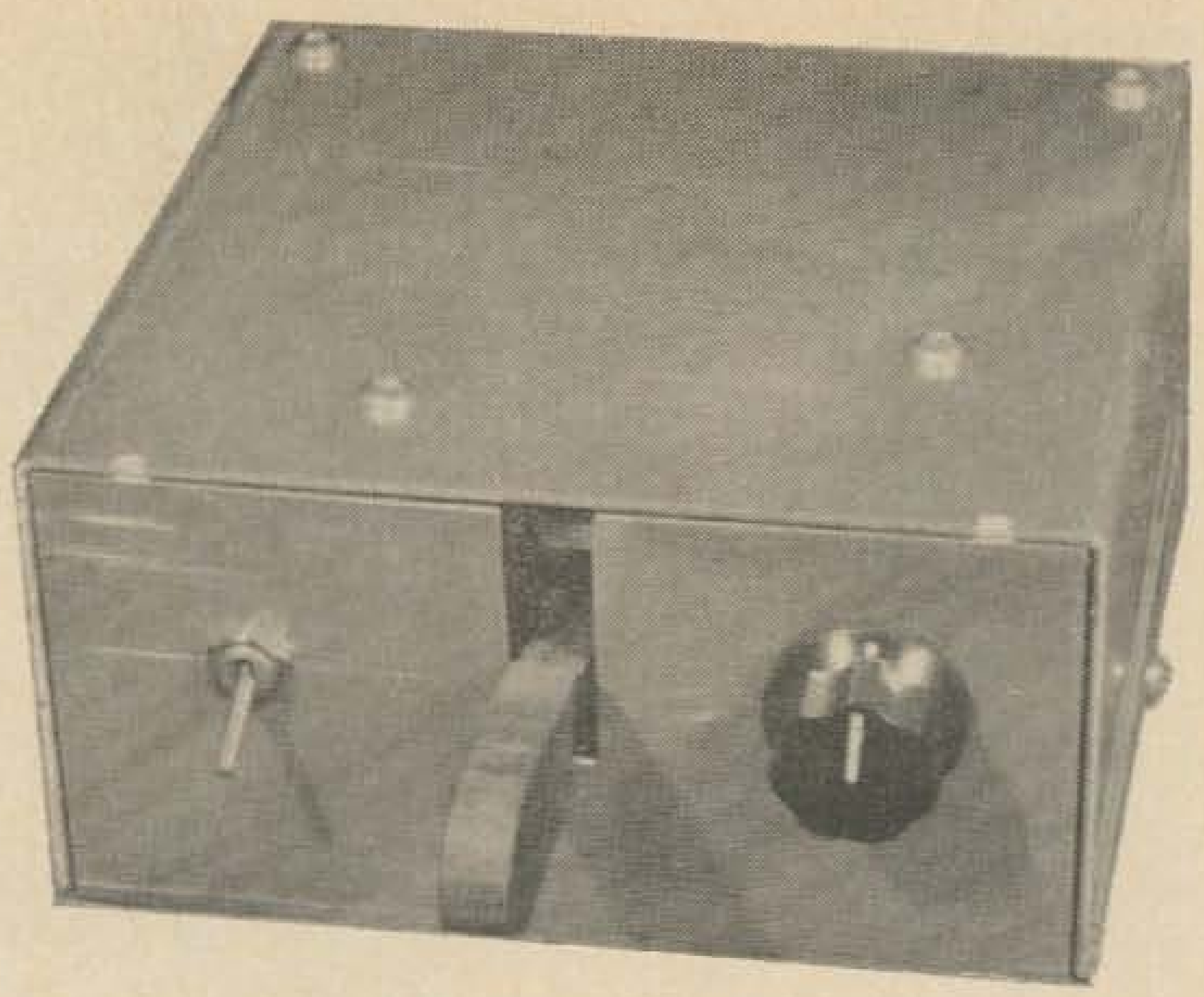
Here is a simple transistor tester designed to check the leakage and gain of any low or medium power NPN or PNP transistor. The circuit is shown in **Fig. 1.** It can easily be built from junk box or surplus parts at low cost. A common multitester is used for the meter.



To check transistors for Ico (leakage), set switch S_2 to Ico and S_1 to PNP or NPN depending on the type of transistor. Insert the transistor in the socket, being careful not to short the leads. If the meter reads over 250 μa for transistors other than power transistors, the transistor is defective. Low power transistors should have very little leakage, 1-5 μa. Medium power ones have more, up to 10 μa.

If you don't know whether the transistor is PNP or NPN, use the lower setting as you switch from NPN to PNP. To check for gain, push S_2 to Gain. The meter reading should be 20 to 40 times the value of Ico as read before.

. . . Ralph Sergo K2PYE



George Daughters WB6AIG
1613 Notre Dame Drive
Mountain View, California 94040

The Kindly Keyer

This electronic keyer is similar in block diagram to the popular "Bugless Bug"[1] and uses approximately the same techniques to generate the signals. It is kind to the pocketbook and to the operator. It has a speed range of 1 wpm to a rate far exceeding 100 wpm!

It was developed in response to a question by K7UTF, "VT" Green, and uses the low-priced silicon epoxy transistors and micrologic elements now available from Fairchild. The total cost is on the order of $30.00 with all *new* parts if you have a machinist friend (or some dexterity) to provide a paddle.

George, former K9KDE, is a research assistant (BS, Illinois) at Palo Alto Medical Research Foundation. He enjoys home-brewing (his rig is all transistor-all home brew) and CW contests.

Operation

Moving the paddle to the "dit" position causes the saturating switch Q_2 to turn off (μL_{5B} is just an inverter), allowing the blocking oscillator Q_1 to run, providing a series of very short negative pulses to the pair of inverter amplifiers μL_{1A} and μL_{1B}. These produce a fast rise and fall time suitable for toggling the flip-flop, μL_2.[2] The output of the

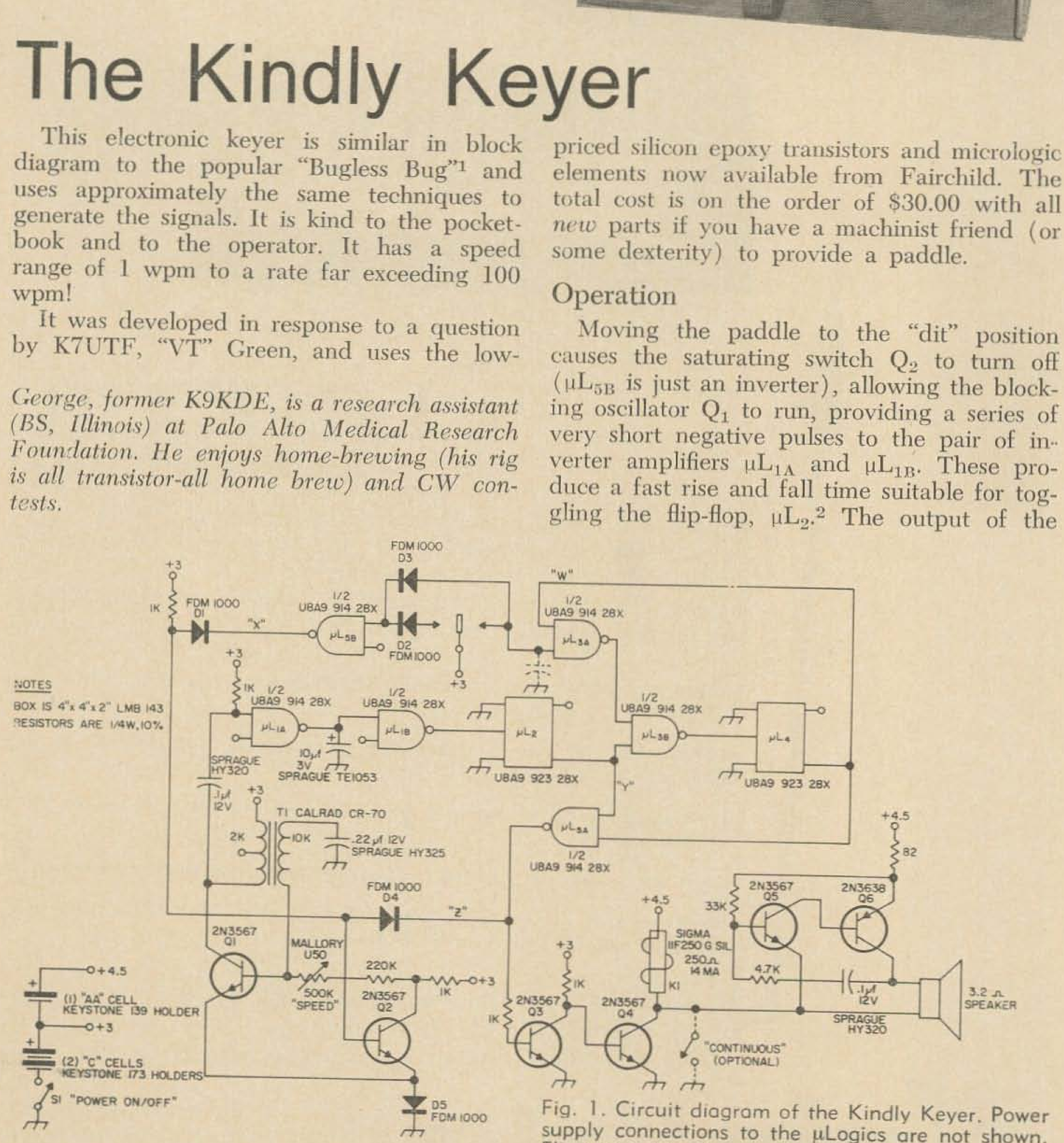


Fig. 1. Circuit diagram of the Kindly Keyer. Power supply connections to the µLogics are not shown. Eliminate dotted capacitor. Label connections to µL2 and µL4 S, T and C from the top. See Fig. 2.

flip-flop is inverted by μL_{5A} and fed to the inverter Q_3 and relay driver Q_4. Thus the relay (and the monitor—a version of G.E.'s "Transistor Manual" audio oscillator) are keyed at a rate which is ½ that of the blocking oscillator. (The flip-flop toggles only on negative going slopes.)

For dahs, all of the above happens, but the gate μL_{3B} allows the second flip-flop μL_4 to toggle also and the output of this flip-flop is combined with μL_2's output to make a dah.

To obtain self completion of a dit or dah, the output of μL_{5A} "Z" is used to keep the blocking oscillator going as long as a figure is in progress. The flip-flop μL_4 is assured of returning to the proper state by keeping the gate μL_{3B} open until a dah is completed.

Construction

The author's unit (**Fig. 1**) is built on a p c board as shown in **Fig. 3**. It can be easily "hard wired", of course. The parts layout shown is convenient, leaving room for the paddle mechanism. Micrologic wiring is a pleasure since all one does is hook wires where he wants the signal (or supply voltage) to go. To indicate the savings in parts here, the actual schematic of the flip-flop is shown in **Fig. 2**. The author's unit, with 3 dry cells and

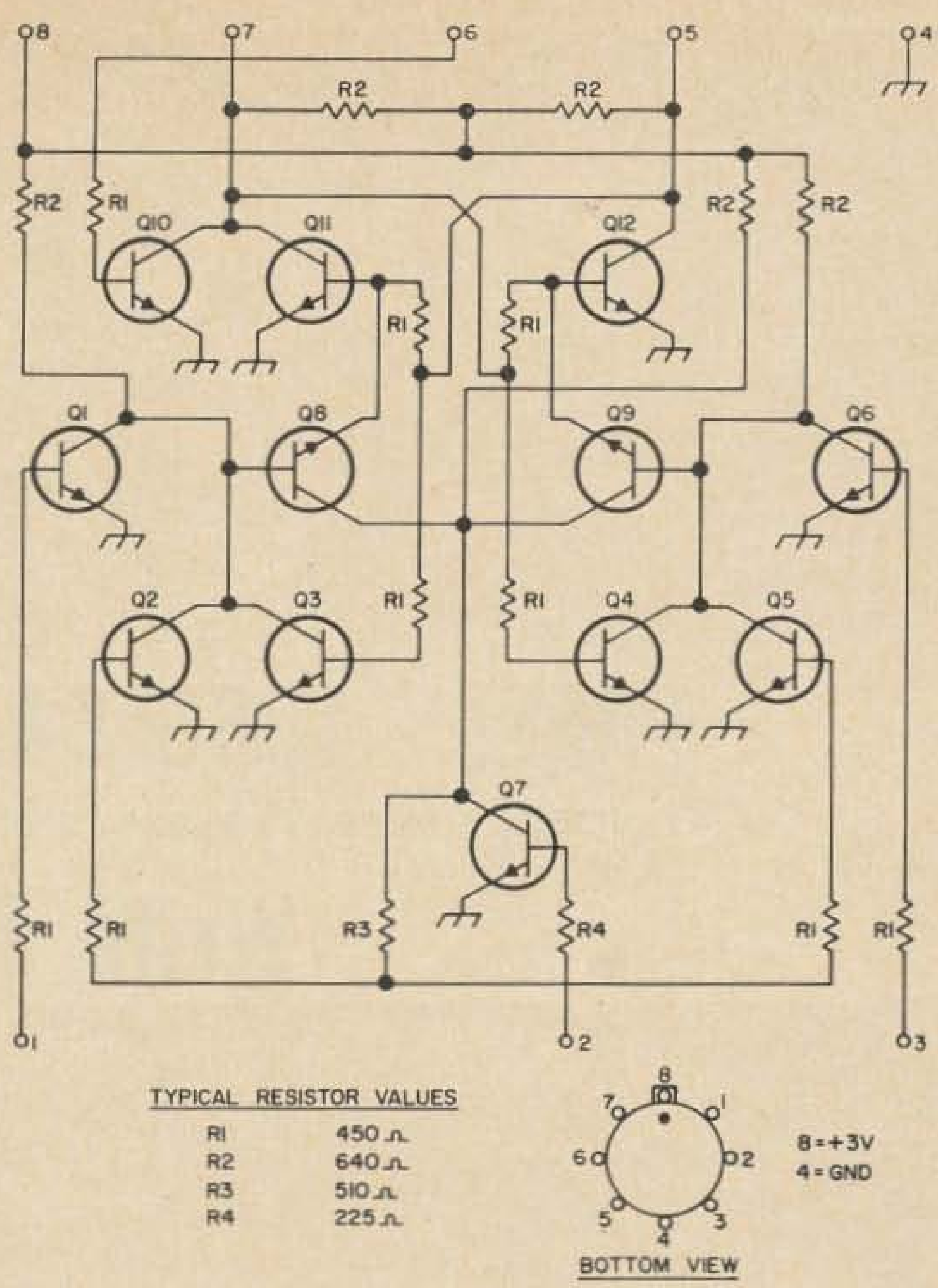
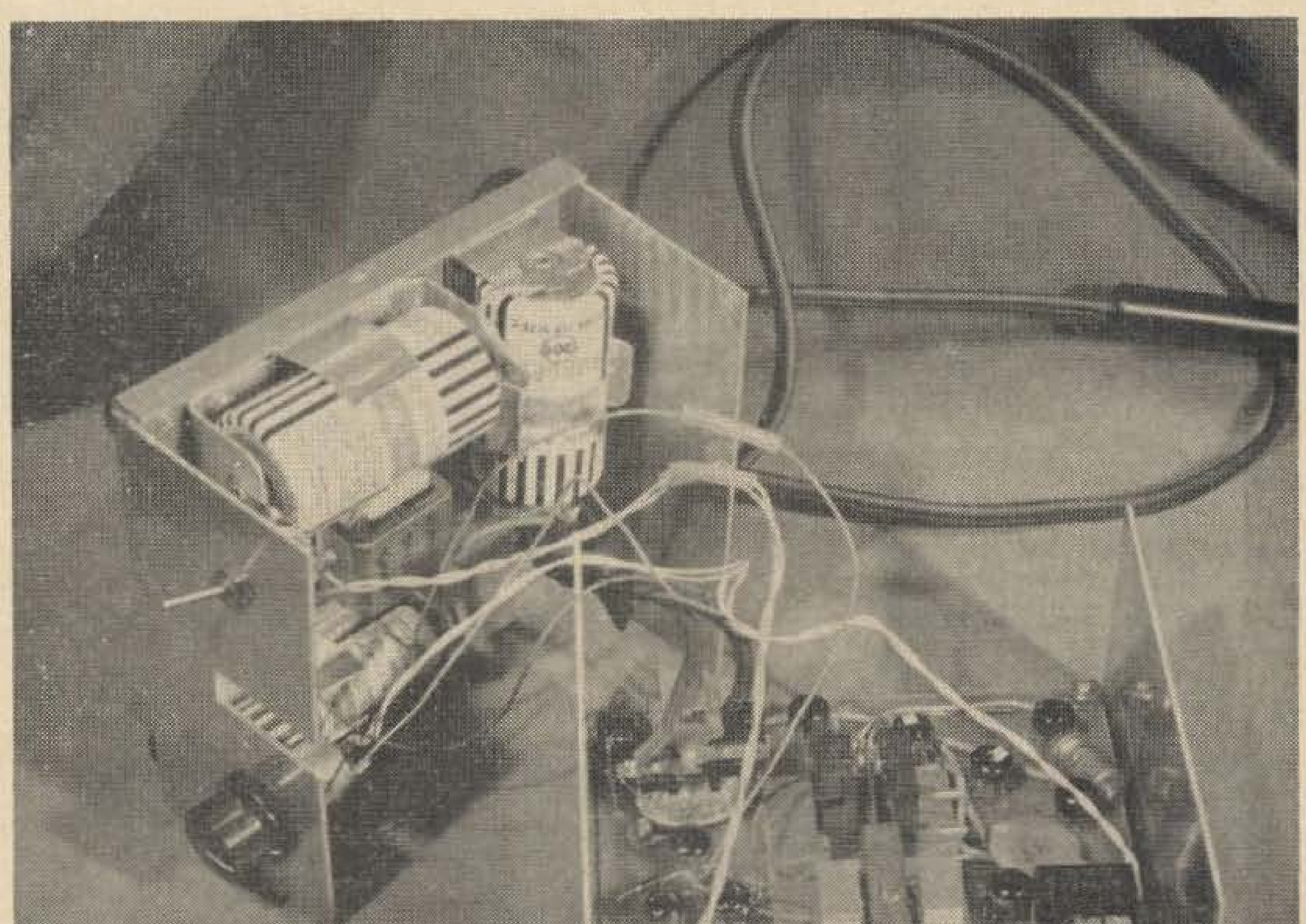


Fig. 2. Schematic and basing diagram of the fip-flop used in the Kindly Keyer. A look at this well illustrates the advantage of integrated circuits over individual components.



Here's the Kindly Keyer opened up to show the etched circuit board with the integrated circuits in place.

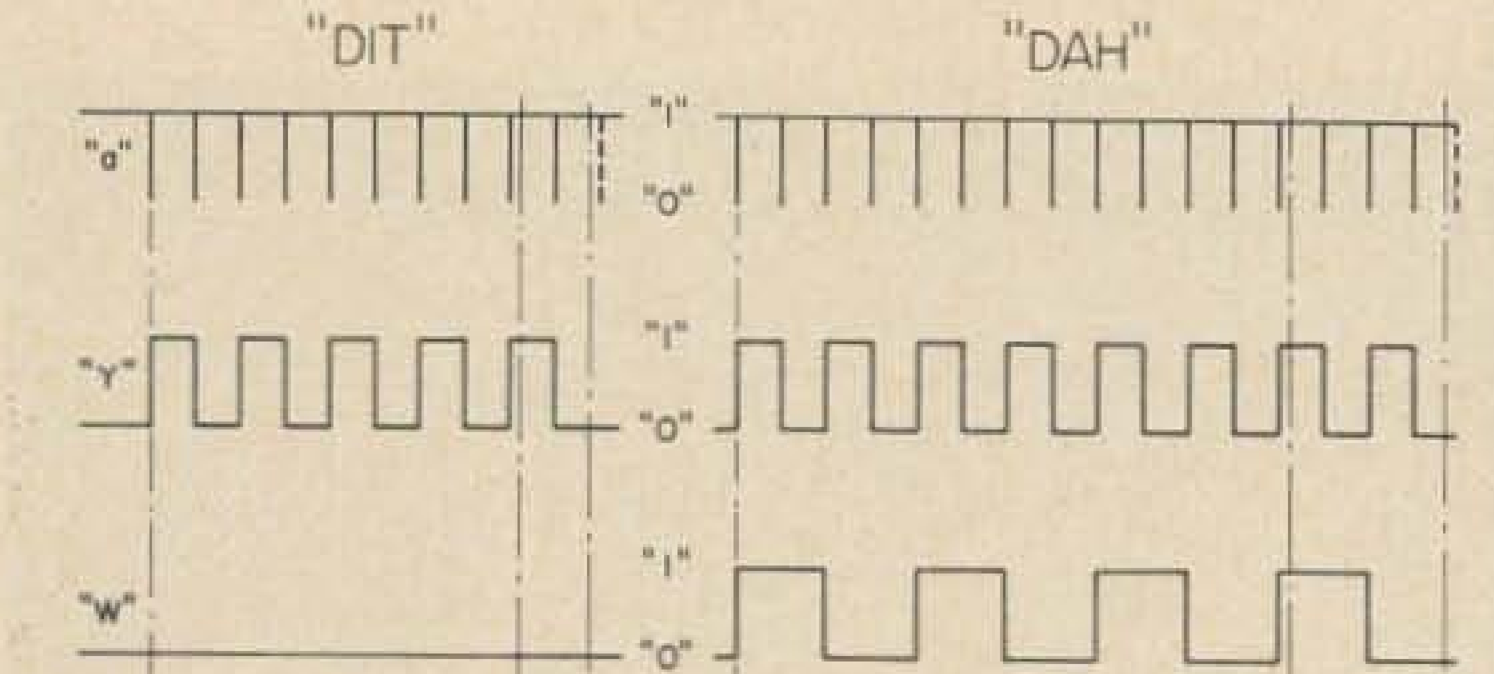


Fig. 4. Wave forms at various points on Fig. 1.

Miscellaneous		
T1 miniature 10K: 2K audio xfmr.	Calrad Cr-70, etc.	.65
K1 relay 250Ω 14 ma	Sigma 11F250 G SIL	1.95
Box, aluminum 4x 4 x 2	LMB 143	1.33
Battery holders	2-Keystone 173	.60
	1-Keystone 139	.23
Switch spst	Continental 6-124 etc.	.32
Batteries	2 "C" cells	.26
	1 "AA" Penlite Cell	.13
	Total New Cost	$27.50

Fairchild epoxy encapsuled integrated circuits.

a 1-¾″ speaker for the monitor, is built in a 2″x4″x4″ box.

Conclusion

An electronic keyer whose electrical quality and operation are not exceeded by any on the market has been described. The little unit has only one disadvantage—it draws quite a bit of current. With the unit on but idling (since there are about 15 transistors saturated), it draws about 60 ma from the 3V supply. That is why "C" cells were chosen. During a dit or dah, this changes negligibly but all cells are then delivering relay and tone oscillator current, about 25 mA.

The size, weight, cost and operation of the unit are just right for carrying to the examiner's office for an extra class exam!

. . . WB6AIG

[1]"The Bugless Bug," Gilbert L. Boelke W2EUP QST; September, 1963.

[2]The flip-flop uses a charge storage principle for toggling, and is insensitive to D.C. (or slow) changes in level. See μL923 data sheet.

Transistors		
5—2N3567	at $ .65	$3.25
1—2N3638 Don't use germanium; they are usually too leaky.	......	.46
Diodes		
5—FDM1000	at .44	2.20
μLogic		
2—U8A9 923 28X JK Flip Flops	at 3.95	7.90
3—U8A9 914 28X Dual Two Input Gates	at 1.65	4.95
Capacitors		
2—.1 at 12V Sprague HY 320	at .15	.30
1—.22 at 12V Sprague HY 325	......	.22
1—10μfd at 3V Sprague TE1053	......	.51
Resistors		
1—.5M Variable—Mallory U50	......	1.02
5—1K 1/4W 10%	at .11	.88
1—4.7K 1/4W 10%		
1—33K 1/4W 10%		
1—220K 1/4W 10%		

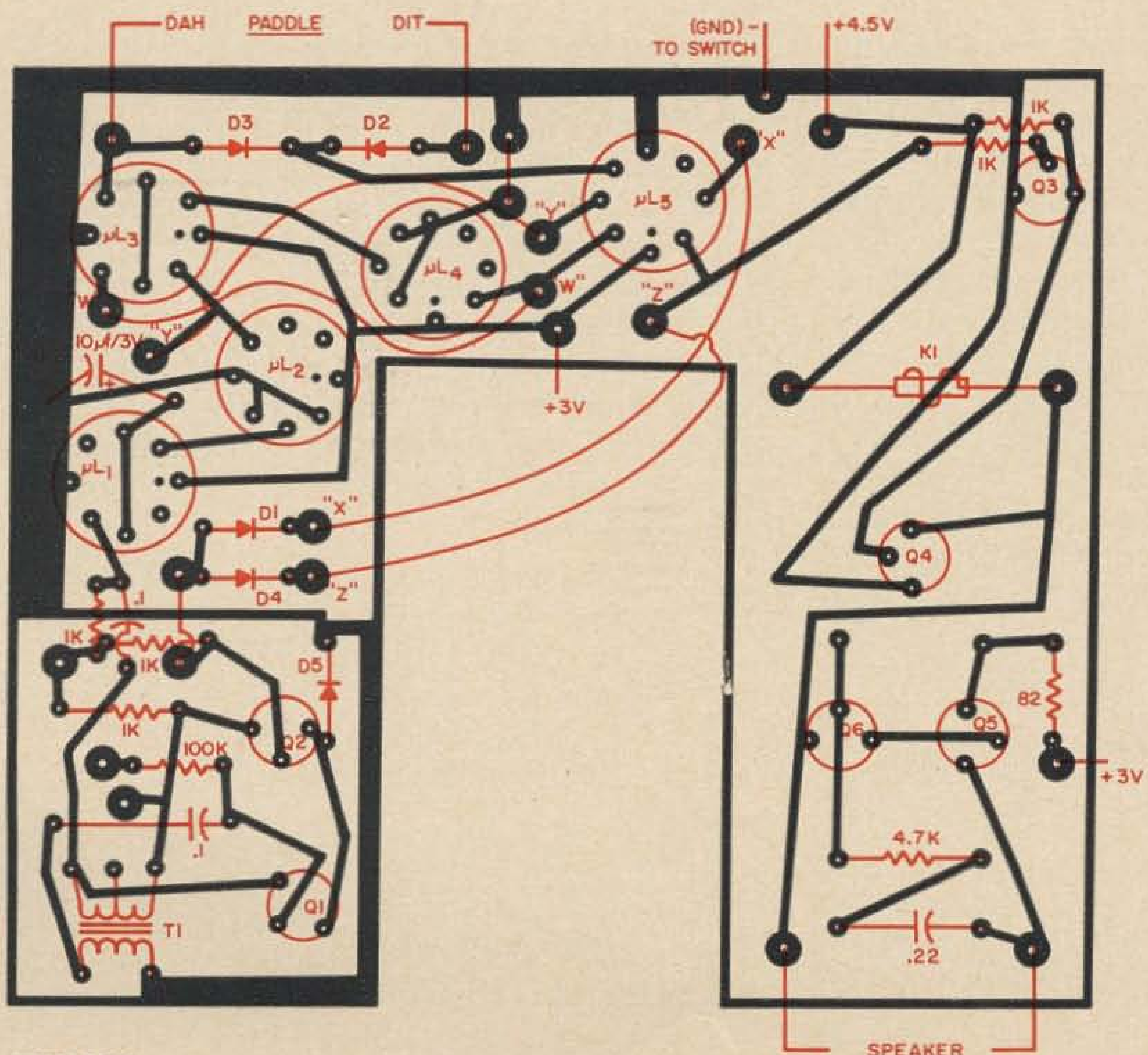


Fig. 3. Full size layout of the etched circuit board used. The components are on the opposite side as this is the copper side.

Don't throw away that silicon transistor with a shorted, open, or broken lead. Use it as a zener diode or varicap (varactor).

Save That Transistor!

E. R. Davisson K9VXL
83 Crestview Drive
Greenwood, Indiana

Need a low cost zener diode? Or how about a low cost voltage variable capacitor (varicap)? How many times have you had the desire to regulate that mobile converter, but didn't want (or couldn't) spend the 2 or 3 dollars additional for a zener diode? Or how about that tunable converter you wanted to remote tune by voltage, but, oh, the price of the varicaps? Well, stop! Remember that silicon transistor with the broken lead, or the one with the open collector, or was it the emitter lead that was open? Anyway, if you threw it away, you could have thrown away that low cost zener or varicap you needed.

First let's see what you could have done for a zener. By reverse-biasing the emitter-base junction of a silicon transistor, you have a very handy zener diode. Some silicon transistors even exhibit better zener diode characteristics than some of the diodes sold specifically as zeners.

Of course, the first obvious test is to determine what the zener voltage is for your specific transistor. Generally, most (there are always exceptions, of course) silicon NPN transistors will exhibit a zener action somewhere between 6 and 11 volts. (Pretty ideal for mobile regulators). **Fig. 1** shows the hookup for determining the zener voltage. A value of 470 ohms for R_s is sufficient to limit the current to a safe value while determining the zener voltage. Connect a variable power supply as shown and connect a VTVM from emitter to base. Notice that the collector is not connected and is not needed in this application. Now, slowly increase the input voltage while monitoring the voltage output on the VTVM. At a specific voltage input, the voltage out will stop increasing. Any further increase in the input voltage beyond this point will now cause only a very slight increase in output voltage. The voltage as read on the VTVM is your zener diode voltage. The next question asked is, "OK, but what range of current can I regulate?" A rule of thumb here is; divide the voltage obtained as the zener voltage into the free air dissipation rating of the transistor. For example, if the transistor zenered at 10 volts and is a 300 mW device, the 10 volts into 300 mW gives 30 mA. This would be a safe operating limit. However, tests indicate that this isn't necessarily the maximum limit, but it is unlikely that you would regulate a circuit drawing more.

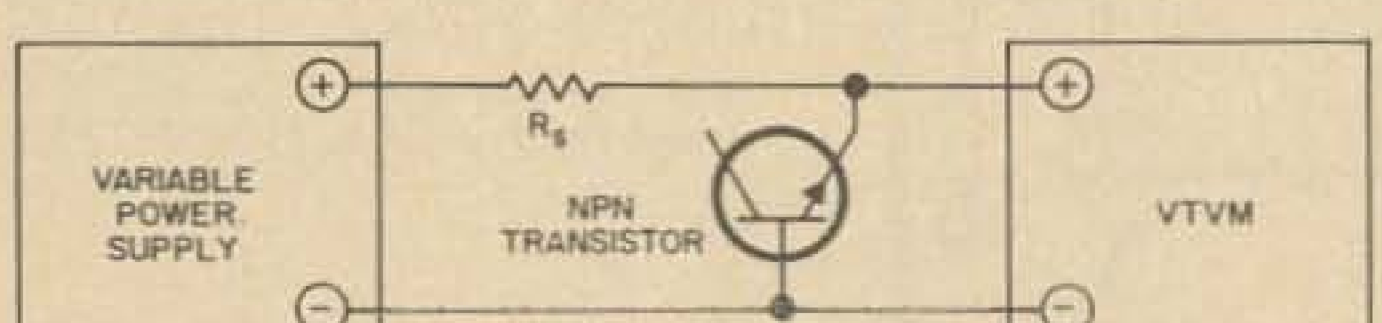


Fig. 1. Checking the zener voltage of diode junctions in NPN transistors. R_s can be about 470 ohms for these low voltage diodes. It limits current flow to keep from damaging the junction in the transistor.

OK, now you know what the zener voltage is and have an idea as to the amount of current you can regulate. Let's apply this to a more specific example. Suppose you want to regulate that mobile converter's oscillator stage. Let's say your transistor zeners at 10 volts. With 10 volts on your oscillator stage, it draws 3.75 mA. Since it's mobile, you will vary between the 12 volts from the battery to approximately 14.7 volts at maximum generator output. **Fig. 2** shows the hook-up. The only requirement is to determine the value of R_s so that the transistor (oops—I mean zener) will regulate properly with a variable input. To determine R_s, the following formula is used:

$$R_s = \frac{V_L - V_Z}{I_L + 0.1\ I_L}$$

where: V_L = lowest voltage input
V_Z = zener voltage
I_L = load current

Therefore, in the example, $V_L = 12$ volts, $V_Z = 10$ volts, and $I_L = 3.75$ mA. Using these values and solving for R_s gives a value of 485 ohms for the series resistor. A 470 ohm resistor would do quite nicely. As a check,

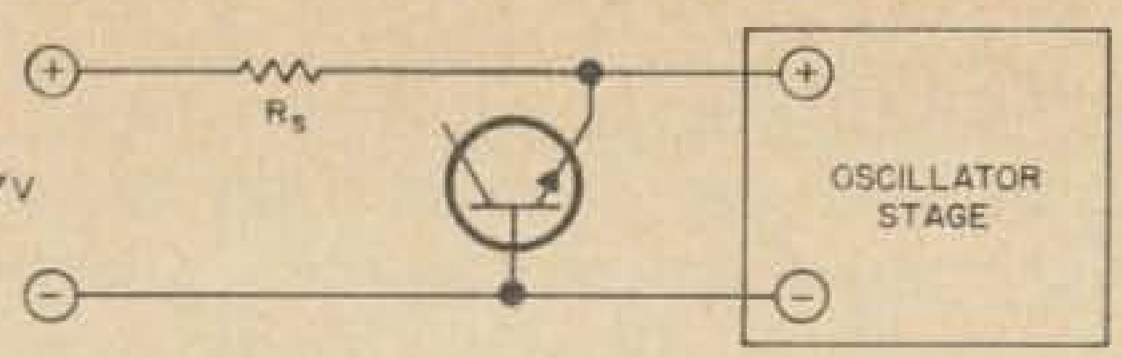


Fig. 2. Using a transistor as a zener diode to stabilize a transistor oscillator stage. Selection of R_s is discussed in the text.

let's determine what the maximum current will be through the zener. This will occur at the 14.7 volt input. At this level, R_s would have to drop 4.7 volts. This represents a total current through the 470 ohm resistor of 10 mA. The oscillator stage draws 3.75 mA. Therefore, only 6.25 mA is flowing through the zener, which is well within the dissipation rating of the device. In like respect, at the low voltage input, R_s drops only 2 volts which represents a total current of 4.25 mA. The zener draws only .5 mA in this case.

If your stage, which you desire to regulate, has a variable current requirement as well as a variable voltage input, use the following formula to determine the series resistor, R_s:

$$R_s = \frac{V_L - V_Z}{I_{Lmax} + 0.1\ I_{Lmax}}$$

where: I_{Lmax} = maximum load current

In like respect, if the input voltage is constant and the load current variable, use the same formula just given, with input voltage used in place of V_L.

These formulas are based on the premise that for conservative designs, the empirical factor of 10% of the maximum load current should be used for minimum zener current. In other words, the zener then is capable of regulating from this minimum current up to the value of maximum zener current as governed by the dissipation rating of the transistor. If your change in input is small, a figure of 20% may be used to better advantage for a little better regulating action.

Table 1 shows typical zener voltages meassured on various transistors. All but the 2N709 are available for under $1.00 as compared to zener diode prices ranging from several dollars and up. Notice that some (the exceptions) like the 2N94 have a very high zener which limits the usable current range. (Possibly low current B+ regulators?)

Pay particular attention to the Fairchild 2N3567. This device sells in the neighborhood of 60 cents and exhibits extremely good zener action. It also exhibits another characteristic to be covered next.

Now let's forget that emitter lead and use instead the collector lead in conjunction with the base lead. **Fig. 3A** shows a typical varicap tuned tank circuit and **3B** shows a NPN transistor connected for use as a varicap. C_1 in the figure isolates the varicap from DC. For this application, device dissipation is of little concern as only leakage current is flowing and will be quite insignificant. As with any series connection of capacitors, some consideration must be given to C_1. If this capacitor is quite large, compared to the varicap, then the tuning range of the tank circuit will be in direct proportion to the maximum change of the varicap's capacitance with applied voltage. If it is smaller than the varicap, then the change in frequency with the change in the varicap's capacitance with voltage will be small.

There are two means by which you can determine whether or not your silicon transistor will be suitable as a varicap. Some will have only a minor change in capacitance with voltage changes and others will have a greater change. The first method and by far the simplest is to refer to the data sheet for the transistor in question. If you're lucky, this capacitance change with voltage will be graphically plotted. The graph to look for is the output capacitance versus reverse bias voltage. This is listed on the data sheets as C_{ob} ($I_E = 0$).

The second method is to actually connect the transistor in question to a tank circuit such as that shown in **Fig. 3B**. Use a large by-pass such as a .001 for C_1 and a 100 K resistor for R_1. Place a suitable coil of known inductance across the transistor and capacitor as shown. Apply a DC voltage of 0.5 to 1 volt and then using a grid dip, find the resonant frequency of the tank circuit. Increase the supply voltage until further increases have little effect on the resonant frequency. Compute the value of the transistor's capacitance at the low voltage level and at the high voltage level. This gives you the range of capacity versus the voltage change required to produce this capacitance for the transistor in question.

Depending upon the application you have in mind, it's advisable to actually plot the

Transistor	Typical Zener Voltage
SE2001	6.1
2N706	6.2
2N3642	6.4
2N709	7.5
SE4002	9.8
SE6001	10.2
2N3567	10.2
2N94	50.0
2N233A	55.0
2N212	50.0

TABLE 1

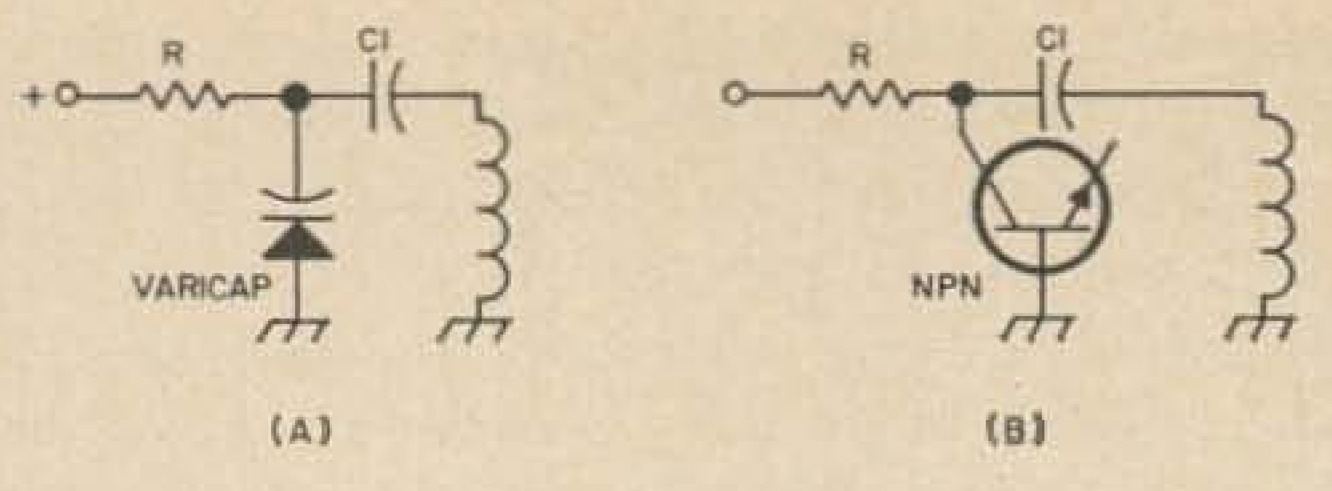


Fig. 3. Use of a varicap or transistor as a voltage variable capacitor in a tank circuit.

capacity versus the voltage. As with a true varicap, maximum capacitance occurs at a low voltage and minimum capacitance at the higher voltages. The rate of capacitance change is greater at the lower voltage changes and vice versa. For tuning applications, you would be concerned primarily with capacitance change obtainable for the range of voltage you have available. However, for an application such as producing FM, it is advisable to choose a section of the curve where linearity is achieved and bias the varicap to this value of voltage through a suitable divider. Then by applying an audio voltage to the varicap, a linear swing plus and minus may be achieved. Be sure that your bias point is sufficiently high so that the level of applied audio voltage doesn't overcome the bias on the varicap causing it to conduct.

Remember the Fairchild 2N3567 mentioned before for use as a zener? Well, here it is again. This little device exhibits excellent varicap characteristics. The capacitance and the capacitance change is ideal for a wide range of applications such as tuning, AFC, FM, etc. **Fig. 4** shows the typical C_{ob} of this device. As an example of the range possible with this particular device, consider a control voltage from 0.5 volts to 10 volts. This represents a capacitance of approximately 28 pF and 13 pF respectively. This is a capactance ratio of 2.15 to 1 which represents a possible frequency ratio of 1.46 to 1. In other words, you could tune from 40 MHz to 58.4 MHz or by proper choice of the coupling capacitor you could easily cover 50 to 54 MHz.

Incidentally, this 2N3567 can also be used, of all things, like a transistor. It is designed primarily for amplifier and switching applications. It exhibits a 40 volt collector to emitter voltage and 300 mW dissipation. Purchasing three of these devices at approximately $1.80 would enable you to build a fairly low cost zener regulated, voltage tuned, oscillator or RF stage.

As mentioned previously, some transistors only change several pF with voltage change, but don't overlook the possibility for FM transmitters where you only require 25 kHz or less swing where a small change in capacitance would be sufficient.

The applications given in this article are all for NPN silicon transistors since the most common silicons are NPN. There are a number of inexpensive PNP silicons now available and they can be used if you reverse the voltage shown.

So next time you start to pitch that NPN transistor with the open, or broken lead, stop and consider the other possible applications for it as a zener or varicap.

. . . K9VXL

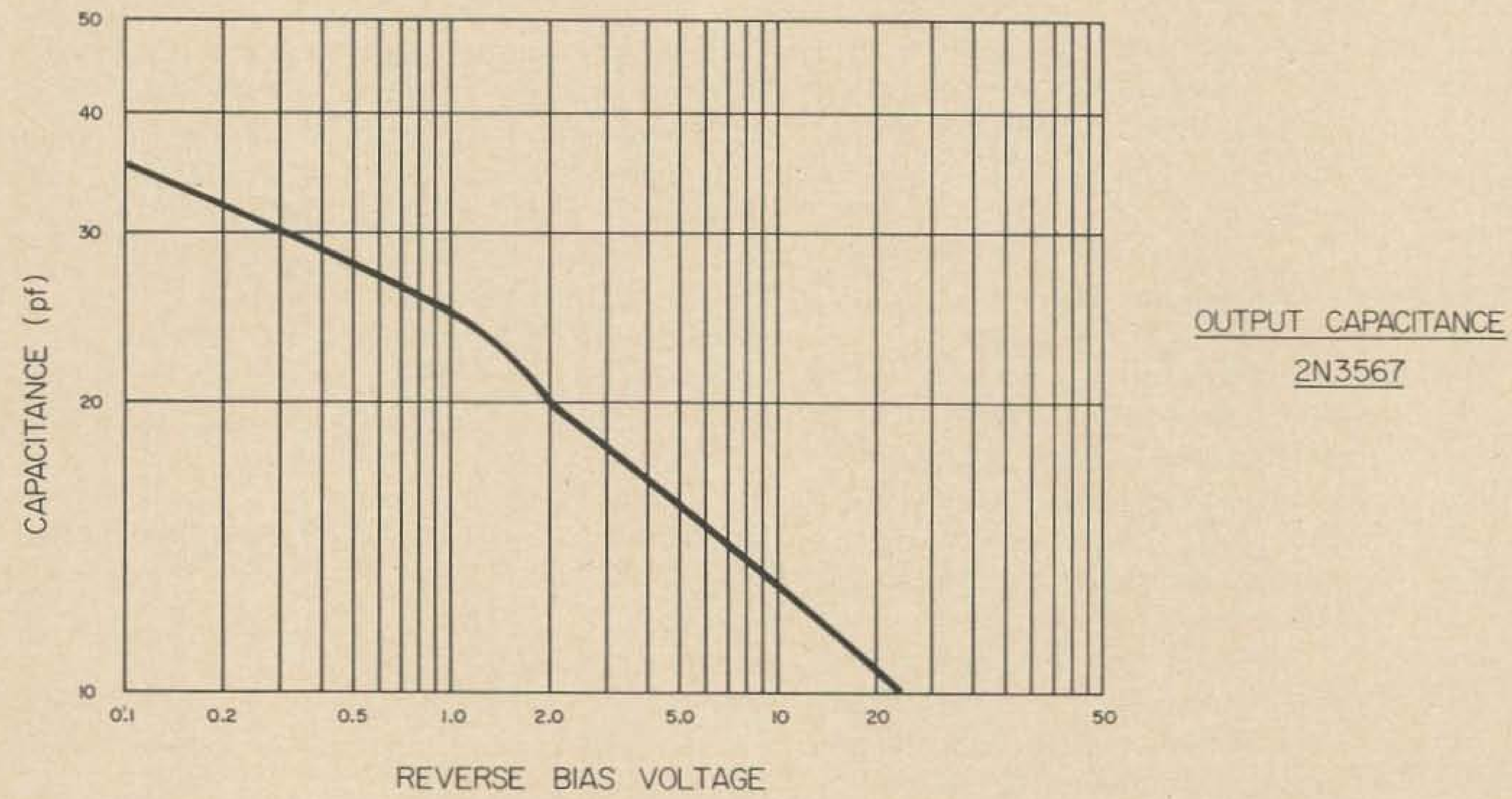


Fig. 4. Capacitance versus reverse bias voltage for the base collector junction of the Fairchild 2N3567 transistor.

Letters

Dear 73:

Re: The article on AGC by Jim Kyle on page 71-2 in the May 73. 4 ms rise time is too fast under conditions of impulse noise, a factor overlooked by the author. I have had to deliberately compromise it down to about 15 ms in order to copy best under static, otherwise the noise "loads up" the AGC so otherwise copyable signals are unhearable. Therefore I believe a slower attack time to be a must unless it can be varied. The distortion caused by the slower 15 ms rise time is quite small.

Will Henry K2AHB
RF Communications, Inc.
Rochester, N. Y.

Dear Paul,

After my article on "Choosing IF and Mixer Frequencies" appeared in the April issue of 73, it occured to me that some of the information in the article might be misleading; from some of the correspondence I have received, this has evidently occurred to some of your readers too. First of all, let me point out that **both** the local oscillator **and** incoming signal must be present to generate a birdie. In addition, because of the selective circuits at the front end of the converter, it must be tuned to this point in the band. If there is not a signal at the spurious point or if the receiver is not tuned to that point, no birdie. Therefore, before your readers scrap all of their converters on the basis of the parameters presented in the article, they should take a close look at their operating condition and locale. If there are not apt to be any signals at the spurious points and/or they are not interested in working that part of the band, then obviously any birdies that occur from time to time are of no consequence.

Jim Fisk, WA6BSO
San Jose, California

Dear 73:

Keep up the good work. Your magazine is getting better every issue.

Levi Mayes

Dear 73:

Here's my renewal. I was going to let it lapse. The magazine isn't too great anymore—not as good as it was the first year but none of the competition is much better.

W. K. McKellips WA6LGI/4
Albany, Georgia

Dear Paul:

I just received new prices on the FET's from Texas Instruments mentioned in my article in the May 73. The 2N3823 is still $12.90, but the TI534 has been reduced from $7.80 to $4.50.

Jack McKay WA5KLY/6
Stanford, California

Dear 73:

If you can't lick 'em, etc. . .

Suggest you change the name of your magazine forthwith, the better to reflect the hamdom of today and to get into the mainstream of ham lingo.

Surely it should be 73's Magazine, or better yet **Best** 73's Magazine.

Let's get with it. . . Is that a BIG 10-4 good buddy?

Best best wishes,
Ansel Gridley W4GJO
Sarasota, Fla.

Dear 73:

The American Morse code listed in the article by W2AAA in the May 73 is full of mistakes. "L" is one long dash. "M" is two dashes. The Ampersand is "ES," not four dots. The semicolon is "SI." Parentheses are designated "PN" for beginning and "PY" for ending parentheses.

D. A. Bunker W7ZB
Portland, Oregon

The errors weren't W2AAA's. The typesetter and proofreaders had fits with those letters. Sorry. Paul.

James Ashe W2DXH
Freeville, N. Y.

Lambda Lines

Here's the simple, cheap, fast approach to lecher lines.

Over the past few years, new kinds of commercial gear and military surplus have made it quite easy to generate VHF frequencies. But the problem of measuring the frequencies has not become any easier for amateurs short on calibrated instruments. Of course this means the newcomer to VHF! What can he do to find what ballpark a circuit is radiating in, if there are no accurate devices available? When this problem came up recently, a simple solution appeared quite by accident. It was so simple, in fact, that its simplicity must be the feature that has kept it out of the ham publications. Another first for 73!

The traditional solution to the rough frequency measurement problem is to make up a Lecher Wire system. There is some question about the value of one of these in the modern ham shack. Narrow-band crystal-controlled techniques guarantee frequency and stability once the multipliers are tuned properly. In the old modulated oscillator days things were not that stable . . . so why go to all that carpentry and construction work for what fairly well promises to be a use-it-once gadget? Particularly when a little reflection (pun intended!) may bring out a cheaper, faster and better arrangement?

Ham and commercial builders of VHF gear have been using tuned stubs for years to match impedances, tune out frequencies, tune in others, etc. Yet it seems to have occurred to very few workers indeed that it might be possible to cut stubs to length accurately enough to serve as frequency standards. Apparently this can be done, with an accuracy of about 5%! This compares very favorably indeed with the performance of lower-frequency grid dip meters and some signal generators. It's pretty good for a pencil and yardstick operation: the only other items required are some understanding of how it works and a piece of 300 ohm twin lead. Belden #8235 recommended. You can calibrate that new GDO for 432 at a cost of just a few cents!

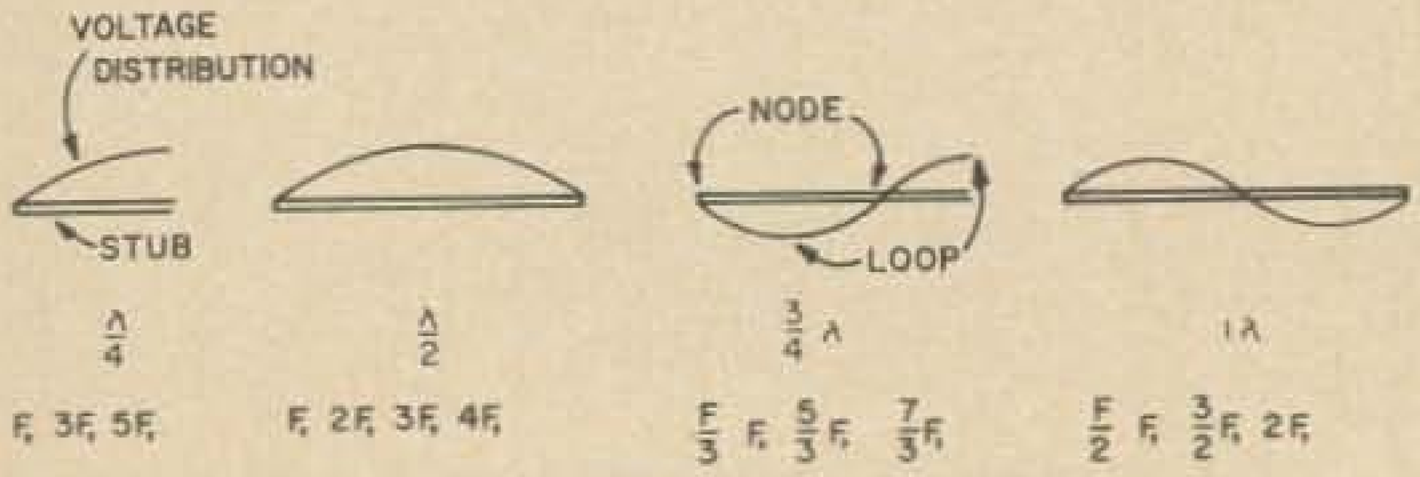


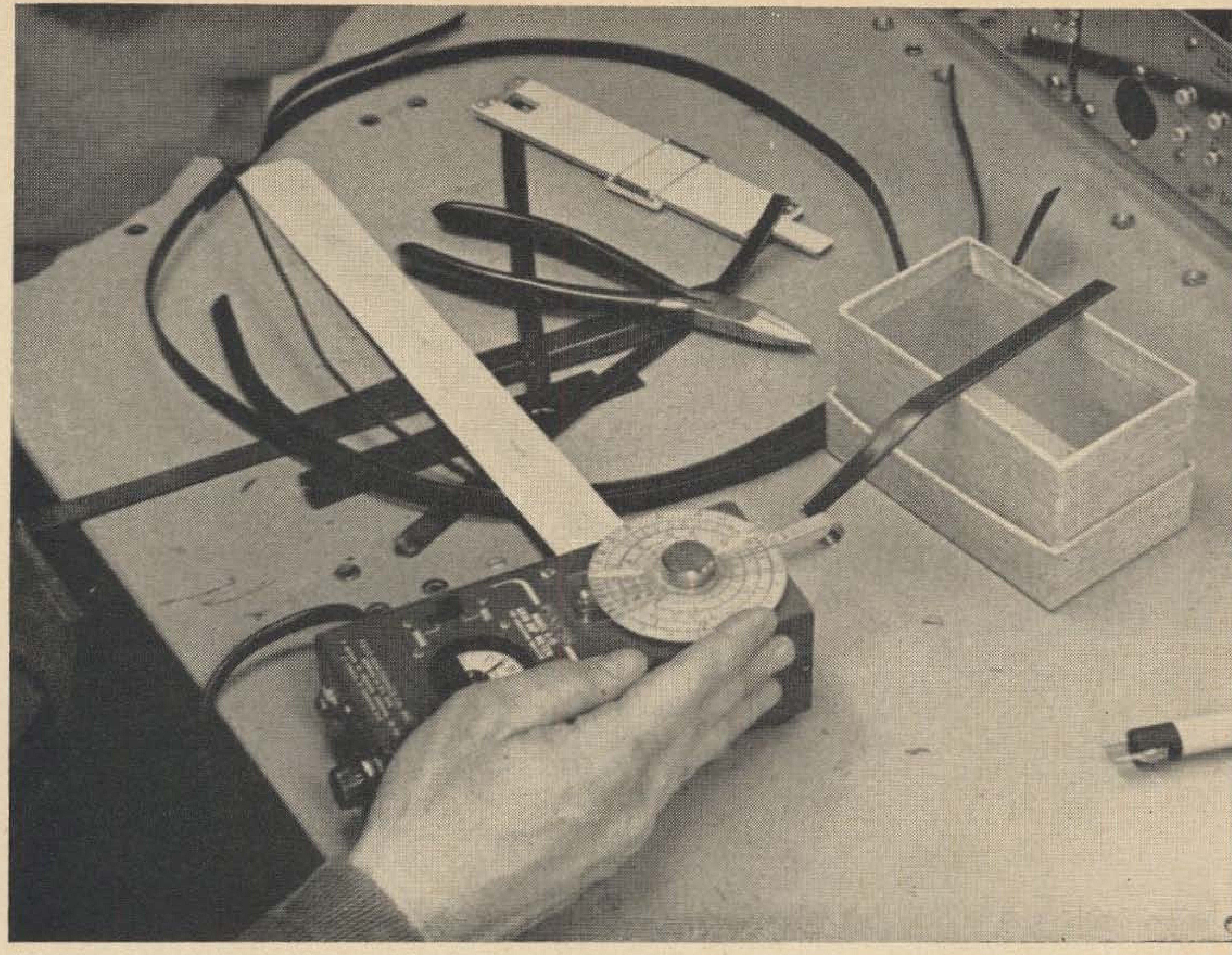
Fig. 1. Four kinds of tuned stubs, taking their fundamental resonances as the frequency producing the illustrated voltage distribution. This shows that none of them has a unique resonant frequency.

Theory

Many kinds of things show a property of tuning sharply to a certain frequency. This property is called resonance. We hear it when a struck piece of metal rings, and see it in the pendulum of an old grandfather clock. The grid dip meter shows a drop in grid current of an oscillator when a nearby resonant circuit steals energy from the oscillator. And it is the nearby resonant circuit that is the subject of this article.

The basic circuit is the quarter-wave stub. A little browsing around in the handbooks and earlier issues of 73 and other ham magazines will tell you lots about quarter wave stubs. The important practical points are that the stub resonates at certain frequencies, and that at these frequencies it can be dipped at its shorted end in the same way as any other resonant circuit.

But the term 'quarter-wave' has to be taken with a grain of salt. The tuned stub will be shorter than a free-space quarter wave, because the dielectric has a slowing-down effect on the rate at which the RF bounces end-to-end along it. Suppose you laid out a mile or so of twin-lead and transmitted a signal, at the same time sending off a reference signal by space wave. The reference signal would arrive at the other end first, in about 5.35 microseconds. The twin-lead signal would arrive a full microsecond later, about a 20% delay. Since this applies even to short lengths of twin-lead,



A quarter-wave lambda line for 220 MHz being used to check GDO calibration. This line should give a good indication of 660 MHz also.

the delay must be taken into account for accurate measurements. Also, there is a considerable difference in velocity factors between different brands and qualities of twin-lead.

Crystals are often used in overtone oscillators for generating stable VHF frequencies. The various modes of oscillation are pictured in the handbooks. Tuned lines will also show overtone resonances, and in the case of large uncertainty, it might just happen that reasonable errors could lead to a consistent but very wrong result. A halfwave line will resonate at a frequency f, and also at 2f, 3f, and so on. Note both odd and even multiples! All other resonant lines have a similar overtone resonance property. The problem is slightly aggravated by the convenience of using relatively long lines at the higher frequencies because they are easier to handle. The solution is to cut a pair of lines whose collections of resonant frequencies have only one resonance in common. The recommended lengths are a halfwave and a three-quarter wave line.

Fig. 1 shows four basic tuned lines. Just which resonance is an overtone and which is not depends somewhat on the application. The simplest way out of this problem in semantics is to say that the three-quarter wave line really doesn't have that resonance at f/3, ignore the quarter and fullwave lines, and stick to the remaining two for test work.

At 432 MHz a wave in free space is about 27.3 inches long. Suppose we are using Belden #8235 twin lead, which Belden says has a velocity factor or propagation constant of 0.77. The twinlead wavelength than is 27.3 times 0.77 or 21 inches. The halfwave stub must be 10.5 inches long, shorted on both ends; and the three-quarter wave stub 15.75 inches long, shorted at one end. These are convenient lengths, not too long to use on the workbench, nor so short that percentage accuracy in cutting becomes a big question.

Using the stubs

The commercially available grid dip meters are not noted for accuracy. It's commonly estimated that the scale calibration can be trusted to within about 20%. With some care, calibration points taken from twin-lead resonators appear to be good to about 5%. The first

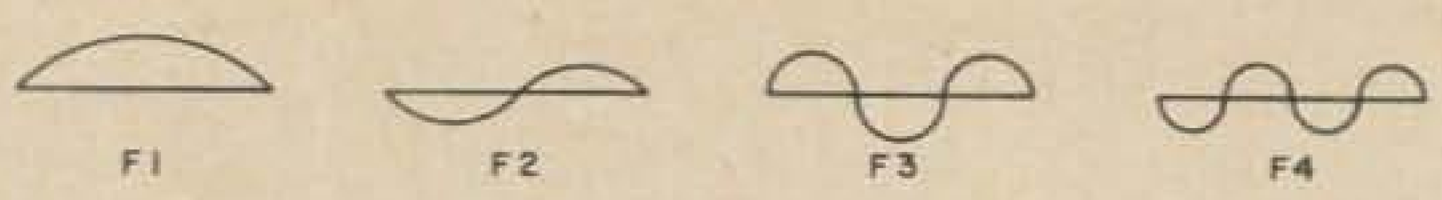


Fig. 2. Some overtone resonances of a halfwave stub (shorted at both ends). F1, F2, F3 and F4 should be 1F, 2F, 3F, 4F.

precaution is accurate construction. Cut the strips slightly long, short one end of each, and cut the three-quarter wave line to length. Then go more carefully at the other end of the halfwave line, which must be shorted at both ends. It should not be too hard to get the correct lengths within one sixteenth inch.

When making frequency checks, the lines must be held off the workbench an inch or two. Use small boxes or pieces of cardboard. Probably the better part of a foot distance is in order if the workbench is of metal or has a copper surface. At two meters, a perceptible change in calibration can be detected if the line is laid out on a wood surface! It's very good practice to make up lines for two meters or lower, and practice dipping them. Some refinement of technique will certainly be required before a halfwave and a three-quarter wave line can be made to dip at the same point on a standard dip meter. Once the trick is mastered, it can be carried up to the higher frequencies.

The lines are dipped in the same way as any coil. Because they have a very high Q, there will be a tendency for the dip oscillator to pull, or to seem to give different readings when tuning down to frequency and tuning up to frequency. The remedy is less coupling: move the dip meter a little further away from the line and try again. Dip the stub at its shorted end!

But what was that trick for calibrating a dip oscillator, mentioned earlier? Can't make up a pair of lines for each frequency. No need to! That's simply the reliable way for finding the right ballpark. When you're there, you can set the lines aside, make up another three-quarter wave resonator cut for the lowest frequency, and after marking that point on the scale, trim the stub up to the next calibration frequency. Throw the remainder away when done calibrating.

The half-wave stub is also useful as a tuned coupler. Suppose you want to tune an oscillator to a particular frequency but have nothing to indicate at that frequency. Loosely couple the RF into one end of the half-wave stub, and take it out the other end with a hairpin loop, through a diode to a 50 μA meter. You will only get a reading at the resonant frequency of the half-wave stub. Simple!

. . . W2DXH

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Designing Transistor RF Power Amplifiers

This article contains information for designing transistor power amplifiers, including a 50 MHz final.

Transistors capable of delivering several watts at frequencies up to several hundred megahertz are readily available at nominal cost, and development of improved devices, in regard to power output and operating frequency, is advancing rapidly. Because of transsistor voltage and current limits, and the need for proper matching, the tube oriented designer must slightly revise his design procedures and take certain cautions he would not ordinarily consider if he was designing with tubes.

These new design procedures, together with some of the precautions and other design dissimilarities are discussed here in sufficient detail to permit most readers of 73 to reap the benefits of technological advances being made by the semiconductor industry in RF power devices.

Voltage-current relationships

The majority of transistor RF power amplifiers fall into the Class B (zero base bias) category because this class of operation provides a greater power gain. (Some may want to call zero base bias Class C because it does take a few tenths of a volt to start the transistor conducting.) However, Class C operation (reverse base bias) with its higher collector efficiency is also suitable especially when efficiency is of greater importance than power gain. Moreover, it is practical, under certain conditions, for example, where a greater power gain than Class B provides is needed to operate a transistor RF power amplifier with a slight forward bias.

However, you must use caution when biasing RF power transistors for Class A operation. Transistors designed for RF power amplifier service, at high frequencies, have a very small base width. Without going into the details of safe operating area, it is sufficient to establish that, this narrow base width precludes operating these devices in a dc biased Class A circuit at even a fraction of their power rating. In fact, if you try, the device will be instantly destroyed. Therefore, if you are planning on building a transistorized SSB rig, where some forward bias is needed for linearity, or if the greater power gain of Class A operation is needed, limit the bias current to the low millampere region.

A basic transistor RF power amplifier circuit is shown in **Fig. 1**. The base has no bias applied to it, therefore, the circuit is operating Class B. With no signal and no bias applied to the base, the circuit is setting at the static operating point. That is, the voltage between the collector and emitter is equal to the supply voltage (V_{CC}) as shown in **Fig. 2**. Since

Darrell Thorpe, former WØPKB, and W9NYI, is the editor of the Motorola Military Electronics Division Engineering Bulletin.

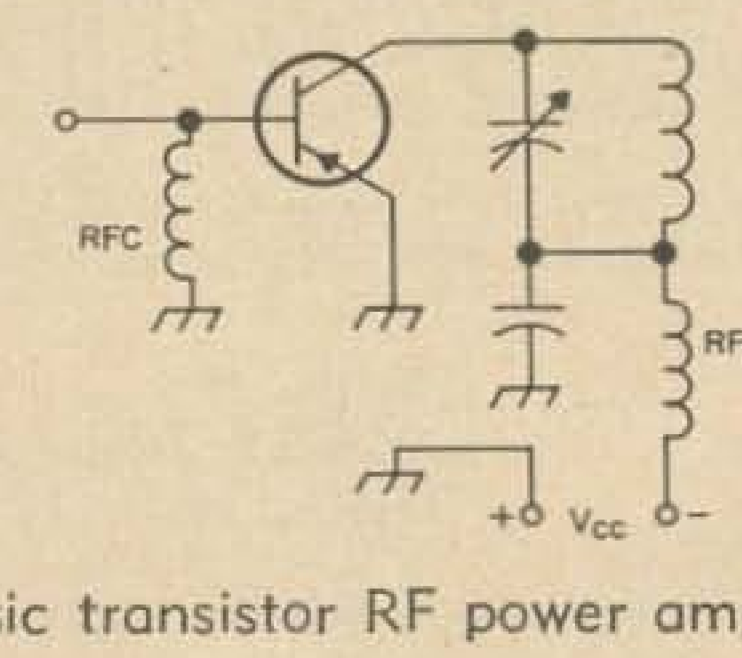

Fig. 1. Basic transistor RF power amplifier.

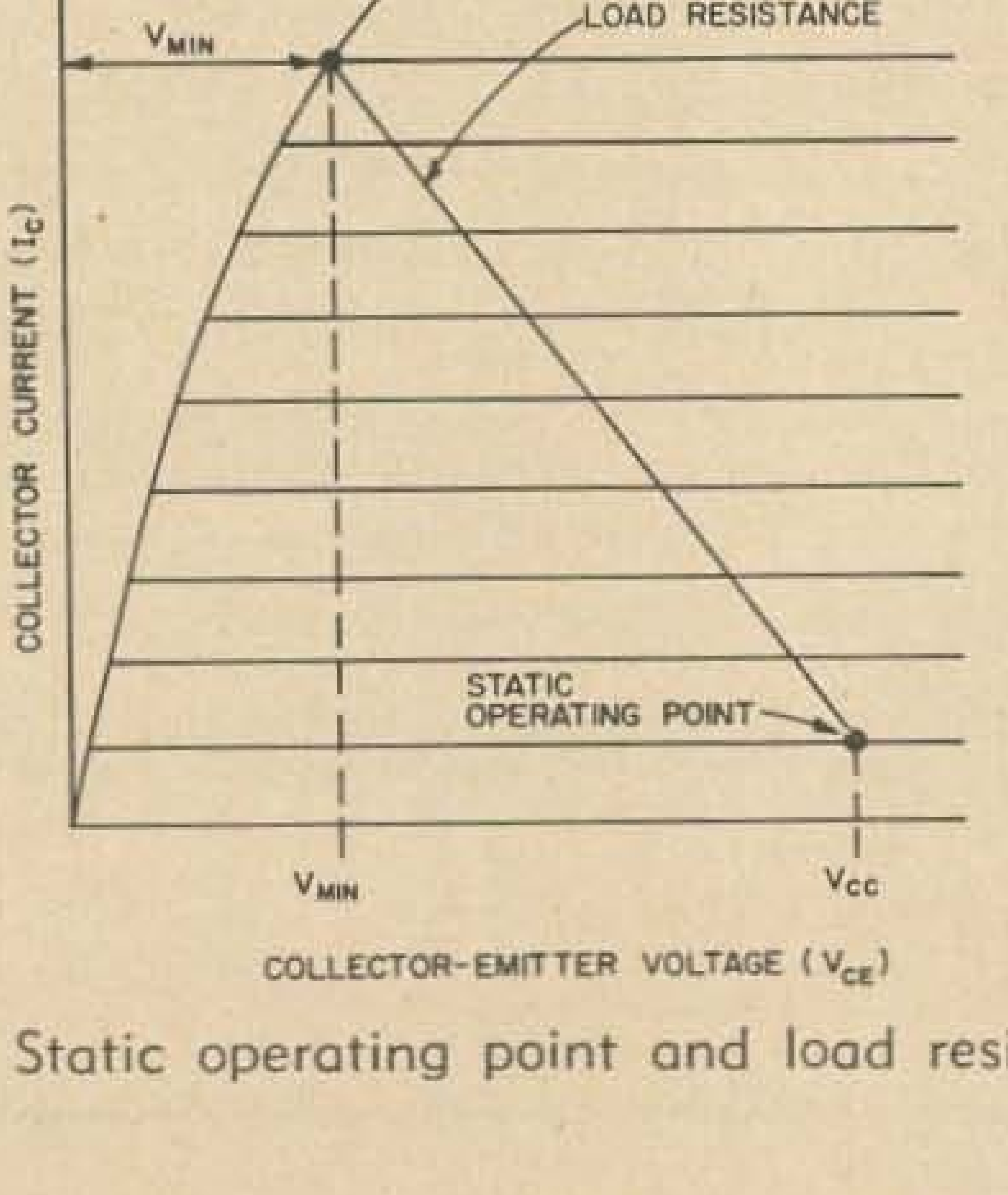

Fig. 2. Static operating point and load resistance curve.

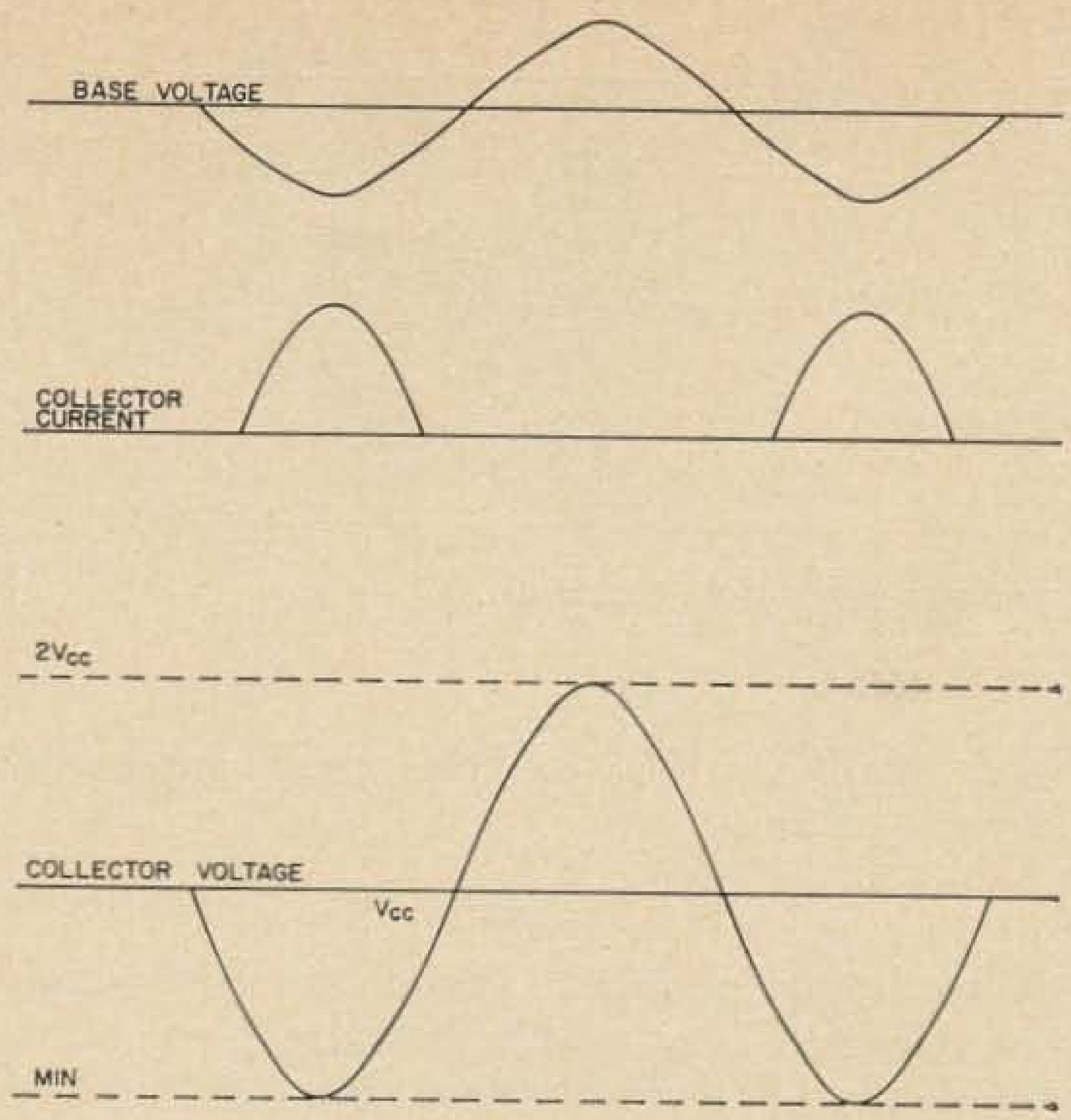

Fig. 3. Affect of base voltage on collector current and voltage.

the circuit illustrated employs a PNP transistor, the transistor conducts only when the voltage (applied drive signal) goes negative. Referring to **Fig. 3**, as the base voltage goes negative, there is a corresponding rise in collector current. Also, notice, from **Figs. 2** and **3**, that as collector current increases, the collector-emitter voltage drops to V_{min}.

Then, as the base voltage returns to zero, collector current goes to zero and collector voltage returns to V_{CC}. However, due to flywheel effect of the tank circuit, the collector voltage returns to V_{CC}. However, due to flywheel effect of the tank circuit, the collector voltage continues to increase until it reaches approximately $2V_{CC}$. The cycle then repeats.

Breakdown voltage and supply voltages

In vacuum tube circuits, breakdown voltage between the plate and other elements is seldom a consideration since it usually is much greater than the usual supply voltage. However, present day transistors are not so fortunate. Therefore, the breakdown voltage of the transistor must be considered when selecting devices and supply voltages.

As previously discussed, for an unmodulated transistor RF power amplifier, the collector voltage swings from V_{min} to approximately twice the source voltage. Therefore, the transistor must be able to withstand the peak-to-peak voltage which is $2V_{CC}-V_{min}$. Since V_{min} is usually only a few tenths of a volt, it can be neglected and the peak voltage can be considered as $2V_{CC}$.

Since the common-emitter configuration produces higher gain than a common-base configuration, the breakdown voltage of the transistor being considered will usually be BV_{CES}. Quite often BV_{CES} and BV_{CBO} are the same value. If the peak voltage happens to slightly exceed the breakdown voltage, the transistor will not be damaged provided the current and time duration are limited, but efficiency and gain will drop.

Thus, from the preceding discussion, it should be clear that a transistor should be selected with a BV_{CES} equal to or greater than $2V_{CC}$ or if this is not practical, V_{CC} should be set equal to or less than $BV_{CES}/2$.

For an AM power amplifier, these conditions must be modified to account for the increased peak-to-peak voltages which result from the modulating voltages. **Fig. 4** illustrates unmodulated and modulated carriers. The m on the modulated carrier represents the modulation index (m = 1 for 100% modulation). From **Fig. 4B**, for a modulated transmitter, the transistor must have a voltage rating of

$$BV_{CES} \geqq 2V_{CC}(1+m) \quad (1)$$

or

$$V_{CC} \leqq \frac{BV_{CES}}{2(1+m)}.$$

Since m = 1 for 100% modulation,

$$V_{CC} \leqq \frac{BV_{CES}}{4}. \quad (2)$$

Therefore, for CW or FM operation, where m = 0, the maximum collector voltage is approximately one-half the breakdown voltage, and for the final stage in an AM transmitter (m = 1) the maximum collector voltage must not exceed one-quarter of the breakdown voltage. Effects of slight clipping caused by breakdown on the upward modulation and saturation voltage on the downward modulation may generally be neglected.

Determining the optimum load resistance

In a transmitter, it is generally desirable to obtain a certain power output or the maximum power that a transistor is capable of delivering. Since the collector supply voltage is often limited either by breakdown voltage or the source i.e.; 6 or 12 volts in the case of mobile transmitters, the only variable is the effective load resistance at the collector.

To get a better understanding of how the load resistance (R_C) influences the maximum power output, it is necessary to examine the properties of an amplitude modulated signal

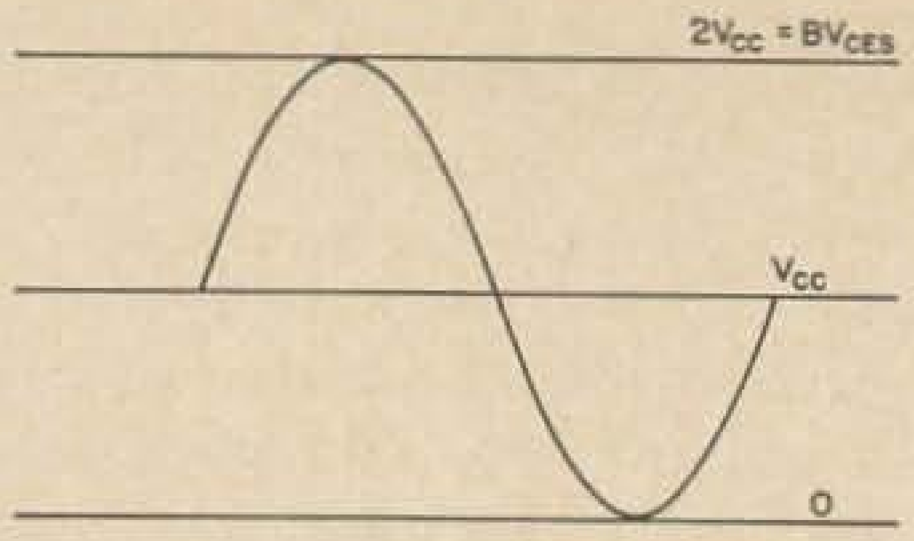

Fig. 4A. Unmodulated carrier.

more closely. The equations developed will easily reduce to the CW or FM case. **Fig. 5** illustrates the output at the collector of an AM final stage. The voltage is given by the expression

$$e_c = E_c\,(1 + m \sin \omega_m t)\,(\sin \omega_c\, t), \qquad (3)$$

where

e_c = instantaneous carrier voltage
E_c = unmodulated carrier amplitude
$\omega_m = 2\pi$ (frequency of modulating signal)
$\omega_c = 2\pi$ (frequency of carrier signal)
t = time, and
m = modulation index = E_m/E_c, where E_m = peak modulation voltage and E_c = peak unmodulated carrier voltage.

The peak voltage, E_p, occurs at the crest of the sine waves and is easily determined to be

$$E_p = E_c\,(1 + m) \qquad (4)$$

Using the standard ohms law equations, the peak power (P_p) is given by

$$P_p = \frac{E_p^2}{R_C}. \qquad (5)$$

Substituting Equation 4 into Equation 5 we have

$$P_p = \frac{E_c^2\,(1 + m)^2}{R_C}. \qquad (6)$$

By inspection of Equation 6 it is seen that the *peak* unmodulated (P_u) power (m = 0) is

$$P_u = \frac{E_c^2}{R_C}. \qquad (7)$$

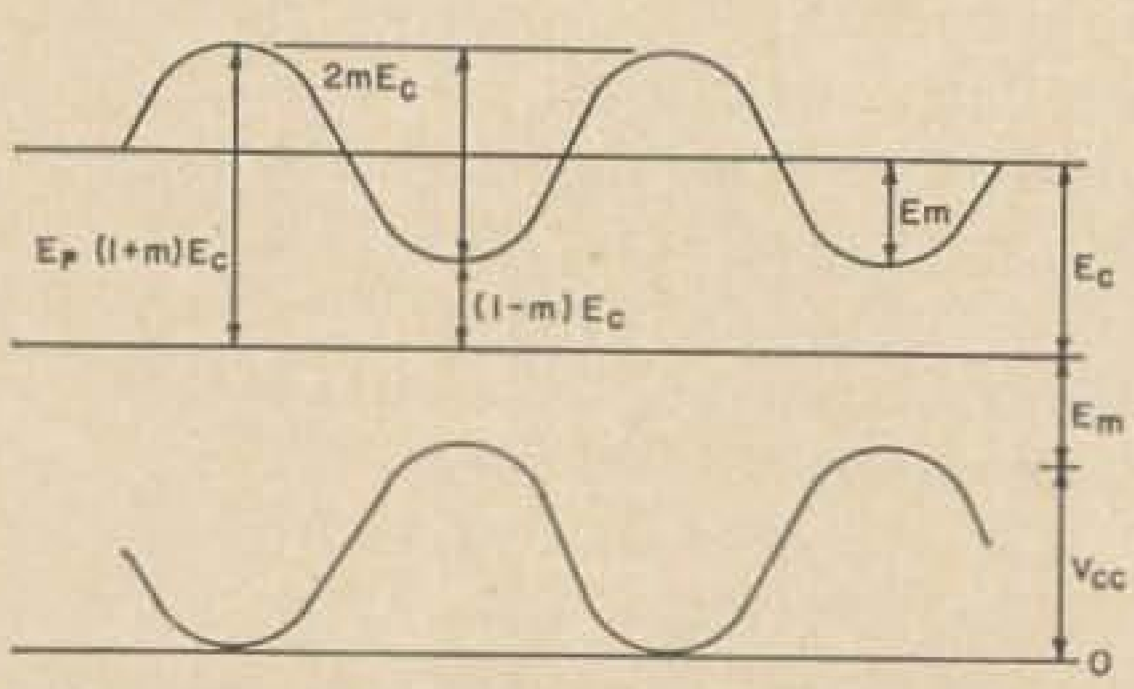

Fig. 5. Carrier with sine wave amplitude modulation.

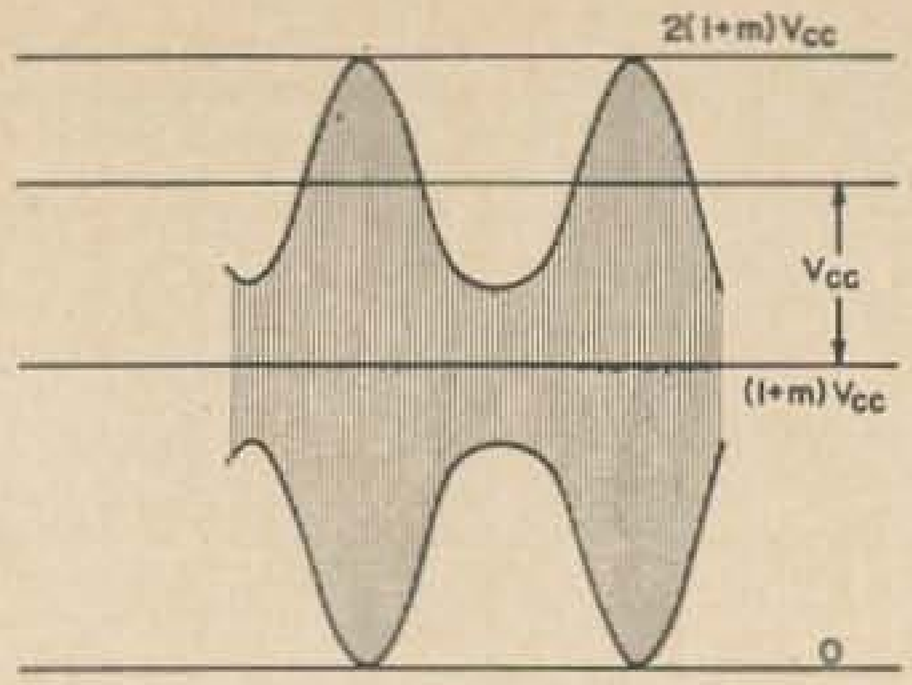

Fig. 4B. Modulated carrier.

and with modulation, the peak modulated power (P_m) is

$$P_m = P_u\,(1 + m)^2. \qquad (8)$$

Note, from Equation 8, that for a 100% modulated carrier (m = 1) that the peak modulated power is four times the unmodulated power. Thus, most of the power of an AM transmitter is contained within audio sidebands instead of the carrier. For this reason, when maximum talk range is desired from an AM transmitter, it should be designed and tuned so as to produce maximum demodulated audio signal with minimum distortion.

Getting back to determining the optimum load resistance for a desired power output, Equation 7 can be written

$$R_C = \frac{V_{CC}^2}{2P_u}. \qquad (9)$$

Where R_C is collector load resistance
V_{CC} is substituted for E_c
P_u is unmodulated power output

the factor 2 in Equation 9 comes from the conversion of peak power to rms power. R_C for a modulated transmitter is obtained by substituting Equation 8 into 9 which becomes

$$R_C = \frac{V_{CC}^2\left(1 + \frac{m^2}{2}\right)}{2P_u} \qquad (10)$$

Table I

	Max DC Supply Voltage (V_{CC})	Max Load Resistance (R_C)	Peak Power
AM (100% mod)	$\frac{BV_{CES}}{4}$	$\frac{3V_{CC}^2}{4P_u}$	$8P_u$
FM/CW	$\frac{BV_{CES}}{2}$	$\frac{V_{CC}^2}{2P_u}$	$2P_u$

Note: The simplification of the equations for the modulated transmitter is arrived at by letting m = 1 which is the case for 100% modulation.

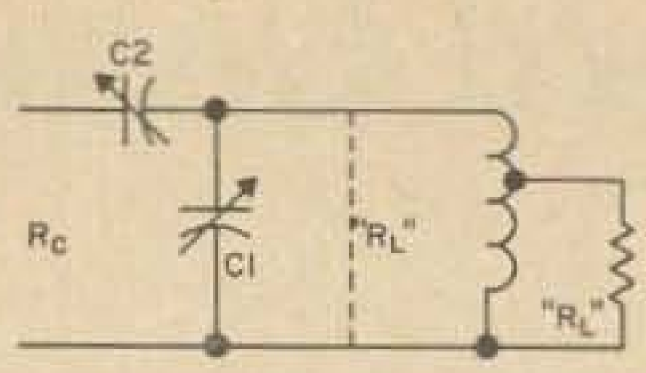

Fig. 6. One method of matching the load to the collector circuit.

From Equation 9 or 10, *the maximum collector load resistance that can be used for a given output can be calculated.*

A summary of voltage and load resistance relations is given in **Table I.**

CW and modulated power output capabilities

At VHF, the factors which limit power output, in most cases, are other than device power dissipation. Usually, high frequency transistors are peak voltage or peak current limited.

The voltage limits have already been discussed; however, a few words about current limits are needed to aid in understanding why transistor circuits behave as they do.

A transistor can be compared to an emission limited tube. That is, the amount of peak instantaneous current available is determined by the transistor structure, and no reserve or space charge effect exists. If a transistor is operated with maximum allowable collector supply voltage and the drive is increased until there is no further increase in output the maximum peak current has been reached. This condition is very seldom encountered in a tube, because the power dissipation limit of the tube is usually reached first.

The peak voltage and current limits are important factors for amplitude modulated transmitters because a device which is already operating at its collector supply voltage and current limits can not be upmodulated from that power level. As discussed earlier, for collector modulation, the supply voltage must be limited to one-fourth of the maximum transistor voltage rating to prevent breakdown, and since the peak current must double in addition to the voltage, a carrier level of one-fourth maximum power output must be maintained if 100 percent up-modulation is desired.

And, while we are on the subject of modulation, it is worthwhile to mention that feed-through capacitance in transistors will allow a residual carrier to be passed from the driver through the final even if the down-modulating audio has reduced the collector-to-emitter voltage to zero. Hence, some modulation of the driver is needed to achieve good down-modulation of the final. Also, modulation of the driver will aid in achieving the higher peak current required by the final on up-modulation.

Design example

Up to this point, we have not considered matching networks to transform the actual load impedance, usually a 50-ohm or 300-ohm antenna, to the load the transistor needs to see so that the specified power output can be achieved. **Fig. 6** shows one method of coupling the collector circuit to the load. There are many other types of matching networks that can be used including the pi and L networks. If you desire to use one of these networks refer to one of the radio handbooks for equations to calculate component values. The matching circuit shown uses a parallel tuned circuit to couple the load to the collector circuit. The collector of the transistor is tapped down on the tank coil. Capacitor C_1 provides tuning for the fundamental frequency and C_2 matches R_C to the tank circuit.

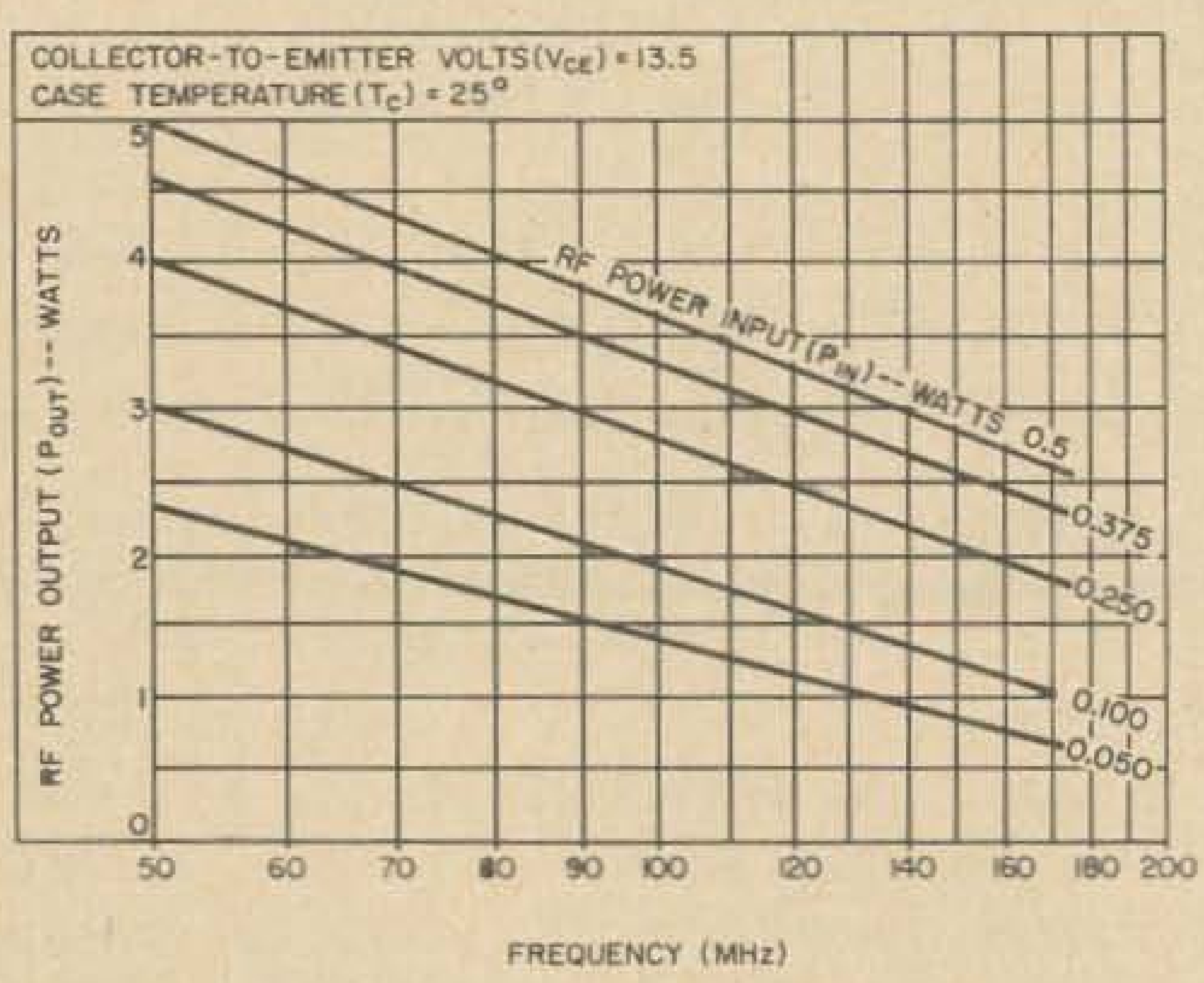

Fig. 7. Characteristic curves for the 2N3553 at 28 volt emitter to collector voltage.

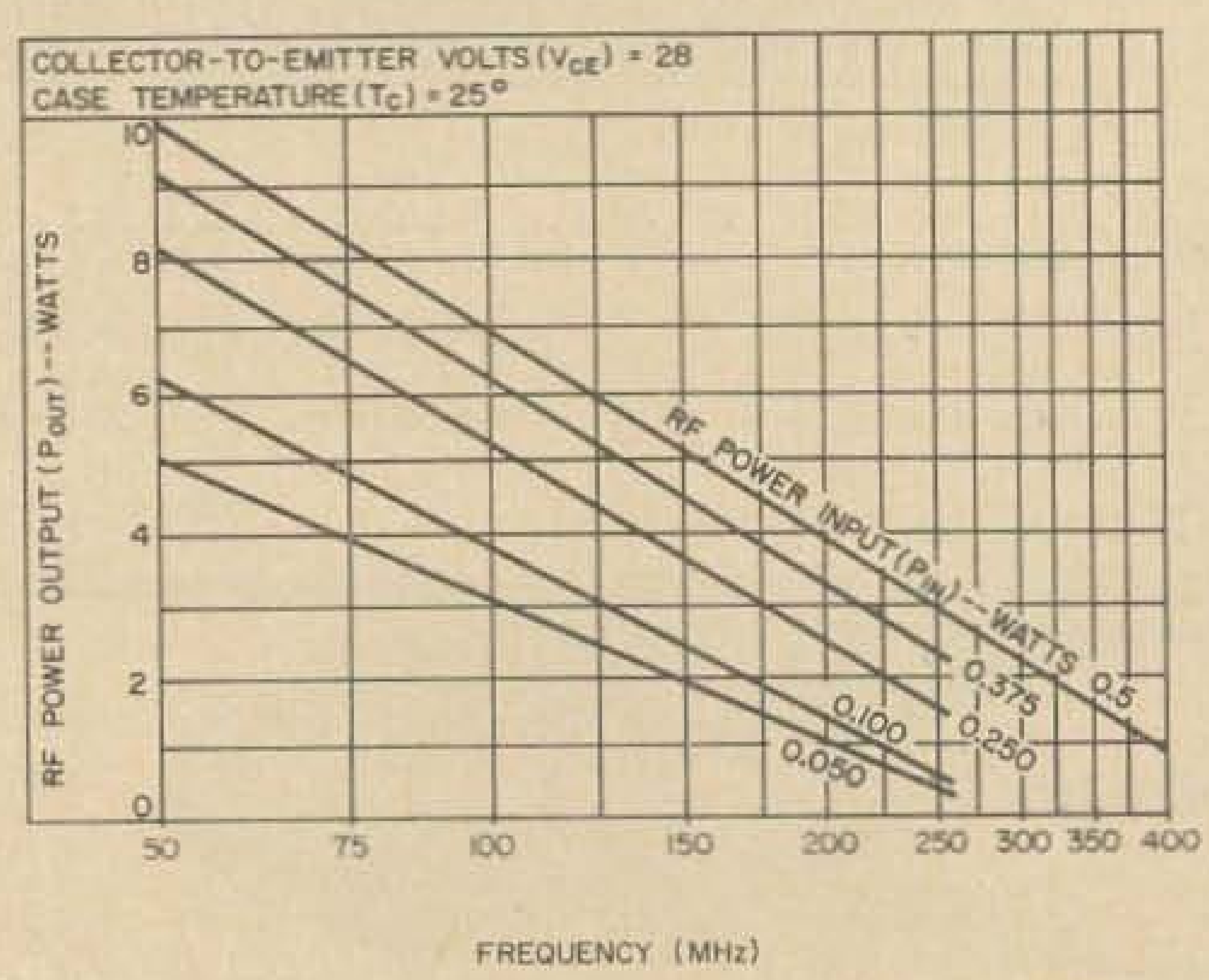

Fig. 8. Characteristic curves for the 2N3553 for 15 volt emitter to collector voltage.

Let's assume we are designing a 50 MHz final using the RCA, 2N3553 transistor. Characteristic curves on the data sheet (see **Figs. 7 and 8**) show that this device can typically provide 5 watts (CW) from a 13.5-volt source at 50 MHz and 10 watts with a 28-volt source. Specified BV_{CES} is 65 volts which is sufficient for either CW or AM from a 13.5-volt source (use the equations and check for yourself). Therefore, let's design for a peak modulated power output of 10 watts which corresponds to a 2.5-watt unmodulated carrier.

The maximum load resistance is (see Table I)

$$R_C = \frac{3V_{CC}^2}{4P_u} = \frac{3(18.2)}{4(2.5)} = 55\Omega$$

Since at 50 MHz, the number of turns needed for L_1 will be rather small, and also, since the collector load impedance is very close to the 50Ω antenna impedance, we will assume a 4:1 turns ratio.

As shown in **Fig. 6**, coil L_1 transforms R_L to another resistance R_L''. This is given by the standard transformer impedance equation

$$\left(\frac{N_1}{N_2}\right)^2 = \frac{R_L''}{R_L} \qquad (11)$$

Since turns ratio is 4:1 and $R_L = 50\Omega$

$$\left(\frac{4N_1}{N_2}\right)^2 = \frac{R_L''}{50} = 16(50) = 800$$

$$R_L'' = 800$$

Let's assume that a loaded Q (Q_L) of approximate 8 or better is desired. Values of loaded Q in the range of 5 to 10 are practical to achieve.

Now, we can calculate C_2

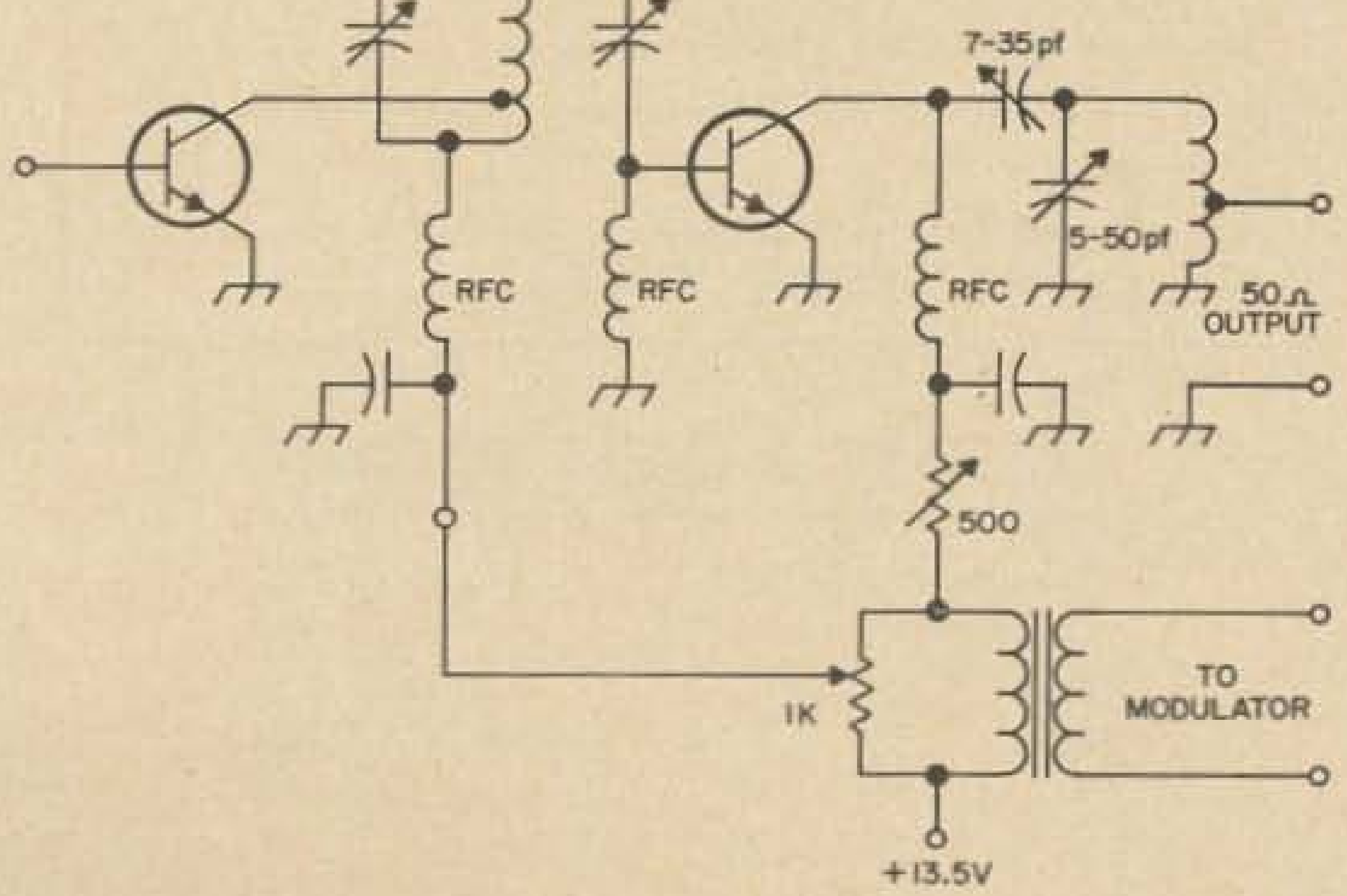

Fig. 9. Complete 50 MHz power amplifier stage and part of its driver. The driver must supply 75 mW for 2.5 W output.

$$C_2 = \frac{Q_L}{2\pi F R_L''}$$

$$= \frac{8}{6.28 \times 50 \times 10^6 \times 800} = 31.4\ \text{pF} \qquad (12)$$

and

$$L_1 = \frac{1}{(2\pi F)^2\, C_2}$$

$$= \frac{1}{(6.28 \times 50)^2 \times 10^{12} \times 31 \times 10^{-12}} = 0.333\ \mu\text{H} \qquad (13)$$

Using a coil nomograph, this turns out to be a 7-turn, one-half-inch diameter by one-inch long coil. Tap 1¾ turns from cold end.

Next, the value of coupling capacitor C_2 is calculated.

$$XC_2 = R_C\sqrt{\frac{R_L''}{R_C} - 1} = 55\sqrt{\frac{800}{55} - 1} = 55(13.8) = 210\Omega \qquad (14)$$

$$C_2 = \frac{1}{2\pi F X_{C2}} = \frac{1}{6.28 \times 50 \times 10^6 \times 210}$$

$$= \frac{1}{66 \times 10^9} = 15\ \text{pF} \qquad (15)$$

The complete 50 MHz RF power amplifier and part of a driver stage is shown in **Fig. 9.** As shown, the driver stage can be designed using a similar matching network. The load for the driver will be the input impedance of the 2N3553 final transistor which, for all practical purposes, can be considered as the base spreading resistance (r_{bb}') of the transistor. For the 2N3553, r_{bb}' is typically 12 ohms. Therefore, the network must transform 12 ohms to the impedance the driver needs to see to develop the required drive power. The driver can be designed using the same procedure as given for the final. From **Fig. 7,** the driver must supply about 75 mW of power to the base of the 2N3553 to drive it to a 2.5 watts CW output. Since the driver should be modulated to improve down-modulation, the needed drive for peak power output of the final is provided by peak modulated power from the driver. Usually, modulating the driver between 25 and 35% is sufficient.

Potentiometers are shown in the modulation circuit to permit adjusting modulation for optimum performance. The pots can then be removed and replaced with fixed resistors after adjustment. Since the driver is being modulated the modulation to the final must be reduced, (i.e., driver modulation plus final modulation must not exceed 100%).

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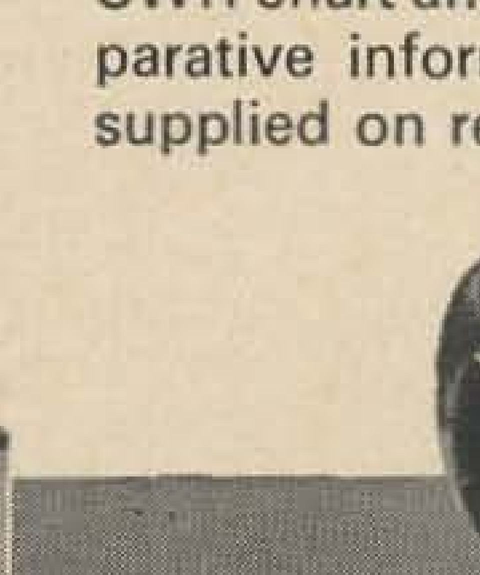

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A 75 Watt Compactron Twoer Linear

Build this simple, inexpensive linear to multiply the output from your Twoer 25 to 30 times.

In response to many inquiries about the Twoer linears described in previous 73's[1], I designed another one using a modern, readily available, low cost tube that I've used before on six and two. I have had this linear on the air for some time now, and find that the change from the one watt Twoer output to a well-modulated 25 to 40 watt carrier is certainly a worthwhile project for the average Twoer owner.

1. K1CLL's other Twoer linears were in the September 1964 73 (used 8025 and 815) and January 1965 73 (2C39).

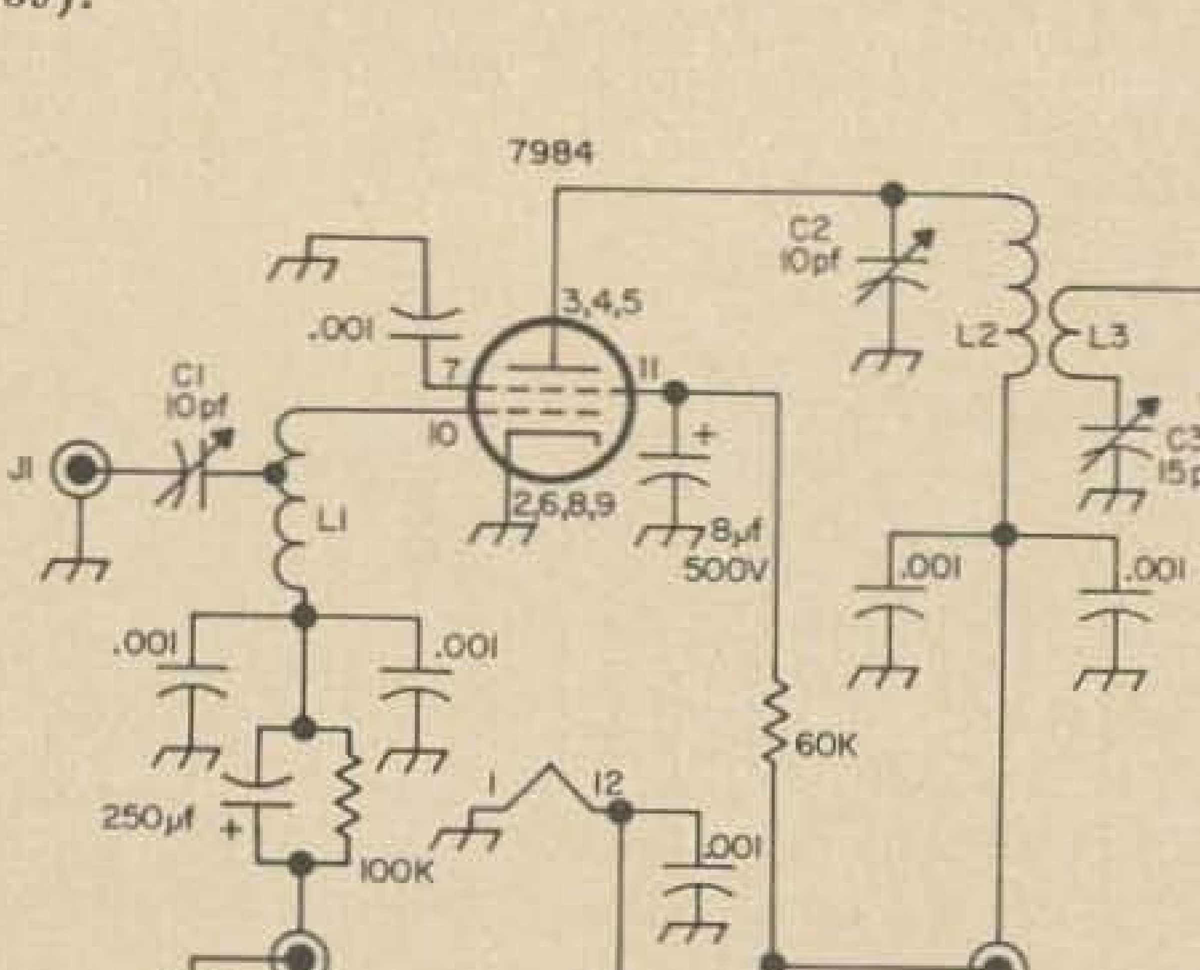


Fig. 1. Schematic of the Compactron Twoer linear. Coil data is given in Fig. 2.

Some notes on AM linears

Information is available on good AM linears, but you have to dig for it. I have been told that many large AM broadcast stations use AM linears and I do not doubt it. Any type of power linear amplifier requires a few simple adjustments, but they're worth it to get an exact, well-modulated reproduction of the input—but 30 to 40 times stronger. As far as performance goes, typical reports have been: "excellent modulation," "modulation clean, clear and crisp," "recognized the Twoer modulation right away." I have checked the RF output with light bulbs and find that 50 watts input gives about 25 watts out. 75 watts in gives about 40 out with 85 to 100% modulation.[2] And no modification of the Twoer. Just plug it in and talk.

Getting good results from an AM linear is easy if you adjust the following controls:

1. RF tuning in the driver. The Twoer must be adjusted for best modulation. This is especially true of the final grid and plate tuning.

2. Some comments about that "85 to 100% modulation: many Twoers modulate downward instead of upward. That is, modulation reduces the power output instead of increasing it. This is the "typical Twoer sound" referred to. Thus this linear might well handle 100% downward modulation, but I doubt that results would be completely satisfactory with 100% upward modulation and 50% efficiency. However, it's very easy to check with a scope. See the article in the December 1964 73, p. 28 by W8HHS (W1CER) for information on improving the modulation of your Twoer. WA1CCH

On the Twoer, these are internally adjusted controls, but once set, they can be left alone.

2. Variable drive to the linear, Cl. You might think this is unnecessary with the Twoer as a driver, but it can easily overdrive the linear. Note that Cl is insulated from ground. The length of the drive cable isn't critical if you have a good match, but I used 21½".

3. Grid bias. The most common type of grid bias for a linear is fixed bias. You could use that in this linear with a simple voltage doubler from the 12 volt filament line. However, here I've used a rather rare type of bias supply that is only suitable for AM linear service, not SSB linear. The amplifier is in AB2 drawing slight grid current. This rectified, furnished bias. The bias is kept stiff by the long time constant of the 100 k resistor and 250 μF capacitor in the grid circuit. Unfortunately, this arrangement furnishes no protection against loss of drive for the amplifier tube since loss of drive means no bias and results in very high plate current and excessive dissipation in the tube. So make sure that the Twoer is always on when you turn on the B+ for the linear. This type of amplifier often uses a clamp tube for protection.

4. Screen voltage. This is important. Changing the screen voltage results in changes in the modulation. The effect is quite noticeable with a variable resistor between B+ and the screen of the linear. Turning down the screen voltage increases the upward modulation percent.

5. Output loading. You can just vary the coupling of the link between the linear plate tank and the antenna, but it is much easier if C3 is used, as you can then adjust the load while operating and listening. The combination of a semi-adjustable link and C3 makes it easy to work with. Note that linears like heavy output loading.

You must listen to the modulation when adjusting the above controls. See the June issue of 73, page 20, for how to do this. It's easy to do the job with a sine wave AF generator and an oscilloscope but lads with those items are generally not Twoer operators.

Exact construction details

I will guarantee that if you build the linear as shown in **Figs. 1** and **2** it will work. The easiest way is to start with a copper-clad baseboard and build up from there. Mount the vertical brass walls and the 12 pin socket (use a tan bakelite socket, not a horrible black one). Then solder the four cathode leads and

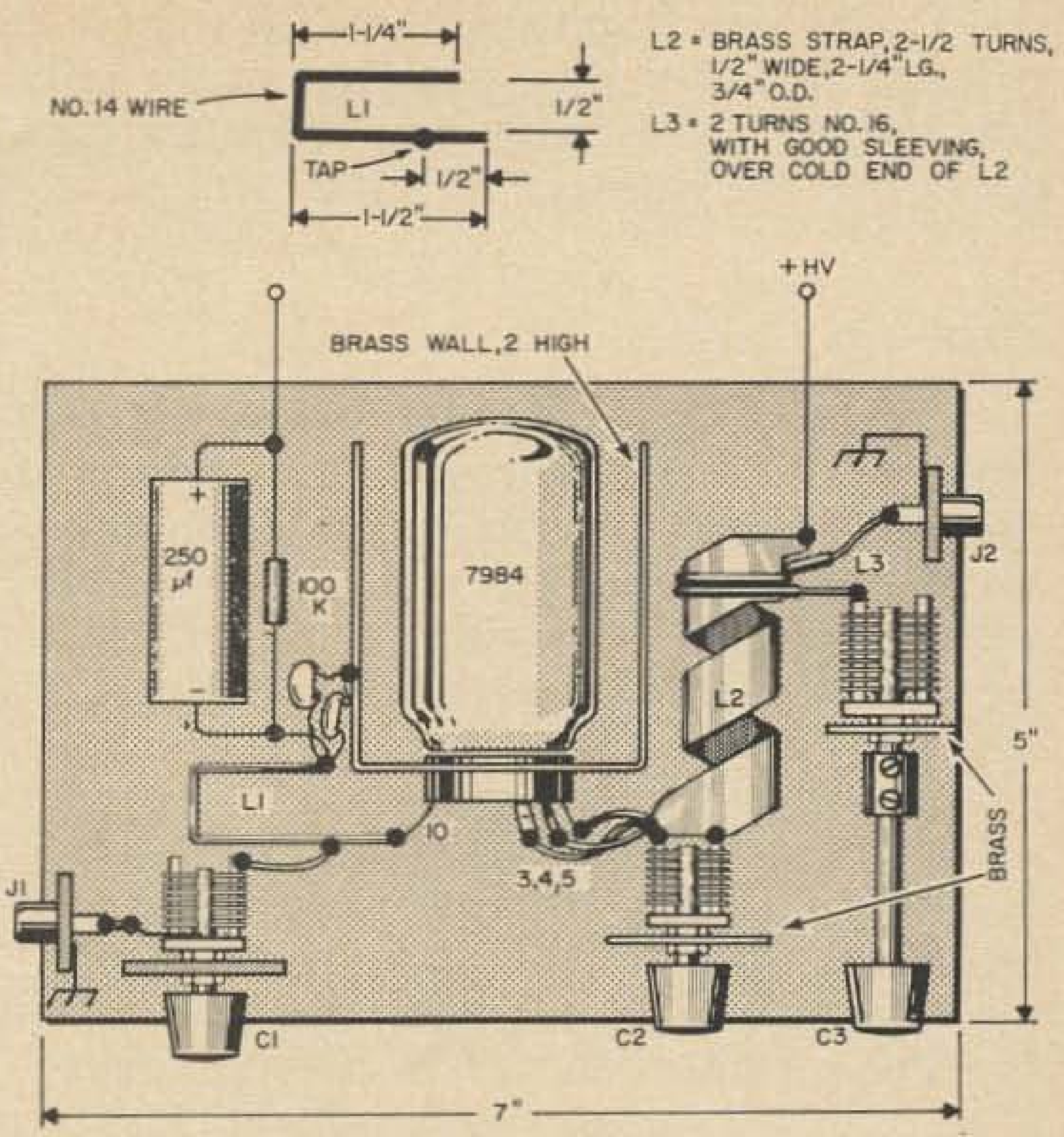


Fig. 2. Layout of the 7984 Compactron Twoer linear.

one heater lead to ground, and also the three bypass capacitors, two on the screen leads and one on the 12 volt heater pin.

The input circuit of the 7984 is a little tough, but I got the best results on 144 MHz with a short heavy loop fixed-tuned to a quarter wave. This is L1 in **Fig. 1**. It really does the job, with most of the quarter wave *inside* the glass bottle. Either loop of capacitance coupling may be used with it but I find the Cl variable as coupling and drive control to be best.

I paid great attention this time to get the proper automatic bias for AM linear operation. The use of a 250 μF capacitor across the 100 k resistor really holds the bias in place. There is no difference in the modulation quality between this type of bias and fixed bias in AM linear service. I tried it several times.

I put a small brass shield across the socket between the input (grid) and output (plate) side because Cl looked a little near the plate leads, but you can leave it out as no self-oscillation was found.

The plate tank is similar to one already described with the addition of a larger antenna output link and C3. This greater amount of coupling allows C3 to be used as a variable loading capacitor, which makes it easier to adjust the plate circuit for heavy loading, one of the requirements for low distortion with a linear. Use a bakelite shaft extender on C2 and C3 to keep fingers off that 500 volts! The rear panel has the grid and plate meter jacks. Use shorted phono plugs in these after tune-up to free your meters for other service.

Tune-up

Check the Twoer for RF output as indicated in its instruction manual. Connect an RG/58-U cable from the Twoer antenna jack to the linear input J1, and check for grid voltage on the 7984 with heater on but no plate voltage. The point between L1 and the 100 k resistor in **Fig. 1** should be 28 volts, or near it. This voltage will rise slowly, while charging the 250 µF capacitor. This is a nice feature as it leaves plenty of bias on the tube, just like a battery!

Current through the grid meter jack and the 100 k resistor should be about ½ mA.

It is best to apply plate voltage in steps. If you don't have a Variac put some resistance in series with the HV lead. Some 115 volt lamps in series are good for this. Just watch those fingers though!

A good plate dip should result on rotating C2, with no load on J2. Plugging a 25 watt bulb into J2 should produce light immediately on turning on the HV. I generally "sneak up" on the 75 watt operation during tune-up. This latter power calls for 500 volts and 150 mA.

Screen voltage is 140 and screen current is 5 mA. Due to the linear's preference for heavy loading very little plate dip will be found at the proper linear operating condition. Plate current at around 150 mA with the RF tank loaded a litle beyond maximum RF output. That is, with the beam in use connected, full plate voltage (whatever you have, 300 to 500) on, first load the plate circuit, via L3 and C3, for maximum RF output as indicated by a small pilot lamp, no. 48 or 49, 120 milliwatts, in series with a 1 to 5 pF trimmer across the output cable, or whatever means you have to indicate *antenna cable* energy. Do *not* allow this indicator to be coupled to the plate tank.

Then, listening to your own voice modulation with a small monitor (you can use a tape recorder if you have one, which avoids the padded earphones), adjust the output coupling, L3 and C3, for a little more loading which will increase the plate mils, flatten out the dip, and decrease slightly the RF in the cable. Only a little, though. Retune the grid input for a check, and then leave it alone. The adjustments are very stable and unless you change beams you should have "excellent" modulation reports from then on.

You can also use this same amplifier later for class C or SSB with only slight bias and screen voltage changes.

On the air

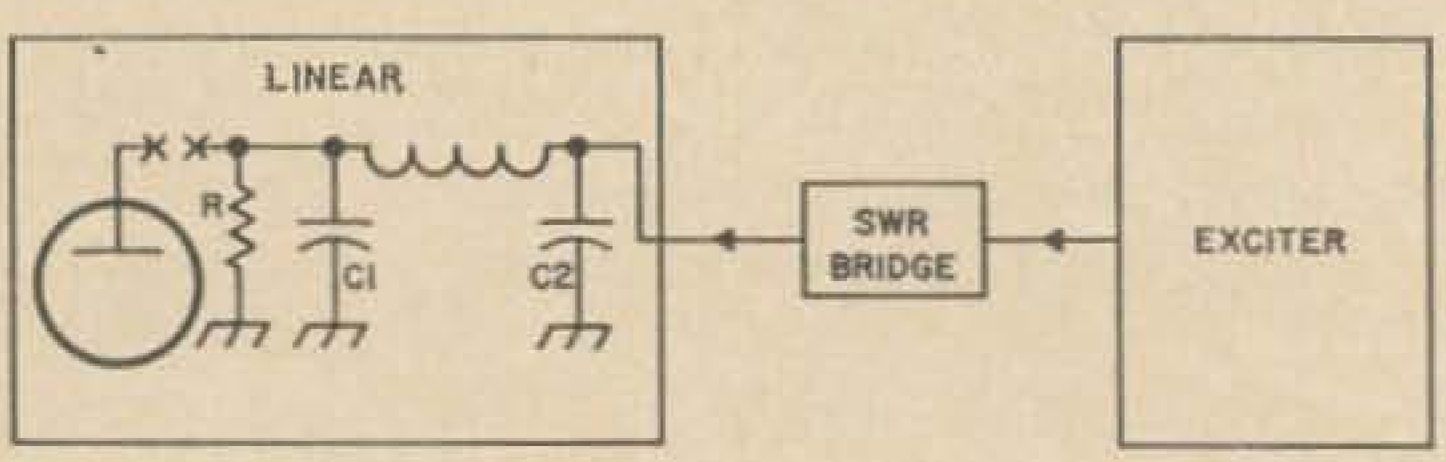
This has been pretty well covered in the modulation reports. The difference in S reports between the barefoot Twoer and the 40 watts out may surprise you, though. Especially if you use another receiver and can hear the other DX like they can now hear you!

. . . K1CLL

Tapping of Pi-Section Inductors

Since many amateurs design their linear amplifier around a favorite tube, only rarely is the plate resistance accommodating enough to allow the use of commercial inductors. So one has to move taps around and, more often than not, the end result is guesswork. I present here an almost foolproof scheme for tapping inductors that does not seem to be general knowledge.

After completing the pi-section, compute the proper values for C_1 and C_2 in the middle of each band. Then disconnect the tube from the pi-section and replace it with a composition resistor of value equal to the plate resistance. Next on each band replace the variable capacitors C_1 and C_2 with fixed value types of the correct value for the middle of the band. Next tune your exciter to the middle of the band and connect it through an SWR bridge to the output of the pi-section. Then applying drive commensurate to the wattage of the composition resistor, tap the inductor for minimum SWR. Do this for each band in turn.



Thus 1:1 swr insures that the 50 ohm output of the pi-section will match exactly the load resistance of the tube or in practice that the tube will match to the antenna. This same technique has many applications as for instance to match grid circuits for maximum transfer of power.

. . . Chuck MacCluer W8MQW

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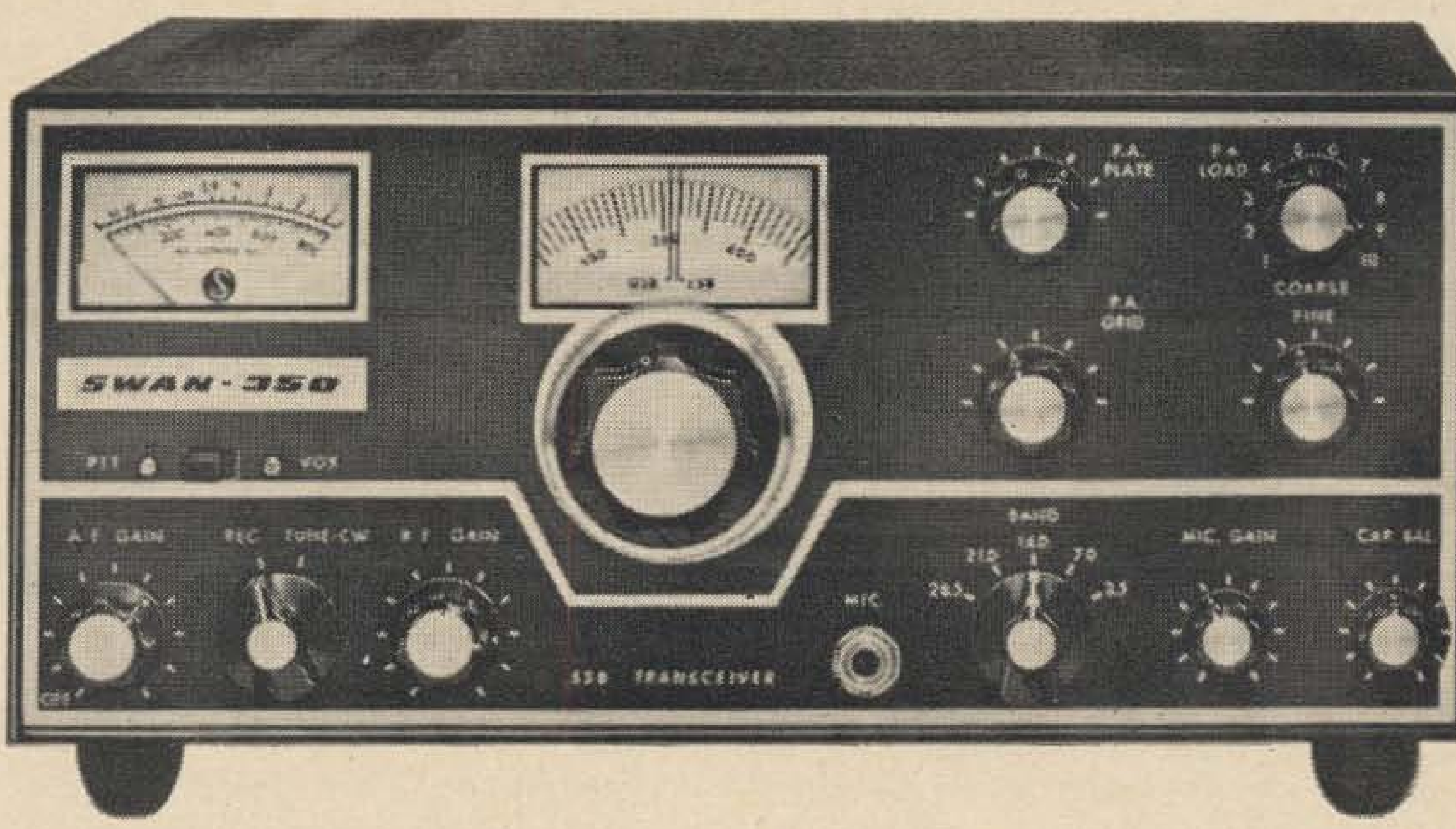

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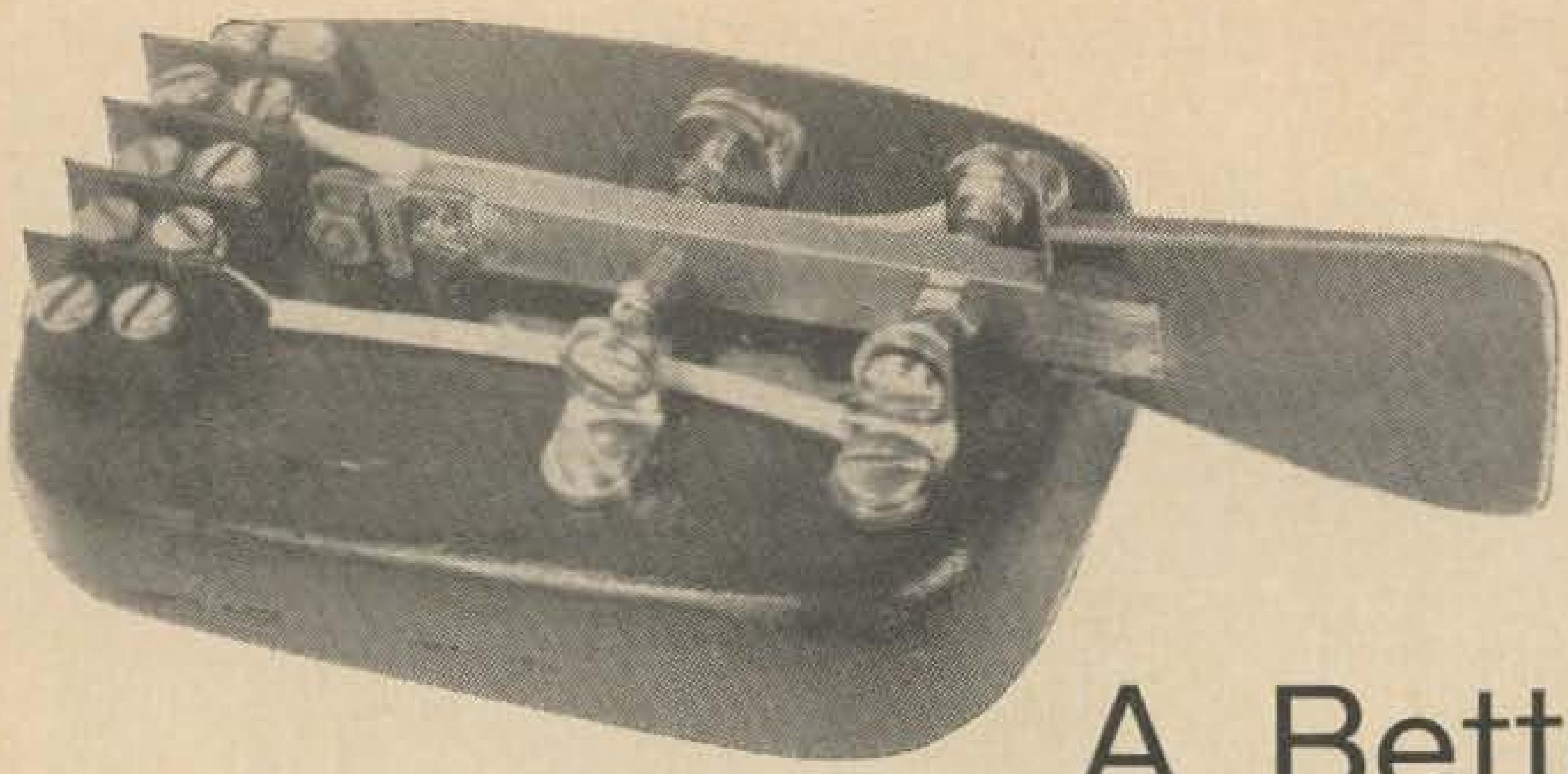

Ed Marriner W6BLZ
528 Colima Street
La Jolla, California

A Better Sideswiper for Electronic Keyers

The local radio parts store, and metal supply have enough simple parts to build a good sideswiper for electronic keys. This idea is better than a makeshift key using a hacksaw blade or tearing up a regular telegraph key.

All of the parts for the key are mounted on a lead base to keep the key solid on the operating table. Lead is also easy to drill and tap,

Ed has been licensed since 1931 with one call-W6BLZ. He is a System Engineer for the U.S. Naval Electronics Lab in San Diego and has had 350 articles printed in various magazines.

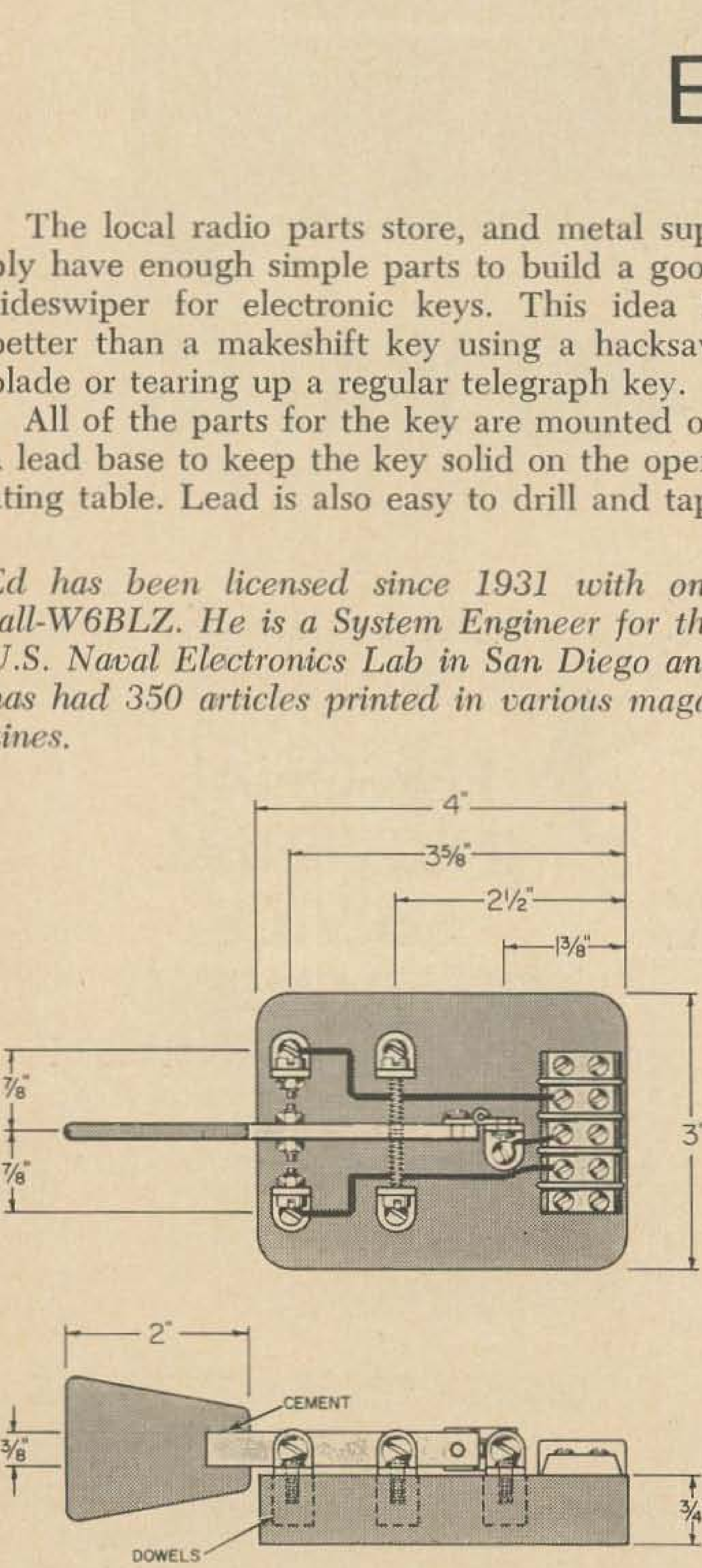

Fig. 1. W6BLZ's sideswiper for electronic keyers. The base is made from lead molded in a sardine can.

and should offer no problem for the home constructor. The mold is made from a sardine can, and the round corners give a pleasing appearance to the key.

Construction

First go to the grocery store and select a nice can of sardines, and a size suitable to your liking. Dispose of the sardines and trim the metal off to the edge of the can and clean it out thoroughly. Heat some lead in a small crucible or small skillet and pour the lead into the can. When the lead has cooled, tear away the tin by using pliers or diagonals. Any roughness left on the surface of the lead can easily be filed away with a rough file, and then smoothed with sandpaper. Use the bottom side of the can for the top of the base. Spray the base with lacquer after all of the holes are drilled and tapped.

To make construction simple, the contact leads are fastened to a Jones type barrier strip mounted on the base by tapping in 6-32 holding screws. All of the radio brackets are found in the Walsco displays in the parts store. The brackets are all fastened by tapping into the lead. The two front contacts for dot and dash are mounted on an insulated dowel of either fiber or wood, which have been driven into a ⅜ inch hole put in the lead.

The contacts for the key are made simply from 8-32 machine screws. These were used because the hole in the 90 degree bracket is just the right diameter for tapping 8-32 threads, and makes a good adjustable contact. A cap head type screw is best so that it will clear the 6-32 head holding the bracket to the base.

A ⅜ inch ¼ metal brass bar was obtained at a metal supply house for the lever arm. It is fastened to the base by attaching a small brass hinge which has been sawed in half. Having tried all of the pivots and bearings, the cheapest and best turned out to be this hinge which only cost 40 cents for a set of four. Any slop in motion can be corrected by pinching the metal going around the pin. It is better to attach the hinge to the lever with a screw and then drop a bit of solder on it with a small torch or large soldering iron. The particular hinge was type #5075XC, manufactured by the Brainerd Mfg Co. East Rochester, N.Y., it is a ¾ inches x ⅝ wide, solid brass butt type hinge.

Two holes were drilled into each side of the lever arm to accept the ends of the tension springs to keep them in line. The springs were found in a hardware store and had a light tension. They could be taken off from surplus relays. The springs should be soldered on to the ends of the adjustment screws going through the bracket.

Adjustment

Once the key is finished, insulated wires can be run back from each contact to the terminal strip. Since the base is ground, a screw can be run through the middle terminal screw and tapped into the base making it necessary to only run two wires from the contacts. The two springs can be used to center the lever arm, or stops can be screwed into the base to suit the operator adjustment.

This key is easy to make, functions smoothly and looks a little better than many other make shift devices used for keying the automatic keyers. Besides, think of the enjoyment Pussy Cat will get eating all those sardines!

. . . W6BLZ

Source of the mold for the base of the key.

Dr. Howard Klein WB2EPG
123-60-83rd Ave.
Kew Gardens, N.Y. 11415

Replace Your 811's with 572B's —The Right Way

Due to the popularity of the 811 tube in both commercial and homebrew linears several manufacturers produced a replacement for the 811's capable of greater plate dissipation and in general a more rugged tube. This was the 572. With its introduction several years ago there were several references to the exchange of 811's for 572's. All of the references I had seen merely suggested the replacement of the existing 811's with the 572's without any further change. This seemed like an easy way to increase power without effort and with small expense. How this increase in power was actually achieved was given little thought.

In my rig which used four 811's, the power supply, a conventional full wave bridge rectifier circuit, delivered 1700 volts at no load and 1500 volts at 600 mA. By replacing the 811's with 572's the output was found to be substantially the same but the odd order distortion products were found to have increased markedly. The only discernible advantage was that the 572's showed no color on the plates.

After some thought and a perusal of the spec sheet on the tube, available from the manufacturer, the following changes were made. It was first deemed necessary to raise the plate voltage on the tube to about 2500 volts. This was done by jumping the input choke which raised the no load voltage to 2700 volts in my case. At the same time it was necessary to increase the filter capacitor rating to a safe working voltage. I originally had five 100 μF electrolytics rated at 450 working volts in series shunted by 100 k resistors. I added three more similar electrolytics and shunted each of these with like resistors. The transformer as used originally had a dual winding secondary, for B plus and filament voltages. Since this was felt to be poor design an outboard filament transformer was incorporated. This also allowed the original transformer to operate without saturating under full load.

Under these conditions the rectifiers must be carefully evaluated, particularly if they are solid state. In my power supply I have three silicon diodes each rated at 1700 piv and 750 mA and each shunted by a 470 k resistor and a .01 μF capacitor in each leg. It is also prudent to place a .003 μF silver mica capacitator of sufficient voltage rating across the transformer secondary.

A further change: 811's are usually operated with about 4.5 negative volts of operating bias. The tube manufacturer for the 572 recommends zero bias so the 4.5 volts was removed.

If the preceding conditions can satisfactorily be achieved the limiting factors now become the plate transformer, the exciter driving power and the FCC. To drive four 572B's to a kilowatt input about one hundred watts is required allowing for circuit losses. Under test conditions into a dummy load the tubes were loaded to one amp. The plate voltage dropped from 2700 volts at no load to 2200 volts at one amp. The output as measured with a wattmeter showed 1400 watts. This is an efficiency of about 64%. Under actual on the air conditions the rig is loaded to 400 mA while the plate voltage is 2250 volts.

The removal of the choke raised questions as to the adequacy of the regulation. However the voltage variation was found to be within tolerable limits. Operating both in the SSB and CW mode, checks made with a scope and on the air indicated the signal was clean and free of excessive distortion products.

An excellent source for these tubes is Scientific Instrument Co. of Union, New Jersey. The price is $12.50. In a recent communication with the manufacturer, it is stated that the tubes have been further improved, the exact nature of which will soon be forthcoming. Waters Manufacturing also distributes 572B's.

. . . WB2EPG

Photo courtesy of Scientific Instrument Co.

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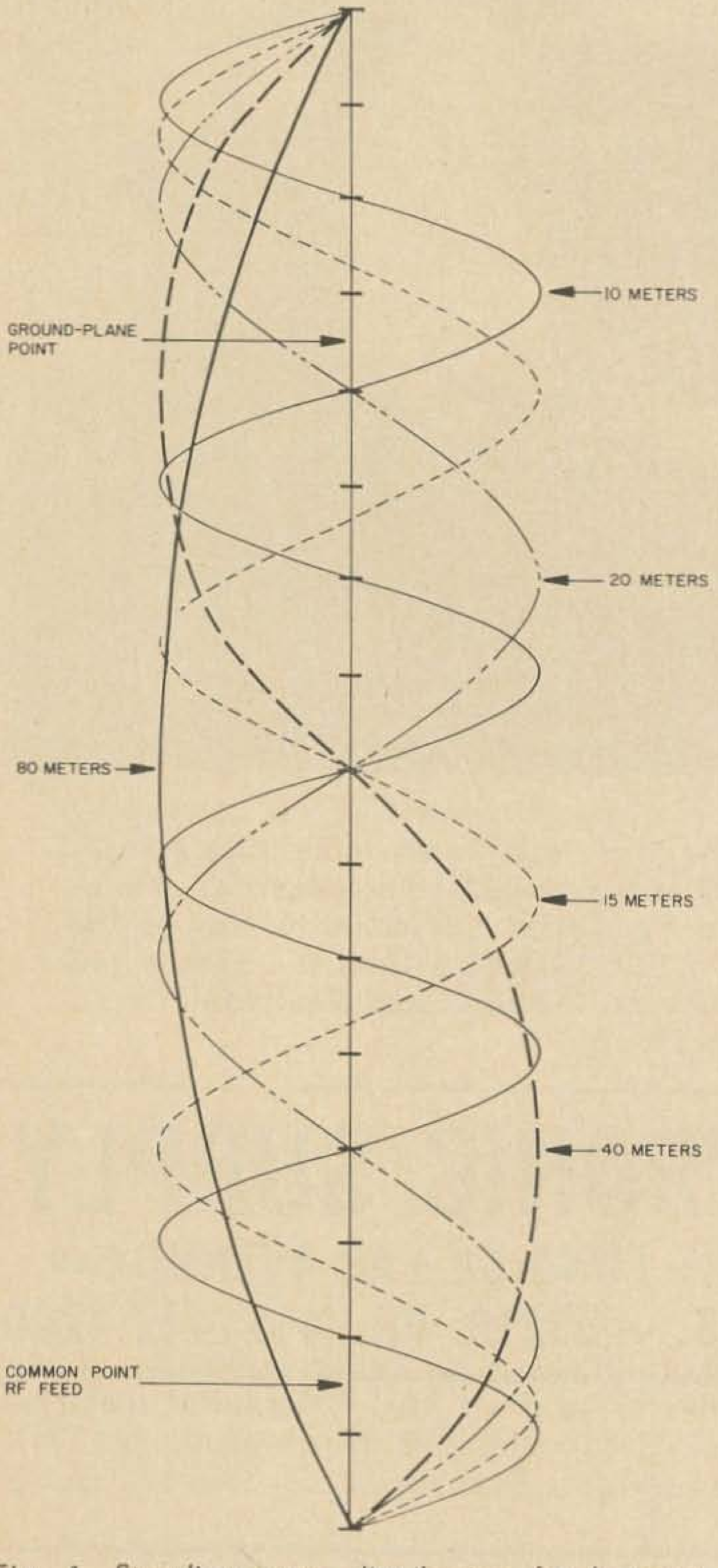

Fig. 1. Standing wave distribution for harmonically related even modes of excitation. Note that these curves are theoretical and assume equal power on the frequencies, constant efficiency, no mismatches and no ground plane effects.

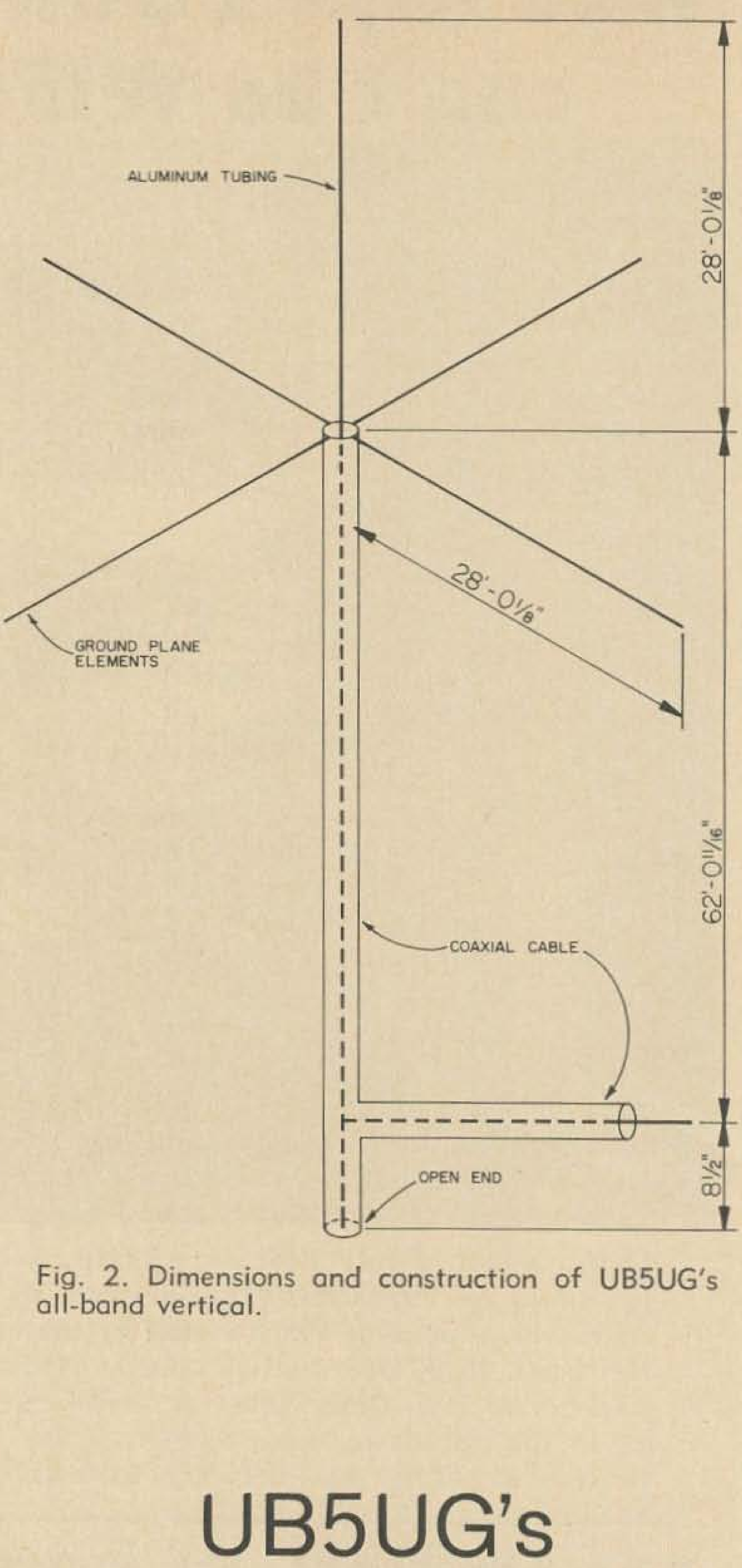

Fig. 2. Dimensions and construction of UB5UG's all-band vertical.

UB5UG's Five Band Vertical

For the past few years, UB5UG of Kiev, has been operating a multi-band vertical antenna that requires no switching and no traps. Moreover, the antenna is excited by a single rf feedline. In theory, the antenna system is quite straightforward, but the construction does require some ingenuity.

Basically, the system acts as two antennas. The frequency of operation determines which mode will take over. On eighty meters, it operates as a half-wave vertical, with the ground plane elements tending to act as a "hat." This effect improves the current distribution both on eighty and forty meters for low-angle dx.

On twenty and fifteen meters, the upper portion operates as a ground plane antenna. On twenty, the protruding rod acts as a 0.5 λ radiator, while on fifteen as a 0.625 λ radiator. Good enough results have also been obtained on ten meters.

Probably the system could be extended in both directions, with some additional tuning arrangements to operate on one hundred sixty meters and six meters. Approximate theoretical standing-wave distribution for the five main ham bands is illustrated in **Fig. 1.**

Like the horizontal Windom all-band antenna, the point of input feed represents a compromised low impedance point for all the bands. The exact point, together with all the other dimensions, is shown in **Fig. 2.** An SWR of 3:1 to 3.5:1 on eighty is reported by UB5UG. On forty, twenty, and fifteen meters it is around 1.5:1, and is 2:1 for the ten meter band. Most efficient radiation occurs in the twenty and fifteen meter bands.

Not much is said about the physical aspects of the antenna. The basic vertical length consists of 72 ohm coaxial cable. The feedline is also 72 ohm coaxial cable. Above the vertical coax section is a 28-foot rod of 1½ inch tubing. Ground plane elements consist of antenna cabling mounted on hazelwood beams.

As a self-supporting vertical radiator, the antenna may present some formidable problems. Probably the simplest solution would be a wooden pole with wooden cross-arms. The cables and rods could then be mounted to this frame via stand-off insulators. To the ambitious and enterprising radio amateur confronted with such a vertical solution to his antenna problem, the actual structure should be just another challenge.

. . . W8FAZ

This article based on an item in Soviet Journal, *RADIO*, No. 9, 1960, page 44, entitled "Five-band Vertical Antenna," by Y. Myedinyets (UB5UG).

To the left is Don setting up his gear (note the foam rubber pillows) on Minerva Reef, where he operated as 1M4A. Above is a shot of part of this luscious tropical island. How would you like to be shipwrecked there?

Don Miller W9WNV DXploring

Here's Don operating 1M4A.

Maria Teresa Reef seems to be pretty moist. Don is shown here setting up his vertical on the dry part of the island. That isn't sand around the rock; Don operated with his feet in the water. The boy isn't identified.

Here's Don operating FO8M on Maria Teresa.

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Gus: Part 13

The operation in Monaco was a success and everyone knew I was on my way. Even had a FB QSO with Harvey Brain VQ9HB to let him know I was on my way to the Seychelles and to have the man who owned the boat have it all shipshape to depart when I arrived there. I made a few stops along the way between Monaco and Bombay. Met some of my old friends in Cairo, Beirut, Aden, a few others. Finally arriving in Bombay a few days before the S.S. Kampala was to depart for VQ9 land. The usual way to get to VQ9 land is by way of Mombasa, Kenya. This is a little cheaper than by way of Bombay, but I tried to get reservations on one of the boats six months in advance and was informed that all reservations were filled up for over a year in advance. It seemed tht every VU2 that was living in Africa was on a one way trip back to VU2 land. Apparently they were of the opinion that things were not going to be good for them in Africa any more and they were going back to their mother country. Passage was arranged very easily from Bombay to the Seychelles. In fact the boat seemed to be about only half filled.

Remember the day I departed from Idlewild we shipped a number of items via air freight to Bombay for reshipment to VQ9 land on the SS Kampala along with me. It was good I got in Bombay a few days before sailing day because there was nothing at the airline offices for me at all. Mind you I had been delayed in arriving in Bombay about twelve days, and I arrived about four days before departure date for the Seychelles. Even with all this extra allowance for air freight shipment delays, etc., nothing had as yet arrived in Bombay. I could not possibly depart on that boat unless I saw my power plant and the other material on the ship. It would have done me no good to arrive on the island without at least the power plant which I was going to use at Aldabra. It took a lot of DX telephone calls to finally locate the air freight shipment. It somehow had been offloaded in Karachi and was just laying there for some strange reason. To be truthful every experience I have ever had with air freight shipments were always like this. The shipment arrived in Bombay one day before sailing day to the Seychelles and on top of that it was a legal holiday. Now you try getting something from Indian Customs on one of their holidays when customs are closed up. Then I had to pay extra for a customs guard to come along with the shipment to be sure it was put on the ship and that it did not end up in India. You don't fool these Indian customs fellows, they trust no one at anytime under any condition. Now all of this monkey business cost quite a few extra rupees. I was the one who ended up paying all this of course and also the DX phone calls too. I tell you these unexpected costs will eat a big hole in your pocketbook. Trying to keep an exact account of such expenses are a real headache and I suppose I have lost quite a good sized sum of money in trying to keep a record of expenses. You have the extra trouble of trying to keep your records in dollars and spending rupees, and every time you move those hands are out for backshee (tips), and these people are real professionals when it comes to extracting the last rupee from you. I was lucky in Bombay to have met Dady VU2MD, Tipi VU2TP, VU2RX and VU2CQ. They took very good care of me with transportation all the time to wherever I wanted to go, and they knew all the shortcuts in dealing with their people or I suppose I would have ended up spending a lots more than I did. These VU2 boys were very wonderful to me and knew how to roll out the Red Carpet. Later on I found that every one of the Indian Radio amateurs was the same way. They will do anything in the world for a fellow ham. After spending a few days in Bombay I could easily see where the expression the "masses of India" came from. You cannot picture in your mind the amount of human beings you see on the streets of Bombay. Later on I found that Calcutta was like Bombay only multiply what you see by about 3 and you have some idea what a tremendous amount of people there were on the streets. I soon found out to not give any rupees to the beggars on the street because before you can bat your eyes there are a hundred where they came from. About the best way, at least with me, when the beggars approached you were to look straight ahead and not ever even let them know that you see or hear them. Trying to overcome the giving of backshee to them is a very difficult thing to do. It's sort of like trying to plug up a dike made of screen wire with a few toothpicks, the little relief you give is so insignificant you may as well not even bother. At least that's how it seemed to me.

You want service in a restaurant, just go to an Indian restaurant, there are usually more servants than there are tables and when you get ready to leave it seems like everyone of them waited on you. I mean when you see all the hands sticking out for their tips. The Airlines Hotel in Bombay is a pretty good place to stay when you are there, their prices are fair and, boy, you do get service. The day to depart from Bombay arrived and the usual rush down at the boat took place, customs was cleared, everything that was shipped by air freight was placed in my cabin, everyone was paid off, I shook hands with the VU2 fellows, the anchor was lifted and we were away for the Seychelles. At that time the fare was around $120.00 for one way passage from Bombay to VQ9 land. This was tourist class, the cabins were very clean and the service fine.

I met a man from Zanzibar who had gone back to Pakistan to see some of his relatives along with his family. He had a brand new Mercury car that he was taking back to Zanzibar on board the ship. I told him that I might get back to Zanzibar and he insisted that I make his home my home when I arrived in Zanzibar. He was in the ivory business and from what I saw of him and his family he was very successful. I still have his address and telephone number in my little white book. But since reading all about what happened down in Zanzibar the past few years I guess he is not there any more. Maybe he was lucky enough to have escaped the fate of some of the others that I read about. I often find myself wondering about him and his very nice family. If any Americans ever get back into that country to do any operating I will be very much surprised. That is not unless there is a big change in their attitude from what it seems to be at this time. When I was in Zanzibar a few years before things were so peaceful and quiet, and everyone seemed to be doing such a fine business. Maybe some day I will get another chance to go there if for no reason other than to see if there has been many changes from what it was when I was there.

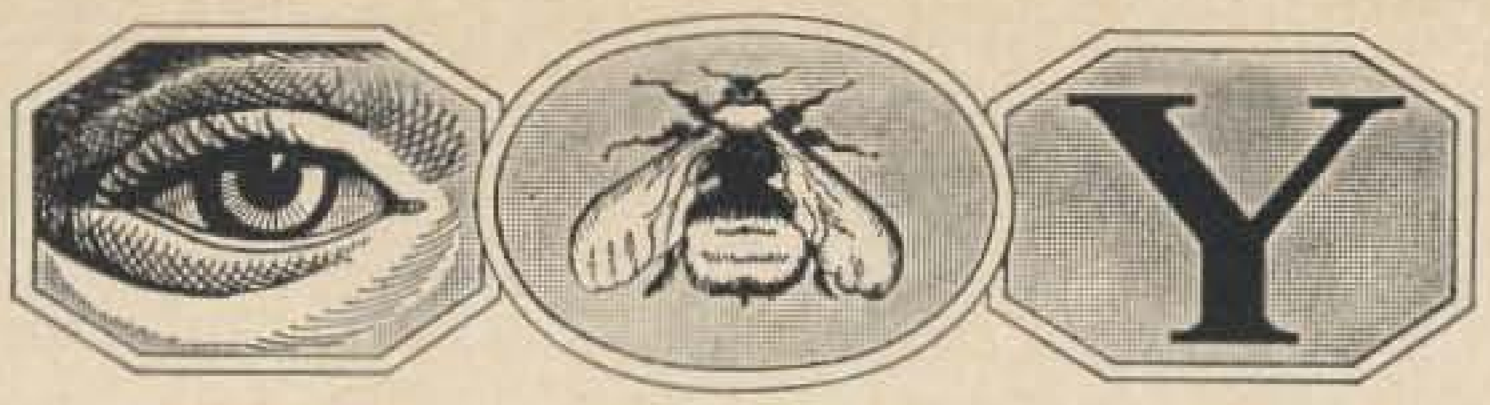
For the benefit of any of you fellows who have never made an ocean voyage on a large ship, let me tell you that you have missed some of the most pleasant things in this world. The meals on these ships are out of this world. Three or four different kinds of meat for every meal and everything else that goes towards making some of the finest eating you will ever have. You know when you pay them the $120.00 for the boat passage you are also paying for all the food for the entire trip. If time is not a pressing matter with you I cannot over emphasize or over-recommend that you take a boat trip the next time you go overseas. Setting up there on the sun deck watching the flying fish sail away when the ship approached them, and occasionally seeing a whale blow in the distance, or just watching the sea gulls following the boat makes things so peaceful and restful. Every morning usually you could see any number of porpoises parading along with the boat usually in schools of three or four. The trip from Bombay to the Seychelles took five and one half days and I must say they certainly were very restful days. Every night there was a movie and afterwards there was dancing with the orchestra. They even played some twist music and this did liven up things a bit. Everyone played many different games all during the day. All I can say is "take yourself an ocean trip by boat."

Remember the only way to get to VQ9 is by boat either from Bombay, Karachi, or Mombasa. Ships sail about once per month and occasionally during certain months twice per month. I tried talking the wireless operator into letting me do some "maritime mobile" but could never get to first base. The fellow that the boys from Kansas City and I met before either was not working on the ship any more or was on leave. I even talked to the captain about it and he just could not understand why a fellow would want to operate from a ship out in the middle of the Indian Ocean. I finally gave up on this and just acted like all the other passengers on board. I sat back in the deck chairs, drank my tea twice daily, was first in the dining room when they rang the bell, went to bed each night early and read a lot of books from the ship's library. The trip was enjoyable and I arrived at VQ9 in a very rested up condition. But I would have preferred it a lot more if I could have been operating W4BPD/MM I am sure. I was busy getting my logs in order, writing a few letters, and sort of going over the equipment. I wanted everything to be "go" when I arrived at VQ9 and was hoping that Harvey and Jake (the owner of the boat) would have everything ready to go also.

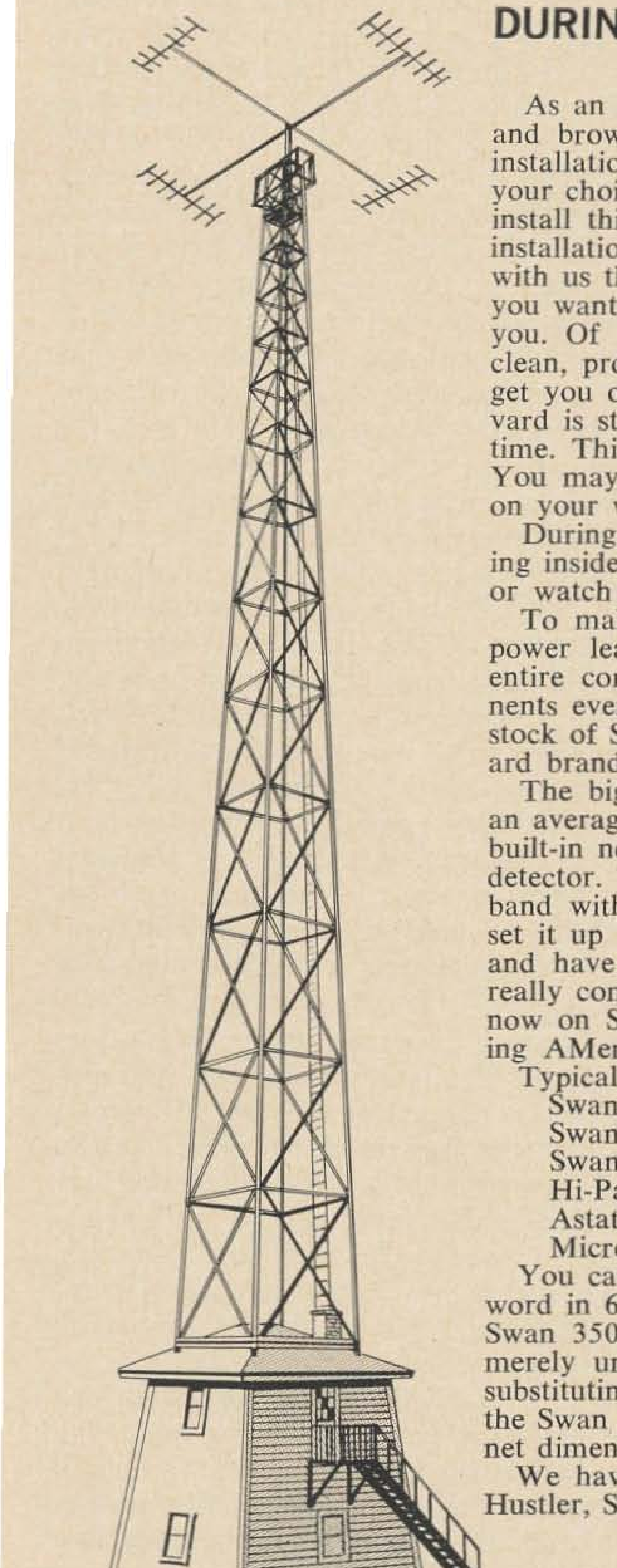
Early in the morning of the fifth day, Mahe, the main island of the Seychelles group was sighted off in the distance, first as a sort of long mountain peak sticking up out of the water with a few of the other smaller islands nearby as smaller mountain peaks. As the ship drew closer the mountain gradually changed into the general shape of an island. A little later on the palm trees and then the beaches could be seen with the breakers breaking on the beaches. The Kampala being a fairly large ship always anchored out in the deep channel about one mile away from the end of the long pier. Many of the island boats always come out to meet the ships when they anchor in the channel. Some pick up the passengers that are leaving the ship at Mahe, and also the ship passengers who want to come ashore to do a little shopping and sight seeing. The ship always stands at anchor for six or eight hours giving everyone plenty of time to come ashore and get back on board to continue on their way to Mombasa. The little passenger launch picked up the few that was leaving the ship, I think there were only about four on this stop.

When the passenger launch stopped to drop us off at the customs and immigration office on the long pier, good old Harvey was there as usual waiting for me. To me each moment was a little bit more exciting then the one before, knowing that all the DXers back home were scanning the bands for my signal. It has always been a thrill to me to know I had so many friends and let's call them "Gus Watchers" like W6ISQ (I love them dots) wrote about some time ago in QST. This fact never leaves my mind when I get overseas, and I try my darndest to appear on the bands as often as possible because I don't want to let them down. I remember the many hours I have spent back at W4BPD waiting for some rare DX station to appear. Many times of course I have been disappointed because some of the stations on these DXpeditions just were not dependable when it came time for them to appear on the bands. I very badly wanted by reputation to be one that could be depended upon to be on the air especially when skip was at its peak, both before and after the peak had come and gone. You DXers remember when I am on DXpedition I am actually more anxious to work you than you are to work me. I have lots more at stake then any one station has. I always remember that lots of money has been spent getting me to these rare spots and I want everyone to feel that they have not spent their money uselessly.

Immigration and customs were no trouble



DURING THE SUMMER MONTHS, WE WILL INSTALL YOUR SWAN MOBILE RIG FREE!



As an inducement to have you visit with us during the summer months and browse amongst our large stock, we offer a summer special of free installation of any mobile rig purchased. You merely pay for the rig of your choice in the conventional manner and if properly scheduled, we will install this equipment at no cost to you. Our experts can make a typical installation in about 45 minutes and so if you will schedule in advance with us the approximate time of your arrival and the date, telling us what you want, the rest can be left to us and we will do a professional job for you. Of course we cannot RFI the car at no charge but we will do a clean, professional job of installing your new Swan 250, 350, or 400 and get you on your way in the shortest possible time. The area around Harvard is steeped in history and is particularly beautiful during the summertime. This is not a city and we are some 35 miles northwest of Boston. You may find it convenient to fit Harvard into your schedule if you are on your way to New Hampshire or Maine for your vacation.

During the time that the gear is being installed or that you are palavering inside, the kids can have fun with Susan, our stump-tailed chimpanzee or watch our many Italian greyhounds frolic in the open field.

To make things easier, we have prepared pre-cut lengths of coax and power leads so as to fit each kind of vehicle. Of course, we have the entire complement of mobile antennas, halos, and power supply components even for the positive-grounded foreign vehicles. We have the largest stock of Swan in New England and can additionally install all other standard brand items.

The big deal this summer is the Swan 6-meter Model 250. It provides an average 80 watts of input on AM and 240 PEP rating on SSB. It has a built-in noise limiter and an AM detector as well as the conventional SSB detector. The receiver is really hot and you can cover the entire 6-meter band with this equipment. In fact, if you're a MARS member, you can set it up for either Army, Navy, or Air Force MARS frequencies as well and have a ball by checking into our New England nets. Sideband has really come into its own this year. It seems to me that 5% or greater are now on SSB, and this Model 250 will really make a dent in the remaining AMers.

Typical installation of the Swan 250 looks like this:

Swan 250	$325.00
Swan 117XC for AC operation	95.00
Swan 14X for converting to DC mobile operation	65.00
Hi-Par halo and mount assembly	16.95
Astatic hi-impact ceramic mobile mike	7.50
Microphone plug and coaxial connectors and balun	n/c

You can see from this that for a total of $509.45 you can have the last word in 6-meters and the beautiful part of it is that you can substitute the Swan 350 for the 250 and operate on 10, 15, 20, 40, and 80 meters by merely unscrewing the gimbal clamp and dropping out the one set and substituting the other. In other words, the power supply requirements for the Swan 250 and 350 are the same and both have the same physical cabinet dimensions.

We have the complete complement of Cush Craft, Hi-Par, New-Tronic Hustler, Super-Hustler, Swan antennas and Webster Band Spanners in stock and so if you really want to load up and go all bands, we'll install everything on your car and do a creditable job. You won't need a linear with Swan.

Birds of a feather flock together—buy a Swan and have fun this summer.

Herb Gordon W1IBY

HERBERT W. GORDON COMPANY

Woodchuck Hill, Harvard, Mass., 01451

Telephone 617-456-3548

at all as is usual in VQ9 land. They did check my things a little bit closer this time, wanting to know how long I was going to stay there, where, and the purpose of the trip. My usual answer to most questions are a flat statement that I was a "tourist" and radio was my hobby. At least those were my answers in VQ9 land. You know they like tourists down there. Oh yes this is one of the few places left in the world that is not overrun with tourists and tourist traps with the usual boosting of prices to take in the tourists. Someone told me the ratio of ladies to men on the Seychelles are something like nine to one—That's a very high SWR and it does make life very interesting down there. I think this ratio is not quite true, but it's still pretty high.

Their only town is Port Victoria with that town clock that strikes twice on each hour. The entire population of Mahe is about 40,000 and the island is about 35 miles long and some 3½ miles wide. The color of the people are anywhere from jet black to 100% white. There is no predominating color there, everyone there lives very peacefully with every other one. No one seems to take life very seriously there, and no one seemed to me to be working very hard. They all really take it easy and no one ever seemed to be in a hurry to do anything. Every morning at about ten there is that tea break and of course at four in the afternoon they have their tea break again. This is one thing that everyone does. The stores all close at about twelve noon and open up again at three.

Port Victoria is the only seaport town on the island and this is where all the ships come to. They have two piers, one called the long pier which is about 1,000 foot long, extending out towards the deep channel where the big boats anchor. Along this pier you will find a few ship repair shops, Customs and immigration offices, and also the turtle pond where they put the live turtles they bring back from Aldabra Island. They keep the turtles there until they are sold. Then there is the short pier which runs parallel with the long pier, it extends out about 500 feet I would estimate and is about 500 feet away from the long pier. This is the pier where Harvey keeps his boat, and others with small boats anchor. Harvey and I walked over to the short pier and out near its end I saw his boat at anchor in the same place it was when the Kansas City boys and I departed from the islands about two years from the date I arrived there.

I was introduced to the owner of the small boat that was to carry us to VQ7 land—a fellow named Jake. The boat was named the Lua Lua. This was a very fine boat, 36 ft. long and about 8 foot wide, made out of 1⁄16 inch steel plate. There is a good story behind this boat and its owner. Jake and his family had been living in Northern Rhodesia for a number of years, just across the border from the Katanga province of the Congo. Jake was in the auto and truck body business. He was from Austria and had been down in Africa a long time. The Congo trouble had finally spilled out of the borders of the Congo and a number of houses very near their little town had been burned and a number of people had even been killed by the Congolese. Apparently they did not know exactly where their border stopped or maybe they did not care. Anyhow Jake and his family decided their days in Africa were numbered and they wanted out. He found a description of the boat in some magazine, maybe Popular Mechanics or something like that. He had lots of sheet steel on hand for building truck bodies and a fully equipped metal shop, and he had the will to undertake the construction of the boat right there in Northern Rhodesia a very long way from any ocean. He even ordered a second hand sextant and instructions as to how to use it. Mind you he had never in his life been at sea before. After about six months of hard work the boat was finished. He used every inch on the boat for some useful purpose. Practically each inside wall was covered with metal built cabinets to hold various items. The diesel fuel tank was built in and the fresh water tank built in. There was a place for each item and each item was in its place. The boat was hauled by trailer overland from northwestern Northern Rhodesia all the way to the Indian ocean, placed in the water and Jake by himself sailed it all the way to the Seychelles. His family (wife and daughter) went by ocean liner from Mombasa. Maybe they did not trust Jake and his navigation with that second hand sextant, or maybe they did not trust the boat, or maybe it was a case of not trusting both. Well here was Jake in his boat in VQ9 land safe and sound. The boat was basically a sail boat with the small diesel engine used for docking purposes mostly. The mast I would estimate was something like 60 foot high and the leaded keel was very deep also to compensate for that extra high mast. The boat looked good to me and I was very sorry that Lee Bergren WØAIW and the boys form Kansas City were not there with me to look it over. I am sure they yould have fallen in love with the little ship. Everything was so ship-shape, everything freshly painted, the engine purred like a kitten. It was not like other boats I had seen before in and around VQ9 land, not by a long shot. The nicest part of it all was Jake was ready to go when I arrived there.

After the usual preliminaries and customs were attended to, the owner of the Aldabras consulted, and his letter of introduction given me we were ready to go. Away we went down to "Temolgees" store and bought all the supplie we would need, a 50 gallon drum of gasoline, lots of Bully Beef I think Harvey's favorit food), cans of soda crackers, plenty of tea, sugar, canned cream, and a lot of other items. Harvey knows what you will need and he did a good job in chosing the right amount of food, fuel, etc. A ll of this took about three days, during this time I checked into the Hotel de Seychelles and did some operating. The bands as usual from VQ9 land were very FB. I told the fellows that Aldabra would soon be on the air. I suppose the fellows back in the USA were already thinking of their excuses to tell the places they worked at why they would not be at work in a week or so.

The Hotel de Seychelles is one of the nicest Hotels in VQ9. It consists of a long row of thatched huts on the beach. Each thatched hut is a hotel room. In about their middle is a larger thatched hut which is the dining room, reading room, and recreation get-together place when there is some social activity. They gave me the hut on the very end after I explained to them that I would be running my putt-putt all during the night and I did not want to keep anyone awake with its noise. This putt-putt I had was one of those very loud ones with a very small muffler which did not do to much muffling. Things on the beach in front of my room were very interesting, especially after sundown. On the nights of the full moon they have a real ball on the beach there with a lots of capers going on practically all night all up and down the beach and under the palm trees that lined the beach. That beach is a very busy place on these full moon nights. There are very few recreational activities around the island but they find plenty to do after sundown, especially on full moon nights. Well you know how it is when a bunch of boys and girls get together, they will find something to do. If there is any chaperoning down there I never saw or heard of them. Oh yes, the rates of the hotel when I was down there was only $22.00 per week and this included room and board. The food is very fine, and no one ever complained about anything there. If you want to go on a very fine vacation I highly recommend that you go to the Seychelles. I have a lots more to tell you all next month. . . . Gus

Bruce Walther W9QAH

ID Key

This is a key designed for use on front panel key jacks to either tune up or identify on RTTY. Construction is very simple and uses parts from almost any junk box.

Obtain an old surplus PL55 plug. Remove the cover and grind off the ring and about half of the bottom shell up to the ground screw.

Find an old telephone relay contact about three inches long. Drill a hole at one end to fit the tip screw on the jack. Then screw the contact in place.

Drill out the old ground screw threads and tap with a 6/32 tap. Then thread in a 6/32 screw to about 1/32 inch from the contact installed above. Cut off the remaining part of the screw and solder to the shell. Also cut the control armature to the desired length and place several wrappings of tape on the end as a knob.

Now cut a half inch slot in the cover as shown. Place the cover on the plug and align the slot on the right with contact armature.

And there you have a real space saver for the no-CW operator to load or ID with. All you have to do to lock it up is shove the contact armature to the right into the slot.

. . . W9QAH

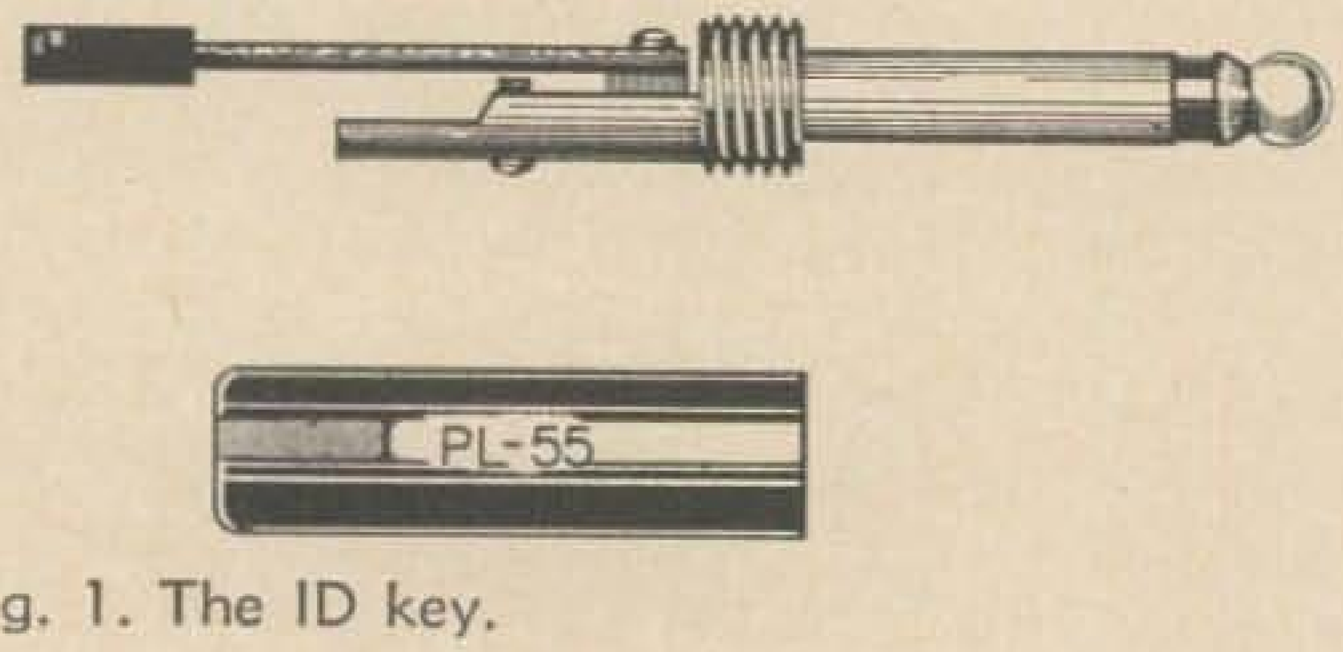


Fig. 1. The ID key.

Souping Up the Heath Twoer

Anyone who has ever purchased a Heath Twoer knows that it is a very good buy for the money. It has enough power for local contacts with the average antenna, as well as plenty of audio to fill the carrier. This article will show how to convert a good rig into a better one.

A stock set has approximately 25 ma at 200 volts going into the 6BA8 final. This can be increased to 7.5 watts with audio to match by simply changing a few resistors and capacitors. Unfortunately, this exceeds the dissipation of the final tube, but the 6BA8 seems to stand it. The difference in output is about 2 db, just discernable.

Start with the power supply. The 330 ohm 2 watt resistor R14 should be decreased to 270 ohms. You can add another electrolytic in parallel with C33A (40 μf) if you wish, but the extra filtering doesn't seem to be really necessary.

Next is the final, V4B. Decreasing the value of the screen resistor (R7) will give more power input. I found that 1000 ohms gave 7.5 watts input.

Now in the audio section, replace R23 (270,000 ohms) connected to pin 7 of V1A with a 27,000 ohm resistor. Also replace C35 (.01 μf) going from pin 6 of the 12AX7 (V1) to pin 1 of the 6AQ5 modulator (V2) with a .001 μf capacitor.

This completes the modifications and now a very slight touch up should be given the rig. As a last comment, I would suggest replacing the 6BA8 (V4) with a 6AU8—it seems to handle the extra power a little better.

. . . WB2JOS

Ear Saver

Inexpensive magnetic headphones have been on the market for years; but not dirt cheap ear cushions. Dozens of suggestions have appeared in just about every electronics magazine. However, a simple and dirt cheap solution has been found. For about two bits, you can make your phones feel like the stereophones being sold for $25.00.

A trip to your local drug store will reveal that a pair of milady's "powder puffs" solve the problem easily. These "puffs" are used as replacements for lady's compacts, but they do a better job on your ears. Just cut a small hole in the middle of each "puff," glue them on the phones, and you're in business.

This kink has been in use here for more than a year and no earaches have been encountered.

. . . D. Hausman

NEW PRODUCTS

New Sams Books

Sams has been busy publishing new books again and here's a quick run-down on a few of them: John Lenk's *Eliminating Engine Interference* has 128 pages and costs $2.50. The title is pretty self-explanatory. *Basic Piezoelectricity* by John Potter Shields covers this more-and-more important field that furnishes many industrial transducers as well as the common "crystal" mikes, headphones and phonograph pick-ups. It's also 128 pages and $2.50. *Color TV Troubles Clues, Volume II* by the PF Reporter Staff is $1.95. *Electronic Corrosion Control for Boats* is by John Lenk and also costs $1.95. A very simple, easy-to-understand book for newcomers to radio is *ABC's of Modern Radio* by Walter Salm. It's been newly revised by the author and costs $1.95. All of these books are available from your local distributor or from Howard Sams Co., 4300 West 62nd Street, Indianapolis, Indiana.

Communications Electronics Circuits

An excellent new textbook for electronics technicians has just been published (3/14) by Holt, Rinehart and Winston. It's *Communications Electronics Circuits* by J. J. DeFrance. But don't let that "textbook" scare you. It's one of the best books for learning electronics I've seen. It's modern and up-to-date, explains the material very well, and gives excellent review questions for the reader's guidance in checking himself. This book is unusually good for hams who want to learn more electronics, whether for getting an extra class license or commercial license, or just for their own knowledge, since it covers many topics that are passed over lightly by most other eelctronics books: SSB, antennas, transmission lines, propagation, etc. It also integrates semiconductors into the discussion of circuits so that they aren't suddenly thrown at you in a last minute addition. Necessary and important design and illustrative math is included, but not too many derivations of formulas—so beloved by mathematicians and confusing to technical students. All in all, it's an excellent book and highly recommended. 550 pages, $9.50. Holt, Rinehart and Winston, 383 Madison Avenue, New York, N.Y. 10017.

Fair Radio Catalog

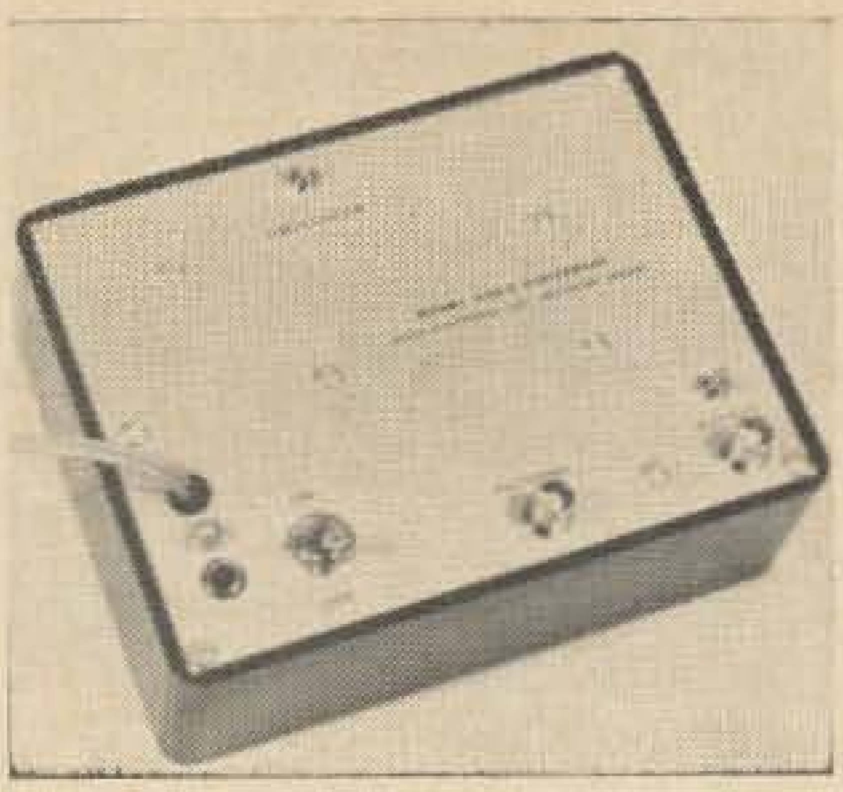
The new Fair Radio Spring and Summer Catalog contains 28 well-illustrated pages chock full of fascinating surplus bargains. Each page contains many items and virtually all are illustrated. They have a very large assortment of motors, transformers, and meters as well as many, many pieces of communications, test and other electronic equipment. This catalog is a must for any hams who aren't AO's. Send 25¢ for it (well worth the small price) and they'll refund 50¢ on your first order. Write Dept. 73, Fair Radio Sales, P.O. Box 1105, Lima, Ohio 45802.

Motorola Circuits Manual

A useful handbook put out by Motorola is their Semiconductor Circuits Manual for $2. Its main interest is power circuits: motor controls, inverters, power supplies and regulators, SCR switching controls, lamp controls, solid state ignition systems, etc. Many of these are very useful to hams and used by them every time they turn on their mobile rig or experiment with transistors. But probably the most interesting part of the book to most hams is the long section on transmitters. Theory and specs, including coil data and design considerations are given for marine band xmtrs (good for 160 and 80), CB (for 10), 30 mc SSB, 76 mc, 120 mc (AM), 2 watts on 160 mc, 5 watts and 8 watts on 240 mc. Binding is Motorola handbook's standard, easy-to-use looseleaf. Your Motorola distributor has copies, or you can order from Motorola TIC, Box 955, Phoenix, Arizona 85001.

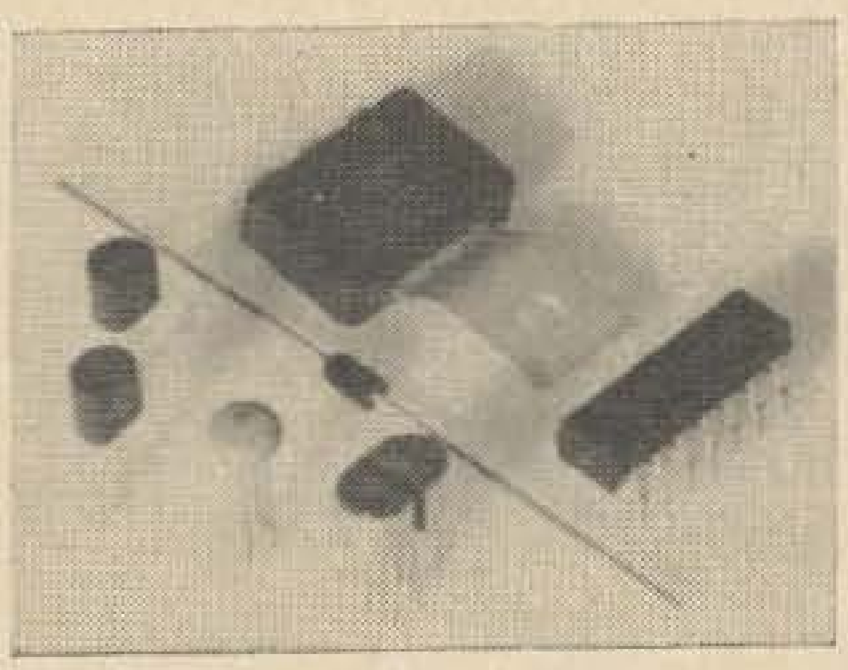
Motorola Application Note Index

The new Motorola Application note Index (April 1966) lists all of the current Motorola application notes with a small abstract of each. A fantastic number are of interest to hams (and engineers, of course) such as Designing Low Noise RF Input Transistor Stages, Low Cost Power Inverters (DC-to-DC) Using Off-the-Shelf Components, High Power Varactor Theory and Application, Transistors in SSB Amplifiers, Solid State Marine Xmtrs, Coax Cavity Varactor Multipliers, High Power RF Switching Can Replace Coax Relays, 40 watt Solid State Xmtr for 6, 5 watts on 3 GHz with Varactors, Epicap Tuning Theory, FET's in Theory and Practice, 15 watts on 2 and many more. Write Motorola TIC, Box 955, Phoenix, Arizona 85001 for your copy of the index.



Parks Solid State 432 Converter

Loren Parks K7AAD makes some of the nicest VHF and UHF gear around and is well-known by all VHF'ers for his gear and his little magazine, the *VHF'er*. He and W6HPH have recently come up with a new 432 MHz converter that is all solid state. It uses the fabulous TI TIXMO5 transistors (see April issue) for extremely low noise figure and high gain. Tuned lines in the converter are all silver-plated and all components and construction are of Parks' usual high quality. Each converter is individually checked for noise figure, too. He makes them in many *if*'s and the price is right: \$49.95, postpaid. You can order from him at Parks Labs, Rt. 2, Box 35, Beaverton, Oregon.



Economy TI Semiconductors

Texas Instruments has recently introduced a wide range of new economy, plastic-encased semiconductors. Among them are the industry's first plastic-encased unijunction transistor, the TIS43 with very low leakage and a very low price—72¢ in 100-quantities. Another is the TIS34, N-channel VHF field effect transistor (see the May issue of 73, page 12) with low feedback capacitance, high transconductance, high figure of merit and low cross modulation. Other interesting ones are a number of regular transistors such as the NPN 2N4254-5 for VHF and HF amplifiers, and the low-cost TIXM10 and 11 for rf amplifiers, mixers, oscillators and *if* amplifiers. You can get more information from TI distributors or Texas Instruments, P.O. Box 5012, Dallas, Texas.

(Continued from page 2)

ernments so that an official complaint can be sent through channels. The more countries we get involved in this business the better chance of it being effective, obviously. The ARRL and RSGB have been working along this line and have been achieving some results with it. It would be nice if we could organize something a little more worldly than this and try to have complaints filed from a dozen or two countries. Perhaps some amateur with a good signal and the time to devote to such a project could establish a net frequency and time for intruder watching and thus international coordination might result. Something on the order of the YL SSB "net" on 14,331 is what I have in mind . . . only without all that phone patching.

Although intentional jamming of signals is against the regulations just about everywhere there are a growing number of amateurs who are organizing this type of intruder defense. This certainly is a move to be considered even if it must remain sub rosa and might be a natural development of the above suggested net. Fortunately our work on 20 meters is not all that difficult for we have but a few intruders there most of the time. On the lower bands we have a formidable task.

While RTTY stations may be difficult to identify for us, even for those with ham RTTY gear, we do know that a well placed CW signal on either of the FSK channels can, if it overrides the intruder now and then on selective fades, cause misprinting. Most RTTY stations cannot abide misprinting on these circuits and will obligingly move to a clearer channel . . . hopefully outside our amateur bands.

Short wave broadcast stations are a bit harder to cope with. Here we may find that we will get beter results through correspondence with the broadcasters direct. I doubt if angry letters asking them to move will get more than chuckles, but sincere letters from SWLs asking them to move out from under all that amateur radio interference so they can better hear the interesting programs they are broadcasting might do the trick. The tourist agencies are also sensitive to pressure from that great benefactor: the American tourist.

While some of the commercial stations operating in the lower bands in Europe and Asia may be legitimate, we here in the U.S. have no mandate to protect them from interference. We may transmit as we like without worrying that we may be causing interference to a legitimate user of these frequencies and thus cause him to seek less crowded regions.

The only good reason that intruders are using our bands is that we are leaving space for them. There are plenty of other spots for them to operate if we nudge. Let's encourage them to find them.

ITU—Africa

Those of you who have been active on our DX bands know that there is virtually no African amateur radio activity other than by whites, visiting or residential. Since the countries are being taken over by blacks it is unlikely that a white activity will rate much protection from the new governments.

Certainly we must do something to get some support for amateur radio from these new nations. For that matter, it may actually be easier to get support from these countries than from the European countries where amateur radio seems to have a rather minimal support. Not that we are doing any better in the U.S. One of the basic reasons that I founded the Institute of Amateur Radio was to work toward getting the support of our Congress so that at future ITU conferences we would know that at least the U.S. government was solidly behind us. In 1959 I was flabbergasted to find that we did not have this support. The U.S. delegation has by far the most influence at this conference and if we don't have it supporting and protecting us to the best of its ability we might as well start work on those moon bounce dishes right now. I have been quite disappointed, though not surprised, at the bitter opposition the League has shown the Institute even though the Institute is organized to carry on work that the League has so far avoided.

To be blunt about the African problem: we don't know what to do there. It would be valuable to somehow set up some amateur radio stations there and train some locals to operate them and start them on the path to becoming devoted amateurs. Unfortunately there are many obstacles. We do have a good idea that we can arouse some interest in amateur radio by the time tested method of PR with articles in the local papers. It is possible that a donated club station plus a few newspaper articles might get things started if we had our own little Peace Corps operation with a team of two or three amateurs spending several months on the project. However, before we go plunging into something like this I think it would be valuable to send a man or two down there on a fact finding tour to see first hand what the problems are and what kind of reception we might get there to such an effort.

Did I hear someone asking how much all this is going to cost? There are always negative thinkers who try to spoil the fun. They should cut it out. I don't think financing of this would be difficult at all. In preliminary talks with a few of the amateurs in the U.S. that I know to be really seriously interested in helping to keep amateur radio going I had offers of large amounts of money and all the equipment we could possibly use. I think we could round up $50,000 easily and maybe even twice that without even asking for a dollar of that 100G the League earmarked for just such projects, but seems reluctant to actually spend.

There is a possibility that our little scheme could be coordinated with the existing Peace Corps, but I'm not sure that things might go smoother if we made every effort to include European and Asian amateurs in the task force and soft pedalled ourselves. We seem to have gotten a bit of a reputation and people often want to see what we have in the other hand when we are "giving" them something.

One of the projects that I had hoped the Institute would be able to tackle was the selling of the virtues of amateur radio to the European countries. Though amateur radio is an old story in those countries I believe that we have had as little PR there as we have in the U.S. and thus have the same lack of support we find at home. Unfortunately the Institute is growing much too slowly for me to look for any help from this quarter in the forseeable future.

The major question is: what do we do next? I don't feel that it is my place to elect myself a committee of one to start all this going. And other than myself what do we have in the way of international organization? The IARU seems hopelessly tied to the ARRL apron strings and ham strung as a result. They are bogged down in a morass of official inertia. The ARRL is on top and even if Region I of the Union wanted to break away and start something going, they would probably all be eyeing each other suspiciously to see who was trying to take advantage of the move. It would be a great step ahead if the presidents of the amateur radio societies of the world could get together in Geneva several times a year for a top level amateur radio summit conference behind closed doors and have the support of their organizations to make decisions binding at these meetings. I think that such an arrangement might make it possible to save ham radio.

W2NSD/SM/OHø/OH2

Having heard considerable about the beauty of Sweden's girls, country and socialism, I thought that I'd better check it all for myself.

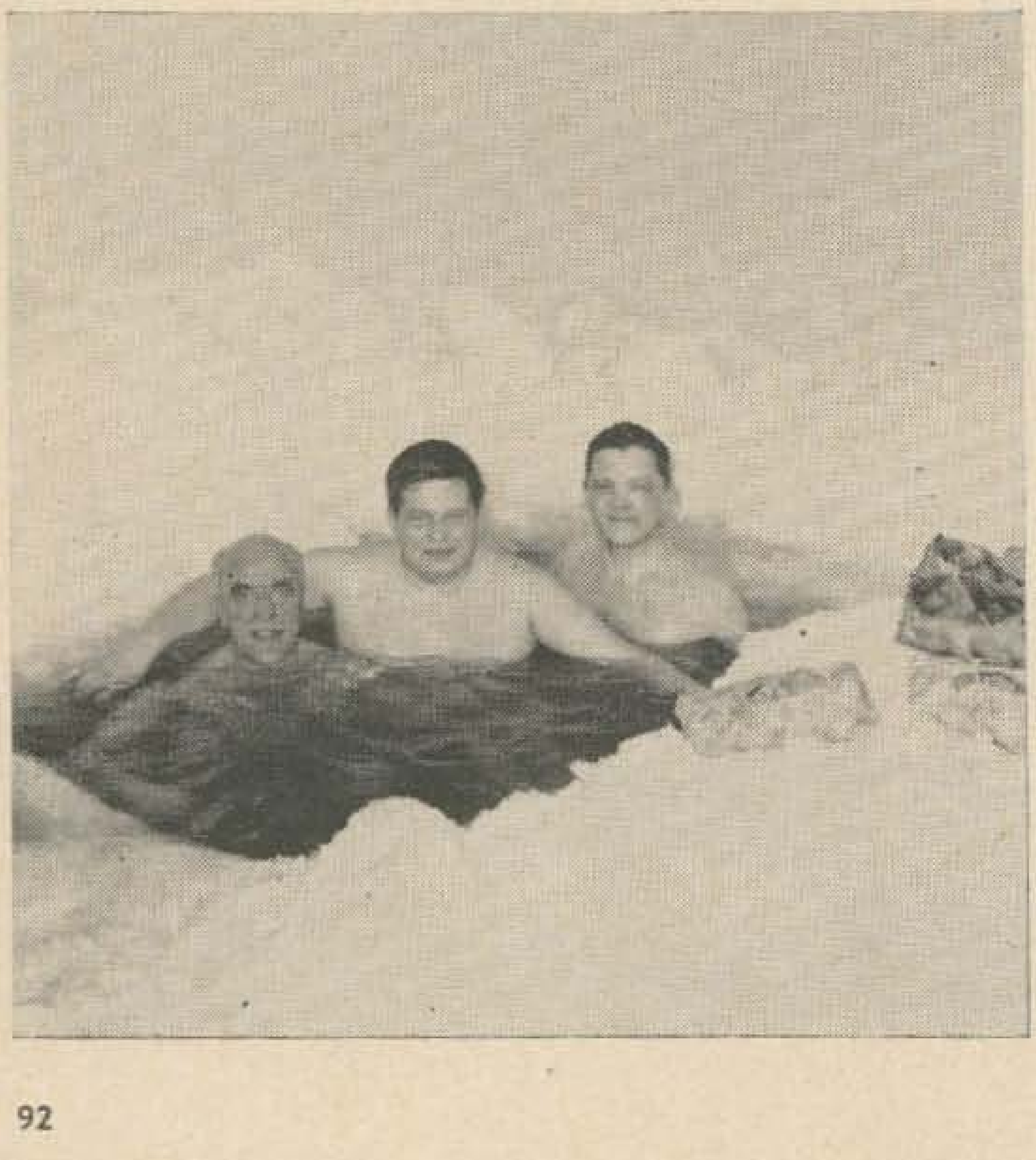
The amateurs in Stockholm were very hospitable when I arrived this spring. Arne SM5AM and Beo SM5LK saw to it that I got to visit many of the active amateurs in the area. Those that I didn't visit (and most of those I did) turned out for a meeting at the Technical Museum where we ate sandwiches, drank beer and listened to me talk far into the night.

In addition to the ham radio side of my visit I did check into the three topics first mentioned. Just before the end of my stay in Stockholm (two weeks), when I thought that I was going to manage to get away without ever meeting one single girl, I found myself having dinner with Peter SM5CZM, his attractive wife and a girl friend of hers. The girl, Eva, was a good looking blond, though I must admit that I was just slightly put off by the enormous German Shepherd Dog that guarded her. Every time I thought of making a pass at her he growled. Hmmm. She didn't really need him though for I found that this lovely should have been on What's My Line. She gently rippled her muscles as she explained that she drives one of those gigantic trucks that they have only in Europe . . . you know, the ones with the huge trailer hooked on behind. Anybody that can heft one of those around could break me in two . . . I think. I didn't check.

The Swedes vigorously deny all those delightful rumors we have heard in the States about their girls. Unfortunately, after an admittedly short visit, I tend to believe the Swedes more than the smart PR men who have built the interesting Swedish girl image for us. Alas, another dream shot down.

Whenever we get to grumbling too much about the creep of socialism in the states we are answered that it works just fine in Sweden so stop complaining. Tell that to the Swedes. I didn't find one single Swede that liked the system. They are very vocal on the subject. All in all their country is very much like the U.S. It is much more like it than any other country I have visited. Their salaries are quite comparable to ours and their costs of food and other things aren't all that different. The only major difference is that they have to pay almost double the taxes we do. I suspect that our administration is aware of this and may be using the Swedish norm as a goal for us. This does limit the possibility for outstanding success in Sweden and I found most of the people a lot more concerned with their summer houses than how to make an extra crown or two.

Arne went with me for a short trip up to Aland Islands to visit the OHØ gang. He had been wanting to make the trip for a long time and this was the excuse he was waiting for. I had bought a Volvo so we drove in it up to a small town 60 miles or so north of Stockholm to get the boat to Aland. The boat left late at night and arrived bright and early at 4:30 AM, just as the sun was really getting going for the day. Despite the grim hour of arrival we were met by Sigge OHØNI and driven the 20 miles to Marieham (town). After a short nap we got up and had an enormous breakfast. We then drove out into the country and visited OHØNF, one of the most active amateurs in Aland. We talked, took some pictures and were served coffee and cake by XYL. It was delicious, but a little close onto breakfast. They had some special Aland Island cake that I had to try. After a short visit with OHØNJ and NC we returned to NI's for a truly magnificent lunch. Urp. Just when I thought I had outdone myself they came up with special Aland Island brew which I had to try. Invented by the vikings, I believe . . . and excellent . . . urp. OK, time to go over to visit Sam NC and talk with all the active OHØ gang which was gathered there. I talked for about an hour and then we had coffee and cake. There was just time to drive out to the boat landing and wave goodbye. A short while after the boat had shoved off for Sweden Arne grabbed my arm and lead me into the restaurant. I protested that I was too full, but he said it would only be a snack. He didn't communicate this too well to the waitress though for she came in with a huge plate of food. It looked like someone with big eyes had gone by a smorgasbord table. It took me quite a while to down it all, but somehow I managed. Then she brought the main course.



A nice gang turned out to welcome me in Norrköpping and Gothemberg. The drive down was fascinating. Much of the part of Sweden I passed through sure looked a lot like our own Minnesota. Now I know why we have that tremendous Swedish population up there . . . it is just like home in looks and climate.

Finland turned out to be as expensive as Sweden for visitors. John Velamo OH2YV dropped everything for the two days of my visit and did a fine job of entertaining me. I got on the air from OH2A, OH2AA, and OH2TH, including a contact with my home station and the latest news from there. I had been in Finland for several minutes before John wanted to know if I had ever been in a sauna. His eyes lighted up fiendishly when I admitted that though I'd heard a lot about them I had never been initiated. OH2SS was selected to show me the ropes.

We reported into a clubhouse type of affair out on a point on a lake. We were issued a small orange towel and a locker for our clothes. Clad only in myself I was ushered into a small dark wooden room that felt like an oven. The towel was not for modesty, it was to sit on to keep from burning the flesh. The thermometer read a little over 120°. It felt warmer than that. Ooops, that is centigrade. It was getting a little hard to think in all that heat, but I slowly worked out the conversion to Farenheit and got 250°. They didn't have a fork so I wasn't sure how you could tell when you were done. After about 20 minutes SS led what was left of me out of the room, out the door, onto the dock and into the water which was under 40°, the ice having just melted a few days before. I agreed that it sure felt good, but I lied. OK, back into the oven for another bout. Baked ham Basted in my own juice. Then back out on that dock and into the ice water. Oh yes, it feels wonderful. Now we try to smoke room. 250° also, with nice smelling mullberry smoke. Smoked ham. Those mullberry switches don't hurt, just tingle a bit when you flaggelate yourself with them. They smell good mixed with the delightful aroma of yourself cooking.

This time instead of going out into the lake we lay down on tables and very sturdy Finnish women scrubbed us thoroughly from hair to toes using nice rough pads something like Brillo. I haven't been that clean in years.

Now that I've tried it I'll have to check into that sauna they have right near Peterborough. Our lakes are warmer, that's for sure. Besides, I'm only half baked now.

. . . Wayne

Coaxial Transmission Line Handbook

Jim Fisk WA6BSO

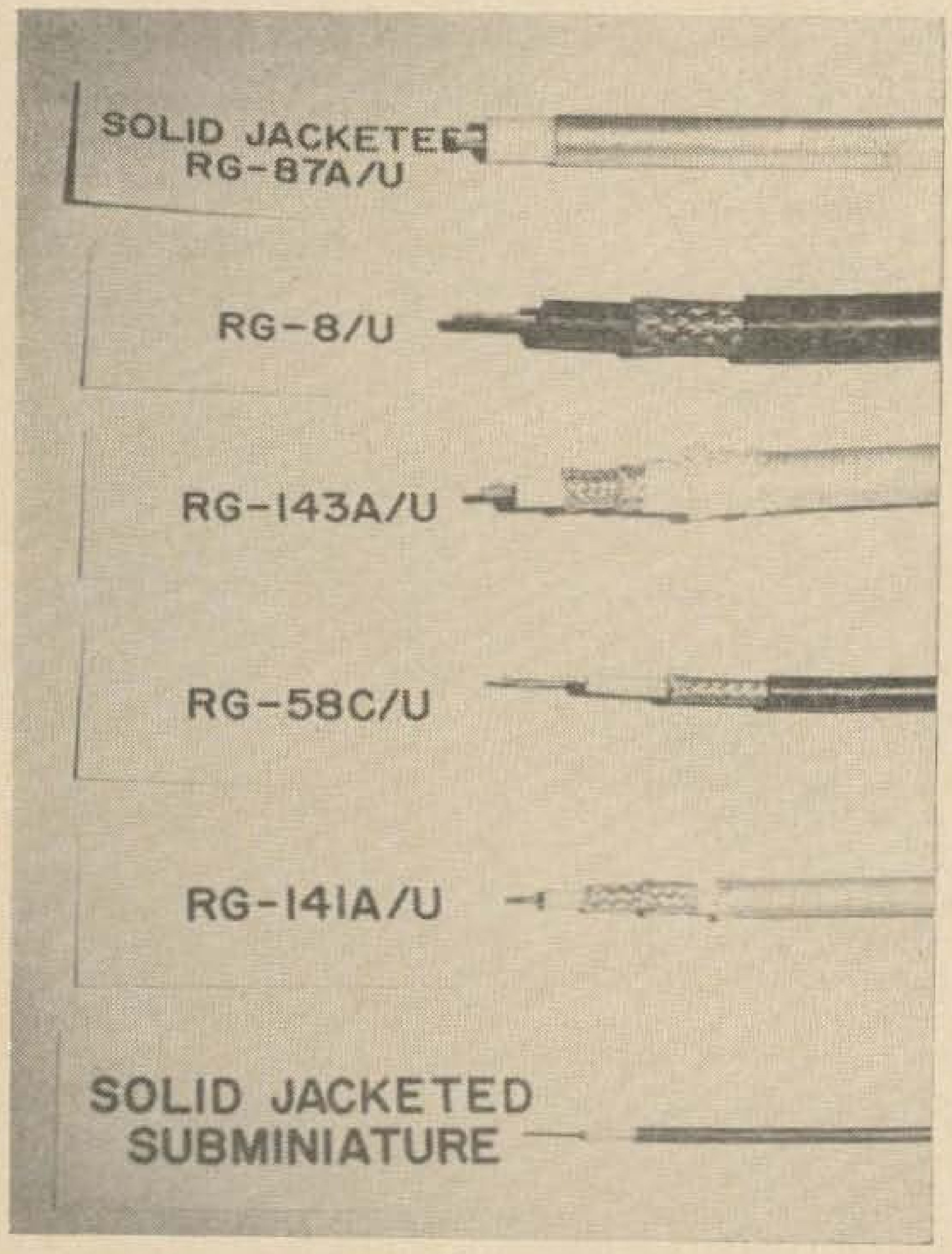
Photo Credit: Jim Harvey WA6IAK

Introduction

The coaxial cable is the simplest, most versatile and most popular means for the transmission of rf energy. However, it would be safe to say that to most amateurs coax means simply RG-8/U or RG-11/U. This is due, at least in part, to their availability and low cost. However, these familiar cables are not always the best choice for an amateur antenna system. Actually, the case of only one cable being able to satisfy a set of requirements is rare; usually there are several cables which will meet most of the requirements of a particular application. Nonetheless, the data which is published for these cables is, in some aspects, quite confusing and easily misunderstood.

Undoubtedly, more transmitted power is lost by the inadequate selection and improper use of transmission lines than from any other source. It is the purpose of this handbook to define and present the necessary data to enable the average amateur to more accurately evaluate and select a coaxial system suitable for the intended operating conditions.

It is interesting to note that the concentric form of transmission line is old—in fact, classical. Although the flexible types of solid dielectric coax available today are the products of modern materials and engineering, Lord Rayleigh, Alexander Russell, and other prominent mathematical physicists of the 19th century did considerable theoretical work with the coaxial structure before the turn of the century.



Miscellaneous coaxial cables: RG-8/U and RG-58C/U are polyethylene types; RG-143A/U and RG-141A/U are Teflon types with Fiberglas jackets; and solid jacketed cables are semiflexible types.

The earliest types of coaxial line were limited to telephone transmission lines and submarine cables. However, in the early 1930's engineers at the Bell Telephone Laboratories experimented with coaxial lines for the transmission of high-frequency radio energy. The rigid air-spaced lines used in these experiments only vaguely resembled the flexible lines in common use today, but it must be remembered that polyethylene wasn't discovered until 1937 or available in commercial quantities until 1943; and Teflon* wasn't even announced until 1946. These early cables were constructed using ceramic disks or beads spaced at intervals along the line to support the inner conductor. Since the outer conductor was fabricated from rigid copper tubing, these experimental coaxial lines were far from flexible, but they proved to be very efficient in high-frequency rf transmission.

Prior to World War II the rigid disk insulated concentric line saw little use in all but the most sophisticated commercial installations. In the late 1930's a few manufacturers advertised rubber insulated flexible coaxial cable, but because of the high cost and attenuation characteristics, these lines were not popular among amateurs. Since relatively few television stations were on the air at this time, the extra shielding afforded by coaxial lines were not a necessity for TVI elimination.

With the advent of an inexpensive low-loss flexible dielectric during the war years, thousands of feet of low cost coaxial cable became available on the surplus market in 1946. Unfortunately, the majority of amateur transmitters of the day were not suitable for the inherently unbalanced coaxial system. It wasn't until the impact of TVI that the coaxial transmission line became the mainstay of amateur transmission systems.

Because of the rapid advances made in transmission line technology during the war, a committee was set up to determine industry-wide standards for coaxial cables, connectors and adapters and to establish a universal numbering system. The familiar "RG"-/U, derived from "radio guide," was designated for rf transmission lines, both coaxial and waveguide. The "UG"-/U system, derived from "union guide," was assigned to rf connectors and adapters used with these lines. The suffix "U" was used to indicate a "universal" system of numbering.

*Trademark of Dupont

Table 1. **Comparison of coaxial cable characteristics.**

Cable Type		RG-8/U	Aljak	Aljak	Foam-Flex	Styroflex	Helical Membrane	Corr-O-Foam	Rigid
Dielectric		Poly-ethylene	Poly-ethylene	Teflon	Foamed Poly-ethylene	Poly-styrene Tape	Poly-ethylene Ribbon	Foamed Poly-ethylene	Air
Outer Conductor		Copper Braid	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Corrugated Aluminum	Copper
Outside Dimension (Inches)		0.405	0.325	0.325	0.5C0	0.500	0.500	0.570	0.875
Weight (lb/100 ft)		10.5	6.9	10.3	15.2	16.5	18.5	15.0	65.0
Minimum Bend Radius (Inches)		2.1	1.8	1.8	5.0	5.0	6.0	5.0	0
Maximum Operating Temperature (F°)		185	185	390	185	185	185	185	—
Capacity (pf/ft)		29.5	31.5	29.5	25.0	23.0	21.0	25.0	—
Peak Operating Voltage		5000	5000	5000	2500	1300	1300	2500	—
Attenuation (db/100 ft)	10 mc	0.55	0.33	0.55	0.25	0.25	0.24	0.25	0.13
	00 mc	2.00	1.50	1.80	0.86	0.80	0.76	0.85	0.41
	1000 mc	8.00	7.60	6.20	3.31	2.80	2.47	3.30	1.60
Average Power (Watts)	10 mc	3490	3700	17000	12600	7700	5800	7600	17000
	100 mc	1000	1000	5200	3800	2400	1600	2300	4600
	1000 mc	240	300	1500	1000	720	560	610	1400

All coaxial cables consist of the same basic elements: a center conductor, a dielectric and an outer conductor followed by a waterproof jacket. Where extreme environments may be encountered, an outside armor or lead sheath may be used.

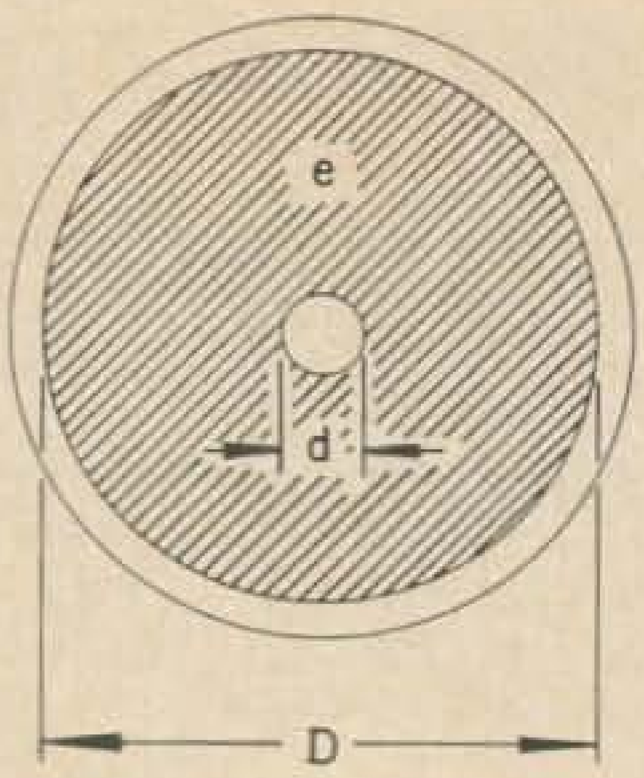
Coaxial cables are available in three main configurations; braided flexible cable, semi-flexible cable and rigid line. The braided cable consists of a solid or stranded inner conductor, solid dielectric, braided outer conductor and a protective plastic outer jacket. This cable is noted for its flexibility but suffers from higher losses than the other two types.

Semiflexible cable is constructed with a solid or tubular inner conductor, a helical or foamed or solid dielectric and a tubular metal outer conductor. This cable may be bent during initial installation but cannot withstand constant flexing.

Rigid lines are usually made from precision hard-drawn brass or copper tubing but extruded aluminum or copper-clad stainless steel have been used to a limited extent. The center conductor is rigidly supported by some type of dielectric bead or rod, mechanically crimped or swaged between the conductors. These lines exhibit low attenuation and high power handling ability and have long been the mainstay of commercial broadcasting. They also find extensive use in television broadcasting and commercial communications at frequencies where waveguide is too bulky.

Flexible coaxial cables

In flexible coaxial lines, solid or stranded copper wire is normally used for the center conductor of the cable. In some cases copper covered steel conductors are used to add mechanical strength to the smaller cable sizes.



e = DIELECTRIC CONSTANT

$$Z_0 = \frac{138}{\sqrt{e}} \text{LOG}_{10} \frac{D}{d}$$

Fig. 1. Coaxial Structure.

Silver plating is applied to prevent oxidation of the copper when the cable is used at elevated temperatures. Tin plating is used to facilitate soldering to connectors; however, the use of tinned conductors should be limited to low-frequency applications where the thickness of the plating will not significantly increase cable attenuation.

A polyethylene dielectric is used almost exclusively where the maximum temperature will not exceed 185 degrees Fahrenheit. The use of Teflon (Polytetrafluoroethylene) is required when temperatures from 185 to 500 degrees are encountered in the vicinity of the dielectric.

As a rule, the outer conductor consists of a close fitting braid of fine copper wire. A number of fine wires are combined to form a carrier comparable to a single flat reed in a woven basket; these carriers are woven in and out to form the braid. To avoid excessive radiation loss and to insure proper shielding, approximately 99% braid coverage is required. This coverage is determined by the stranding of the carrier, the number of carriers and the "lay" of the braid. The lay is defined as that length of cable required for the carrier to make one complete revolution around it and determines ultimate cable flexibility. Tin- or silver-plated strands are used for the same reason as for the inner conductor, as well as the apparent rf resistance of the braid. Occasionally, a second braid of either copper or steel is used to improve the shielding properties of the cable. The second shield has only a minimum effect upon attenuation and is designed primarily for improved flexibility and shielding.

The jacketing material generally used with polyethylene cables is composed of black vinyl resins extruded over the outer conductor. There are two types of vinyl which are used for jacketing purposes: regular vinyl and noncontaminating vinyl. Because polyethylene has a chemical affinity for some of the plasticizers used in the regular vinyl jacket, the development of the noncontaminating type was undertaken. Although the dissipation factor of nearly all dielectric materials except Teflon increases with age due to natural oxidation, the use of a noncontaminating jacket limits deterioration in cable performance. Since the rate of aging is temperature dependent, the use of cables with the noncontaminating jackets is especially important where the cables will be subjected to elevated temperatures.

The graph of **Fig. 2** compares the attenuation of two samples of coaxial cables, one with a contaminating jacket (RG-8/U) and the other with a noncontaminating jacket (RG-8A/U), to the number of days at a temperature of 200 degrees Fahrenheit. After 160 days, the attenuation of the cable with the contaminating jacket at 3000 megacycles increased nearly four times while the attenuation of the cable with the noncontaminating vinyl jacket increased only 0.01 db per foot at the same frequency. It must be emphasized that while this 200 degree test simply accelerated the aging process, normal aging will cause the same effect at a slower rate.

The useful life of cables jacketed with the contaminating type of vinyl is in the neighborhood of three to seven years. Beyond this point the attenuation increases exponentially and reaches very high values. On the other hand, cables with noncontaminating jackets offer life expectancies well in excess of fifteen years. Considering that their extra cost only runs about a penny a foot, the noncontaminating types of cables are a good investment.

Some polyethylene cables are jacketed with high molecular weight carbon-black loaded

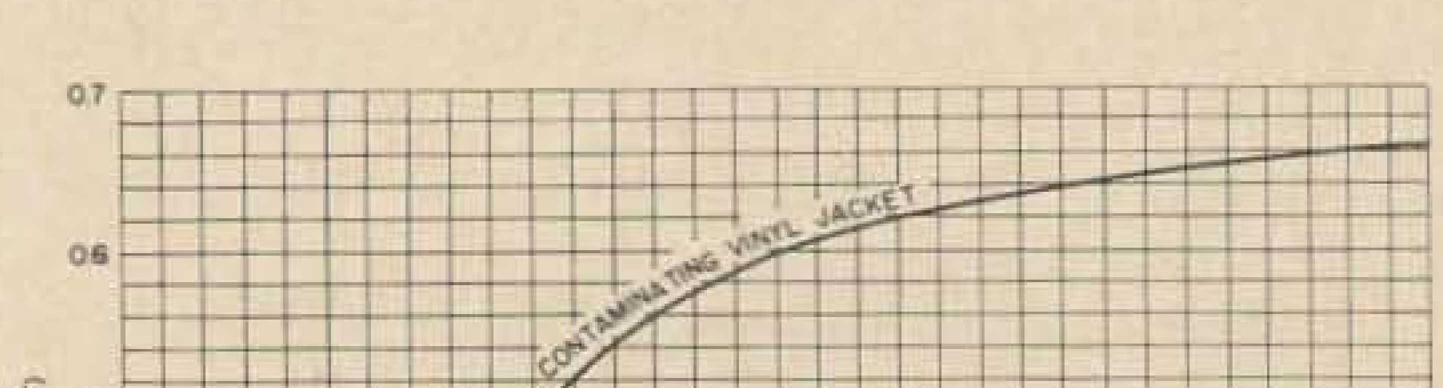


Fig. 2. Effect of contaminating jacket on cable attenuation.

polyethylene. These jackets contain no plasticizers whatsoever and offer life expectancies well in excess of twenty-five years. In addition, they are ten times less permeable to moisture than the vinyl jackets.

Teflon insulated coaxial cables are jacketed with slightly different materials. Because of the higher temperature characteristics of the Teflon dielectric, it is desirable that the jacket also exhibit these same properties. For this reason, Teflon cables are usually jacketed with a close wrap of Teflon tape, followed by one or more fiber glass braids impregnated with silicon varnish.

A relative new addition to the family of flexible cables is the foamed dielectric version. These cables were designed to satisfy the requirements for a low attenuation, low capacity, lightweight, flexible r-f cable. The dielectric consists of cellular polyethylene, foamed with an inert gas to produce completely enclosed cells within the polyethylene. Amphenol Polyfoam and Belden Foam-Core cables are of this type.

Compared to a standard RG-/U cable of equivalent size, the attenuation of foam dielectric cables is reduced by as much as 35%. This is particularly desirable where long cable runs are required or for VHF and UHF applications.

Semiflexible coaxial cables

There are many constructonal variations between the extremes of rigid coaxial lines and flexible cables which fall into the category of solid-jacketed or semiflexible cables. These cables have a number of outstanding characteristics for a wide variety of applications. Their electrical advantages over the standard RG-/U type flexible cable are lower attenuation and minimum signal radiation or pickup. Mechanically, they are somewhat lighter in weight than flexible cables and have the advantage of small size and complete weatherproofing.

Instead of the conventional braid shield and vinyl jacket, the outer conductor of these cables is a seamless or corrugated ductile metal tube. Aluminum is most often used for such applications because of its lighter weight and lower cost than copper, but both steel and copper have been used to a limited extent. These cables may be formed into moderate bends during installation and in some applications protective coverings may be added for greater abrasion or corrosion resistance.

Since the seamless outer conductor prevents contamination of the dielectric material, nearly unlimited operating life may be expected. Also, the seamless outer conductor allows negligible energy radiation. Because of the lower losses associated with semiflexible cables, it is possible to use a smaller size cable to obtain loss figures equivalent to a braided cable system.

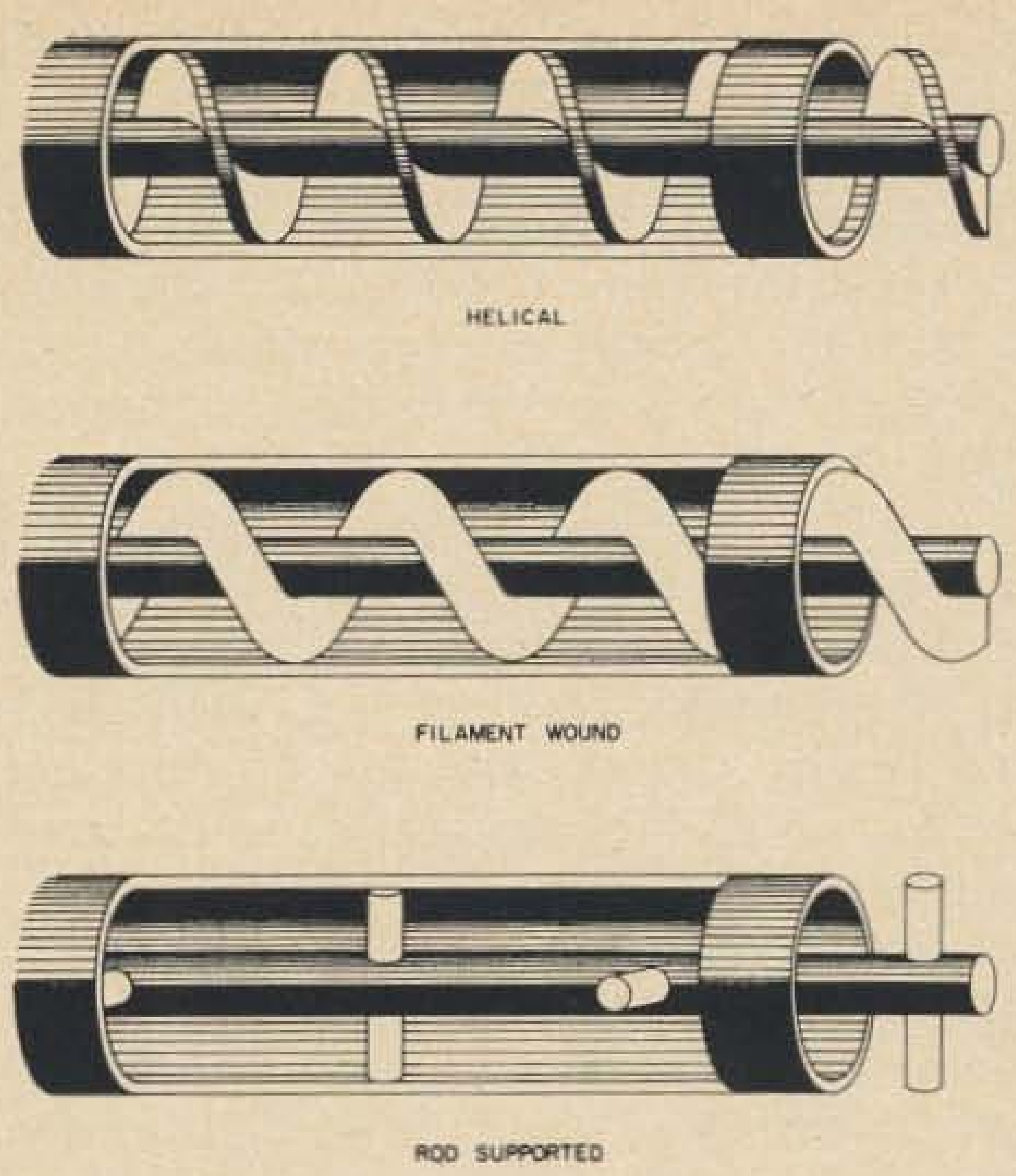


Fig. 3. Special types of coaxial cable.

The dielectric used in semiflexible lines may be either an airspaced structure or some form of solid dielectric. In the former, a continuous or rod of dielectric material is spirally wound around the center conductor to support it as shown in **Fig. 3.** Styroflex* cables are manufactured with a continuous laminated helix composed of thin flexible polystyrene tape; this tape is a unique form of polystyrene, characterized by excellent electrical and mechanical properties. No plasticizer is needed to achieve flexibility because this property is obtained by means of special manufacturing processes. The laminated type of construction has a great deal of strength and permits the finished cable to withstand heavy crushing loads. These lines are available in both 50 and 70 ohm versions in many different sizes from ⅜ to 6⅛ inches in diameter.

Another type of helical construction which is popular consists of a flat ribbon of polyethylene or Teflon helically wound around the inner conductor. This ribbon is made by machining a spiral from a hollow dielectric tube and drawing an aluminum sheath tightly over the open spiral. This type of construction results in less attenation than the laminated helix, but is not as strong. Also, greater care must be taken during installation to insure that the center conductor does not shift be-

* Trademark of Phelps Dodge Electronic Products Corporation

cause of cable bends or thermal expansion. Helical Membrane* cables are of this type.

Heliax** is a special variety of helical construction that uses a thick polyethylene ribbon to support the inner conductor. The outer conductor is a length of corrugated steel tubing, copper plated on the inside for improved conductivity. The cable is protected on the outside with weatherproofing compound, impregnated paper tape and a vinyl jacket. The main advantage of this construction is the ability of the outer conductor to withstand repeated flexure (50 to 200 times) without failure. Also, no special straightening or bending tools are required during installation.

For smaller size cables, sufficient strength is obtained with a spirally wound filament of Teflon or polyethylene at a much lower cost. Spirafil* cable is an example of this type manufacture.

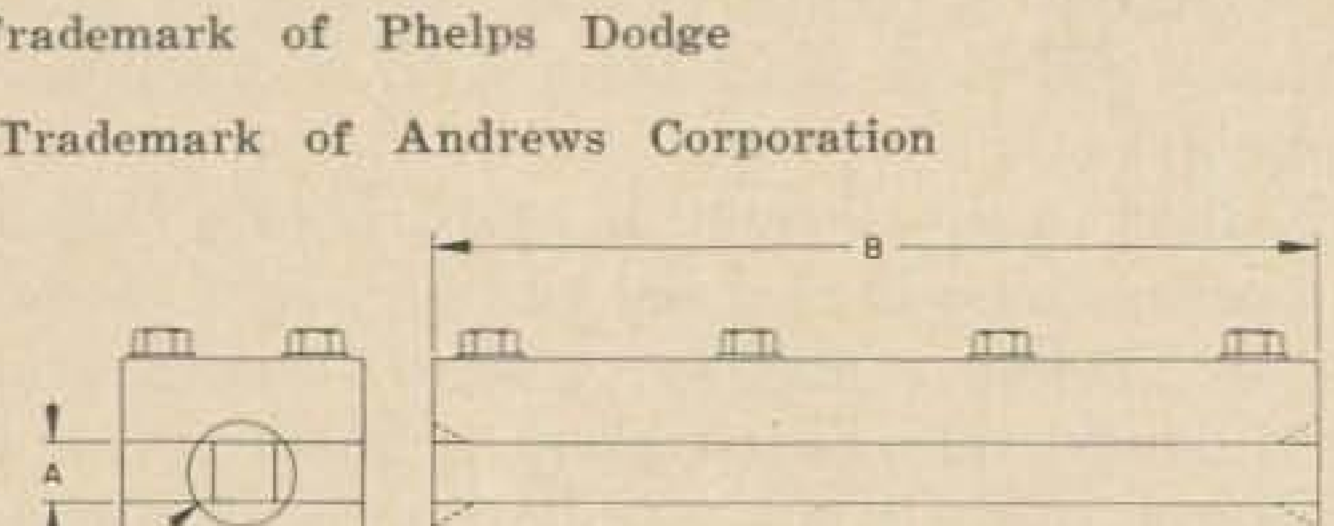
The second type of semiflexible cable uses a solid dielectric. Recent cables of this type use polyethylene or Teflon dielectric (Amphenol's Aljak) or foamed polyethylene (Phelps Dodge Foamflex) with an aluminum sheath. The use of solid dielectric increases the peak operating voltage and the attenuation, but maintains the equivalent power handling capacity of air-spaced lines.

Foamed polyethylene insulation offers a practical form of a homogenous air-filled dielectric which retains its normal dielectric strength without pressurization. The reduction of dielectric constant, compared with solid polyethylene, results in lower attenuation.

Semiflexible coaxial lines provide a compact, rugged installation, with mechanical protection equivalent to lightweight conduit for permanent installations in cable raceways, along bulkheads or similar applications. Close contact with metallic supporting structures greatly enhances their heat dissipating properties. Other advantages over conventional braid cables are low attenuation, no radiation,

*Trademark of Phelps Dodge

**Trademark of Andrews Corporation



NOMINAL CABLE DIAMETER	DIMENSION "A" (SQUARE)	DIMENSION "B"
5/16"	21/64"	8-1/8"
3/8"	25/64"	9-3/8"
1/2"	33/64"	12-1/2"
3/4"	25/32"	18-3/4"
1"	1-1/32"	25"
1-1/8"	1-5/32"	28-1/8"
1-5/8"	1-11/16"	40-5/8"

Fig. 4. Semiflexible cable straightener.

high phase stability, uniform electrical characteristics over wide temperature variations, and unlimited operating life.

The main disadvantage of solid-jacketed semiflexible cables (other than those with foamed dielectric) is that all newly installed air dielectric cables must be purged and then pressurized with either dry nitrogen or dehydrated air before being placed into operation. This is to insure that the cable is and remains dry. The use of nitrogen gas is generally preferred over dehydrated air in purging and pressurizing relatively small and medium sized cable systems.

Semiflexible coaxial cables are becoming increasingly popular, particularly in those applications requiring critical impedance, maximum shielding or noise-suppression requirements. Although they have seen little use as yet in amateur applications, it is expected that they will become popular in the UHF region where waveguide is prohibitively large and expensive.

Although it is difficult to make an accurate comparison between flexible, semiflexible and rigid lines because of the difference in diameters, **Table 1** lists some of the more common cables with their respective characteristics.

If care and the proper tools are used during the installation of these cables, sharp bends and kinks can be avoided and the cables may be reused. Precautions should be taken to prevent continued vibration or flexing from "work hardening" and eventually cracking the sheath. From this standpoint, copper is less susceptible to work hardening than is aluminum.

The semiflexible cables are received from the manufacturer in a coil and it is usually necessary to straighten it before use. A simple straightening device consists of a close fitting wooden box as shown in **Fig. 4.** The recommended box length and cable cutout for the common sizes of semiflexible cable are given in the illustration. This box may be constructed from any standard knot-free wood of suitable dimensions. The box entrances should be countersinked as shown and a small amount of mineral oil applied to minimize friction.

Threading the box onto the larger cables, particularly one inch in diameter and larger is facilitated by using bolts. In this case, the top of the box is opened slightly to allow insertion of the cable and then is cinched down with the bolts. For smaller cables this is usually not necessary and the box may be put together with common wood screws.

Most manufacturers furnish semiflexible coaxial cable in 1000 or 5000 foot lengths, but Phelps Dodge has special kits of ½ inch, 50 ohm Foamflex with connectors for amateur applications. These kits are available in 50 or

100 foot lengths with connector, cable clamps, pressure-sensitive tape and seven foot length of flexible RG-8A/U jumper included. For applications where direct burial of the cable is desired, this cable is available with a special Habirlene jacket at a slightly higher cost. Although the non-jacketed version costs 50¢ per foot, the nearly unlimited operating life offered by this type coax seems to outweigh the disadvantage of its higher cost over conventional braided transmission lines.

Coaxial cable characteristics

There are six basic coaxial cable parameters for which values are normally published. These are:

1) Characteristic Impedance
2) Attenuation
3) Capacitance
4) Velocity Factor
5) Power Rating
6) Maximum Operating Voltage

The first four characteristics are critically dependent upon the dimensional variations of the cable and are carefully regulated during the manufacturing process. The last two parameters are considerably less affected by any dimensional variations, but are rather functions of the overall dimensions and type of coaxial cable. In addition, impedance, capacitance, attenuation, and velocity factor are all interrelated, while the voltage rating and power rating are pretty much independent of each other.

Impedance

The characteristic impedance of the cable is undoubtedly the most discussed and most used parameter. This quantity is directly proportional to the dimensions of the conductors and the dielectric constant of the insulating material as shown in **Fig. 5.** It is interesting

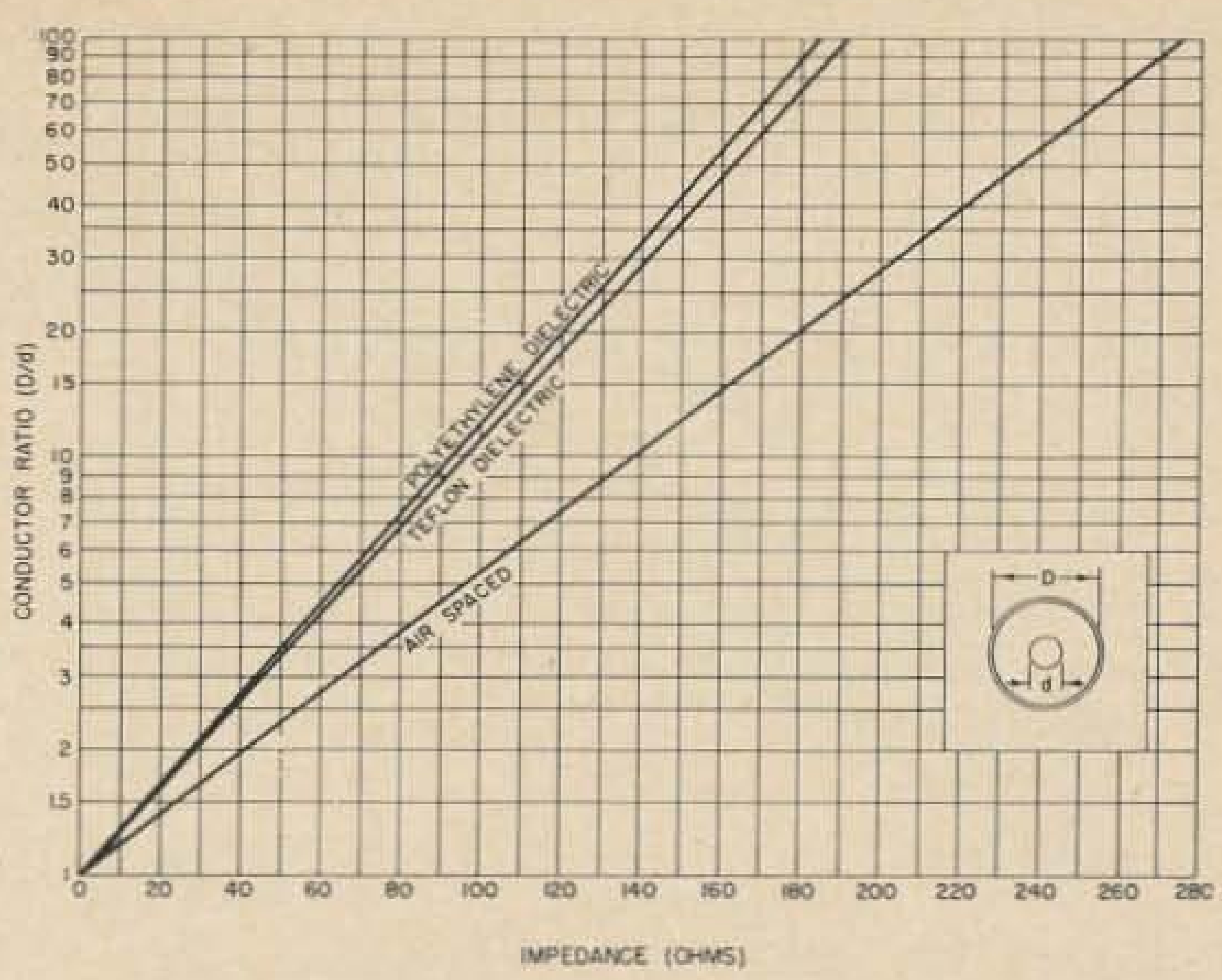


Fig. 5. Characteristic impedance of coaxial cables.

to note that the dimensions of the conductors in a coaxial line may be selected for minimum attenuation, maximum power or maximum voltage rating. Sadly enough, the dimensions for optimizing each of these characteristics are not the same; corresponding impedance values for optimizing each of the characteristics are listed in **Table 2.**

Table 2. Comparison of optimum diameter ratios and impedances for coaxial lines.

Condition	D/d	Characteristic Impedance (Ohms)		
		Air Dielectric	Polyethylene Dielectric	Teflon Dielectric
Minimum Attenuation	3.59	76.6	51.0	52.9
Maximum Voltage	2.72	60.0	39.9	41.4
Maximum Power	1.65	30.0	20.0	20.7

Fortunately, moderate departures from these optimum values do not introduce rapid changes in the electrical characteristics of the line. For this reason, three impedance levels are generally accepted as reasonable compromises between the infinite number of possible values:

50 ±2 ohms Preferred for VHF and UHF applications, test equipment, and transitions between coaxial line and waveguide.
75 ±3 ohms High-frequency use to 30 mc, very long cable runs.
95 ±5 ohms Low capacitance, twin conductor cables.

Generally speaking, the uniformity of the characteristic impedance has a greater effect on circuit performance than the absolute value of the impedance chosen. The larger center conductor of the 50-ohm line results in a stronger physical structure and a more uniform line. Also, 50-ohm lines facilitate the design of coaxial connectors with excellent impedance matching characteristics.

Attenuation

As a signal proceeds from the transmitter along the line to the antenna, the signal will decrease in magnitude because of cable attenuation. The attenuation in coaxial cable is made up of two kinds of losses; series losses in

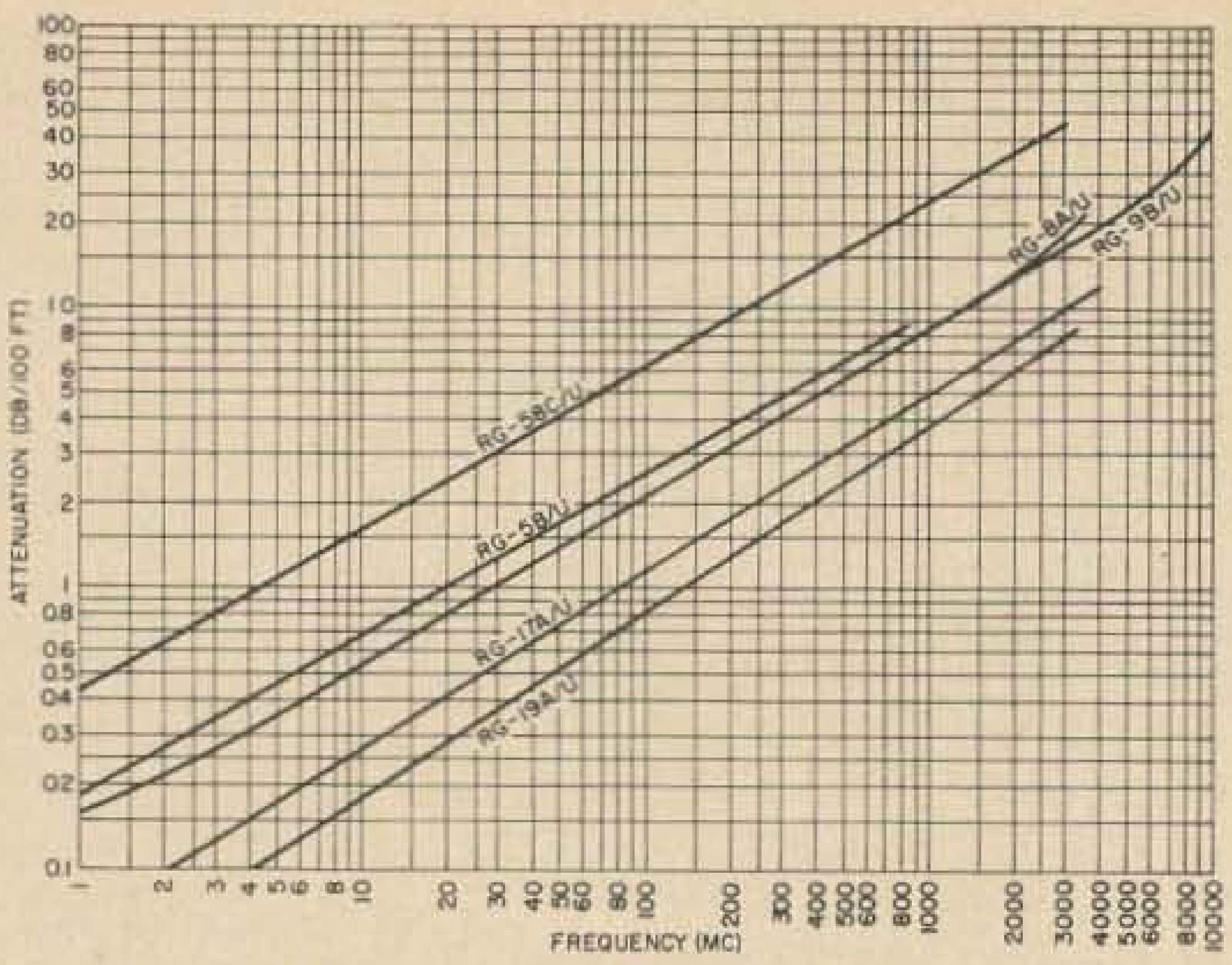


Fig. 6. Attenuation of polyethylene cables.

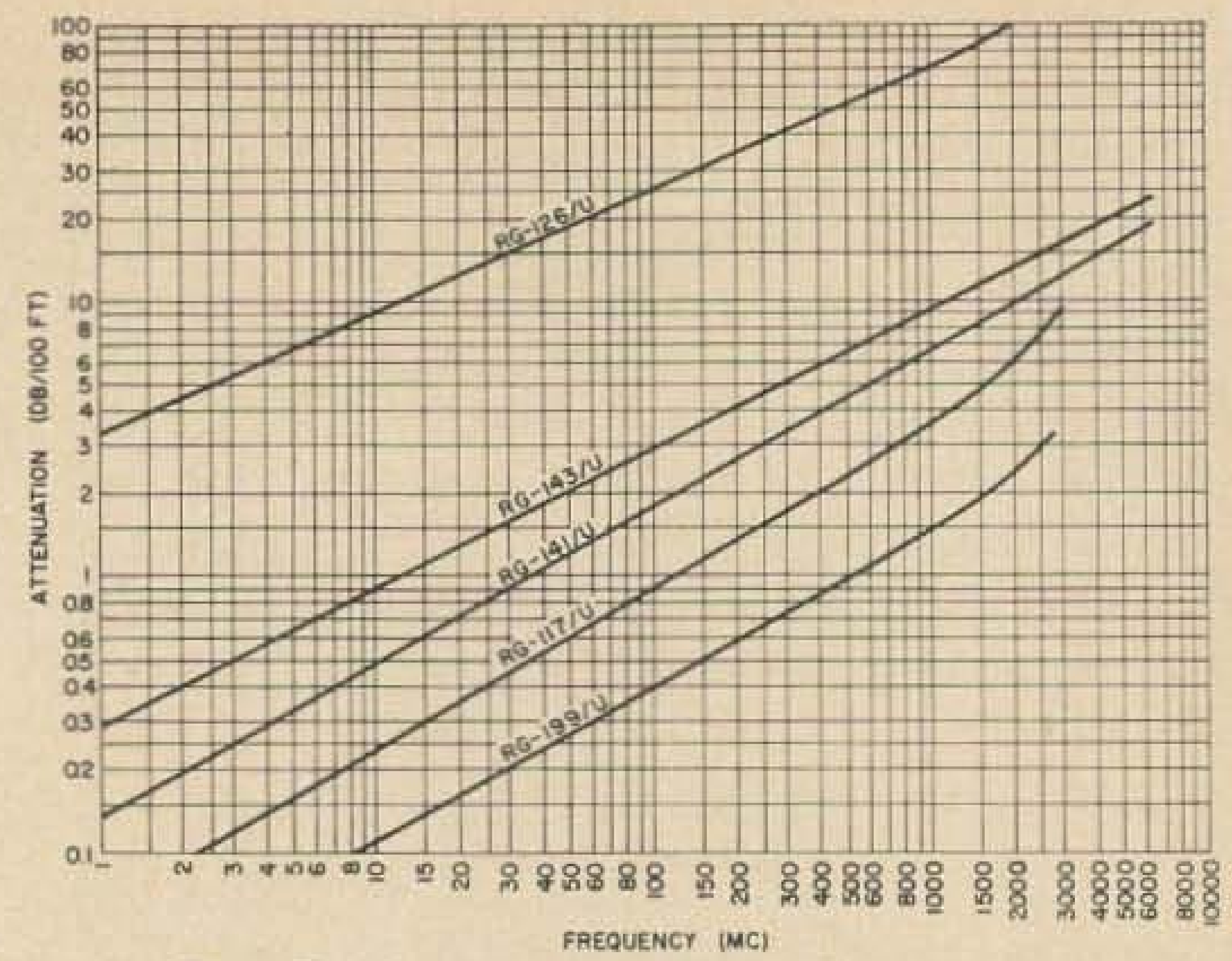


Fig. 7. Attenuation of Teflon cables.

the center and outer conductors, and shunt losses in the dielectric. The series losses are proportional to the square root of the frequency and constitute the major portion of the cable's attenuation. Shunt losses are caused by the conductivity of the dielectric material and are directly proportional to frequency. Attenuation measurements at 100 mc indicate that the conductor losses are about six times greater at this frequency than the dielectric losses. On the other hand, at 10,000 mc, the dielectric losses are about twice as great as the conductor losses.

The losses associated with the conductors are considerably increased when stranded conductors are utilized. For instance, a braided outer conductor will multiply the losses over a solid outer conductor by two or three times. This is because the rf currents in a coaxial line are always in the direction of propagation. At the lower frequencies the currents tend to follow the individual braid wires spirally around the cable. At high frequencies however, the currents move in a straight line from strand to strand, dissipating energy in contact resistance. Therefore, a braid having a long lay will have less attenuation than one having a short lay. Mechanical considerations limit the lay of the braid however and greater stability with flexing may be attained with a shorter lay. The tightness with which the braid is woven is also important in eliminating instability under flexing and in decreasing contact resistance between braid wires. Since a loose or open braid, or any form of surface contamination, may cause erratic attenuation when the cable is flexed, it is important that the individual braid wires are not embedded in the dielectric or jacketing material. The braid signed for increased stability at UHF frequencies.

Attenuation curves for the more commonly used coaxial cables are plotted versus frequency in **Figs. 6** through **9** respectively for polyethylene, Teflon, foamed and semiflexible lines. The attenuation curves plotted in these graphs are based on an operating temperature of 68° Fahrenheit, and for accurate calculations at other temperatures, the attenuation must be scaled according to the graph of **Fig. 10.** For the climatic conditions normally found in the continental United States, the changes will amount to less than three percent, but under extreme temperatures, these changes should be considered.

When calculating the attenuation of a transmission line, the effect of any standing waves along the line must be considered if accurate results are desired. If the standing wave ratio is greater than one, line loss is multiplied because the greater effective voltages and currents along the line increase its resistive and dielectric losses. Line loss multiplication due to standing waves may be calculated from the relationship

$$\text{Line loss multiplier} = \frac{\text{SWR} + \frac{1}{\text{SWR}}}{2}$$

For convenience, line loss multipliers for standing wave ratios up to 11:1 are plotted in **Fig. 11.**

Since coaxial line attenuation is given in decibels, it is helpful to convert to power ratios to determine the effect of line attenuation on transmitted power. **Fig. 12** charts the transmitted power versus attenuation up to 10 db. If more accuracy is required, the "DB-Power, Voltage and Current Ratio Table" may be used.

Example 150 feet of RG-9B/U is used as the antenna transmission line in a 144 mc amateur installation. With an ambient temperature of 85°, standing wave ratio of 2.6:1 and transmitter output power of 580

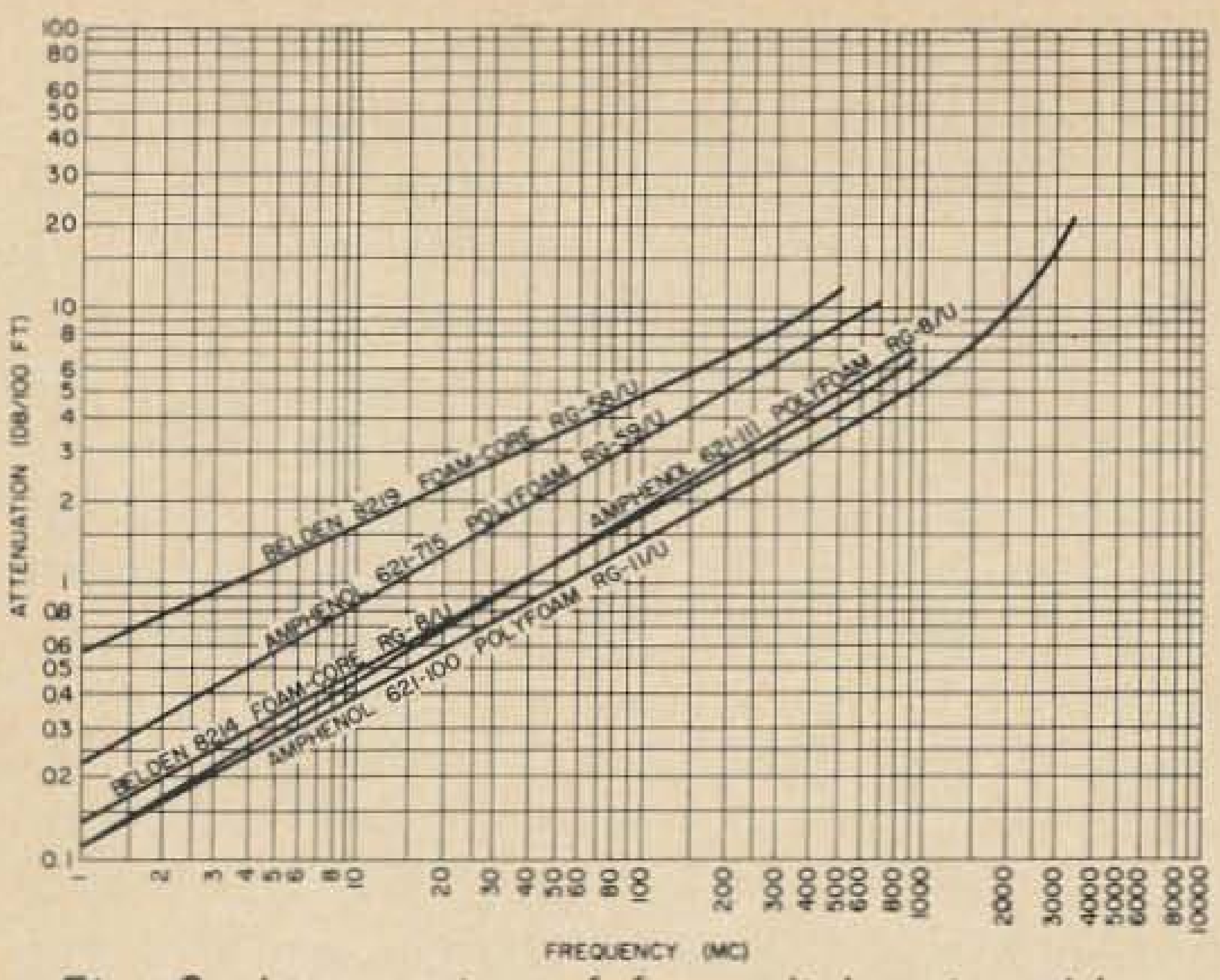


Fig. 8. Attenuation of foam dielectric cables.

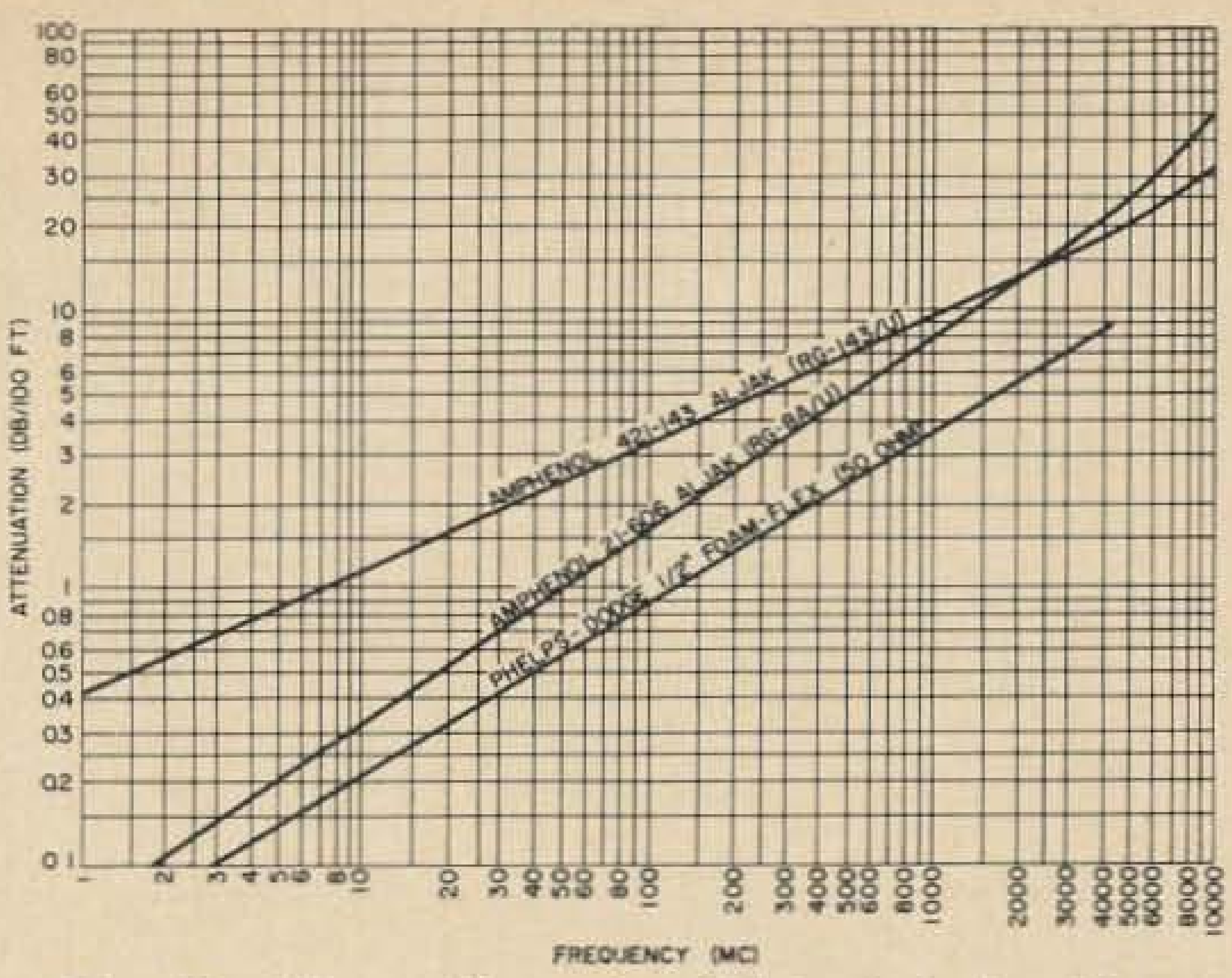


Fig. 9. Attenuation of solid jacketed cables.

watts, what is the total attenuation of the line and how much power will be transmitted to the antenna?

From **Fig. 6**, the attenuation of RG-9B/U at 144 mc is 2.7 db per 100 feet. The attenuation per 150 feet then may be found from

$$\text{Loss (db)} = \frac{L\ (db_{100})}{100}$$

Where L = Length of transmission line in feet
db_{100} = Attenuation of line per 100 feet in db

In this case,

$$\text{Loss (db)} = \frac{150 \times 2.7}{100} = 4.05 \text{ db}$$

This is the loss of 150 feet of RG-9B/U at 144 mc with unity SWR at 68° Fahrenheit. With an ambient temperature of 85°, the loss must be multiplied by 1.02 (see **Fig. 10**). From **Fig. 11**, an SWR of 2.6:1 corresponds to a line loss multiplier of 1.49. Under the stated operating conditions then, the total loss of the 150 foot transmission line is

4.05 db × 1.02 × 1.49 = 6.16 db

From Figure 1-12, 6.16 db corresponds to 24.2% of the transmitter power (580 watts) will be transmitted to the antenna.

0.242 × 580 = 139.4 watts to the antenna

Cable capacitance

The capacitance of solid dielectric cables varies inversely with the characteristic impedance and averages from 21 to 29.5 pf per foot respectively for 75- and 50-ohm cables. It is often desirable to have lower capacitance, particularly in conjunction with high-impedance circuits where the coaxial line shunts the input to the device. To obtain lower capacitances, a very thin center conductor or an air spaced dielectric is usually provided. In any case, the characteristic impedance of low capacitance lines normally varies between 95- and 185-ohms.

Velocity factor

The velocity factor is defined as the ratio of the velocity of propagation of an rf signal in a cable to the velocity of propagation in free space. When a dielectric other than air is used as the insulating material, the propagation of the waves is slowed down by the dielectric medium in much the same way that light is slowed down (and refracted) by a glass lens. For the case of polyethylene cables the velocity factor is 0.66; for Teflon, 0.695; and for foamed cables, between 0.78 and 0.80, depending upon the manufacturer. The important consideration here is that when a length of coaxial line is being cut to some specific electrical length it must be foreshortened by the velocity factor. As an aid in designing coaxial impedance transformers, baluns, match-

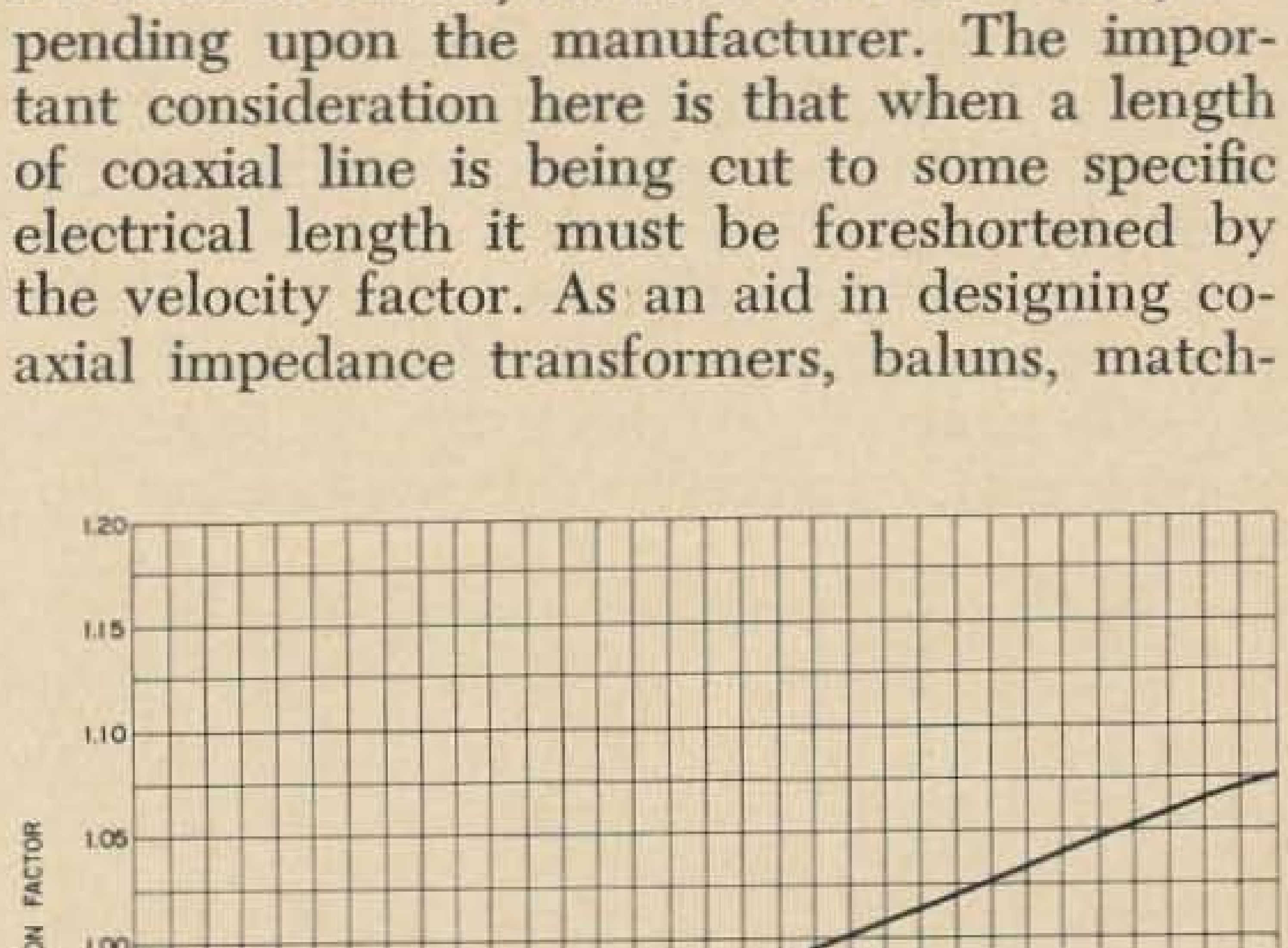


Fig. 10. Temperature correction factor for coaxial cable attenuation.

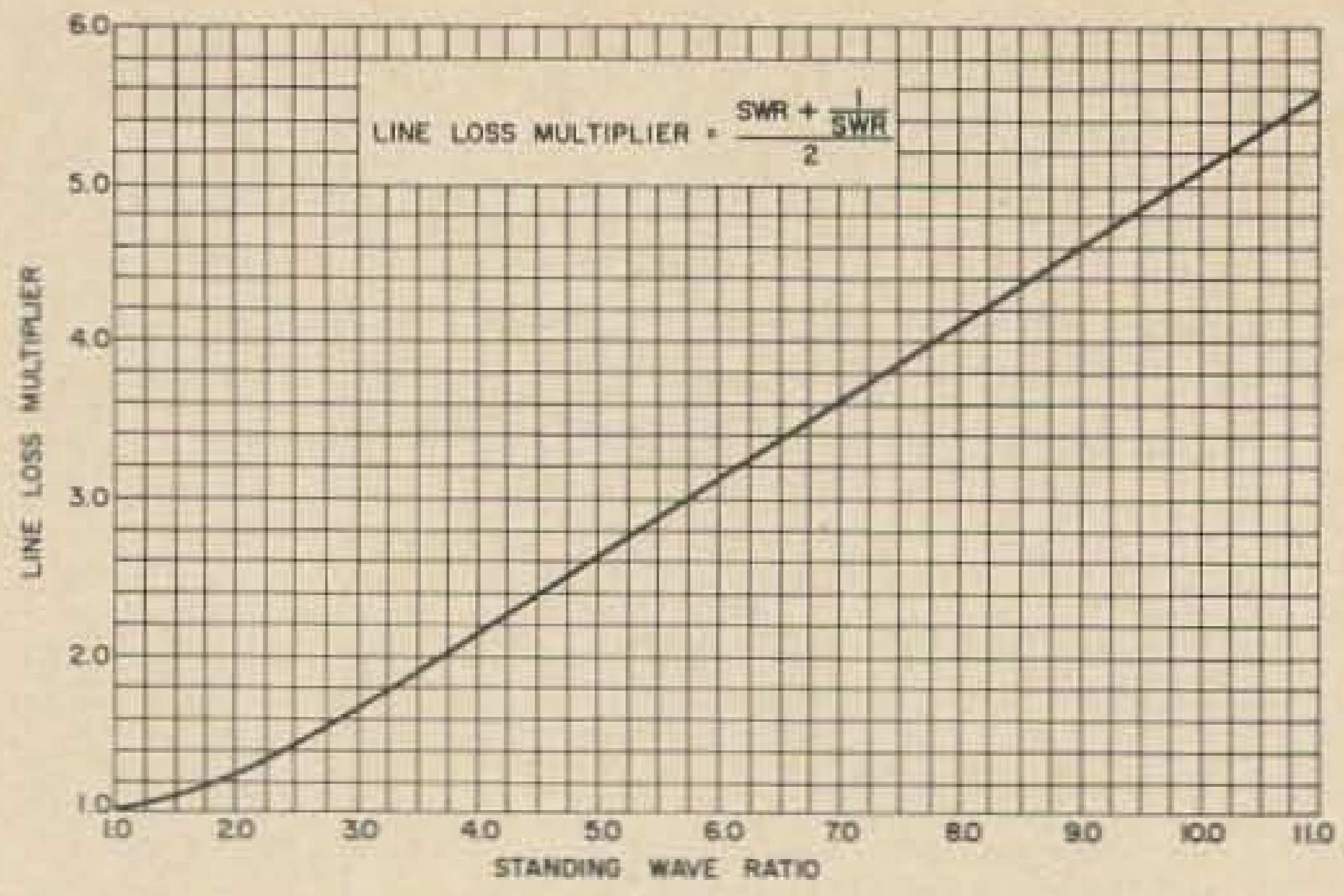


Fig. 11. Effect of SWR on line attenuation.

ing stubs, etc., the electrical wavelengths of various cables are tabulated in **Tables 4** through 8, for the amateur bands up to 1296 mc.

Power rating

Of major importance in the selection of a coaxial cable is the ability of the cable to safely carry the anticipated power. Since most of the medium sized cables used today will safely carry a full kilowatt at the lower frequencies, this parameter is usually of little consequence to the amateur who limits his operation to 30 mc and below. However, the power rating of any coaxial cable decreases with frequency and must be considered when running high power on the VHF and UHF bands. The maximum r-f power that a coaxial line may safely transmit is limited by either (1) the voltage introduced by the peak power, or (2) the thermal heating due to the average power. Which of these factors will predominate varys with the operating conditions of the transmission line.

At operating frequencies over 10 mc the power rating of the cable resolves itself into a problem of efficient heat transfer from the coaxial cable surface to the surrounding environment and the maximum temperatures which the cable materials can withstand.

As might be expected, the voltage and power ratings increase directly with the diameters of the cable. Additionally, the amount of heat which flows radially from the line depends upon the thermal properties of the dielectric and jacket. Radio-frequency energy generates heat at the center conductor, within the dielectric and at the shield in direct proportion to the individual attenuation of each. Excessive heat can result in movement of the center conductor due to softening of the dielectric, mechanical damage due to thermal expansion and shortened life because of accelerated chemical action. Therefore, for any praticular construction, the average power rating will depend upon the permissible temperature rise above a stated ambient.

Assuming that the internal temperatures are the same, the power rating at one frequency is inversely proportional to the total attenuation at that frequency, and the power ratings at any other frequency may be determined from the following expression:

$$P_x = P_t \frac{a_x}{a_t}$$

Where: P_x = Power rating at unknown frequency
P_t = Power rating at test frequency
a_x = Attenuation at unknown frequency
a_t = Attenuation at test frequency

Using this equation, a complete set of power

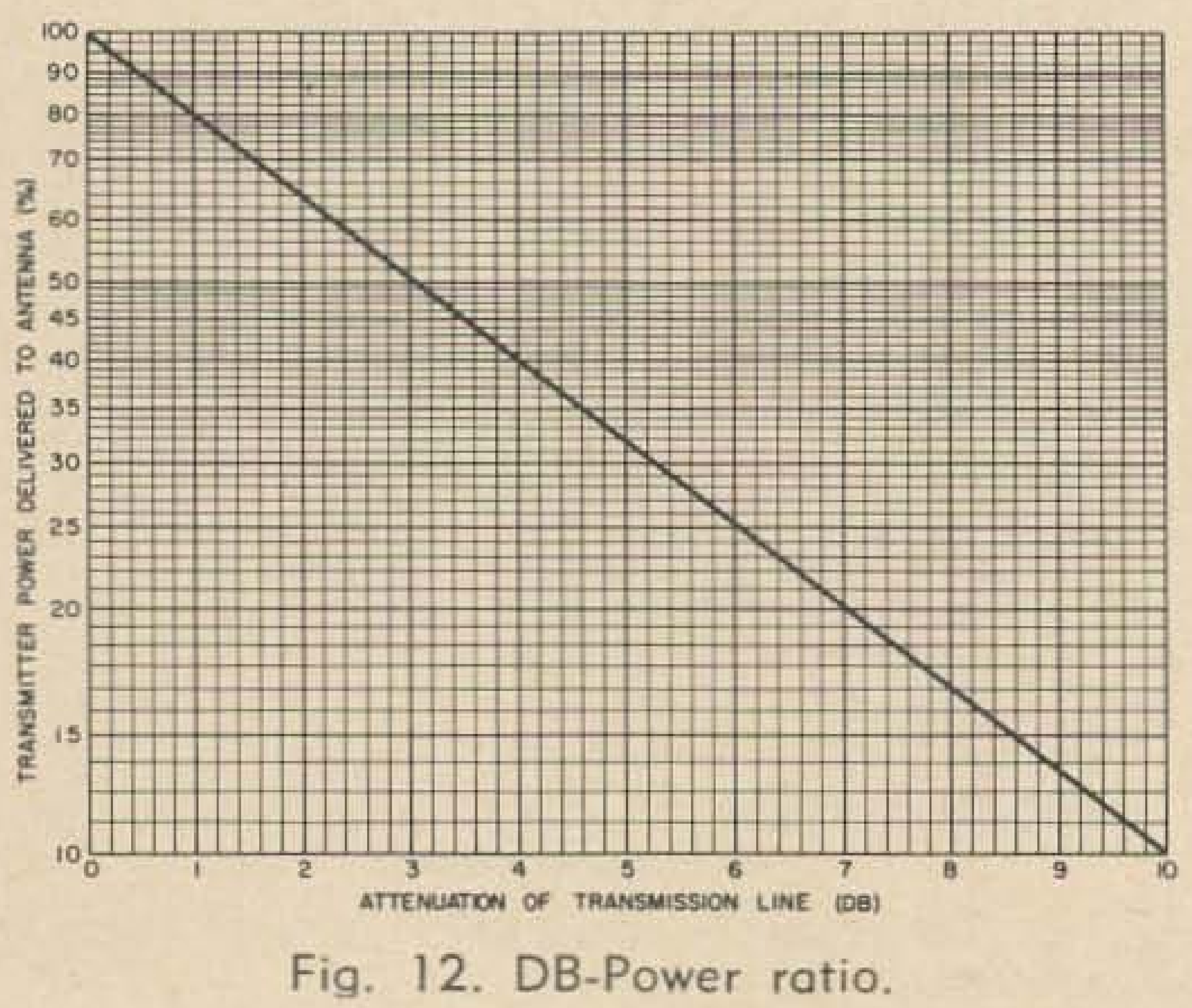


Fig. 12. DB-Power ratio.

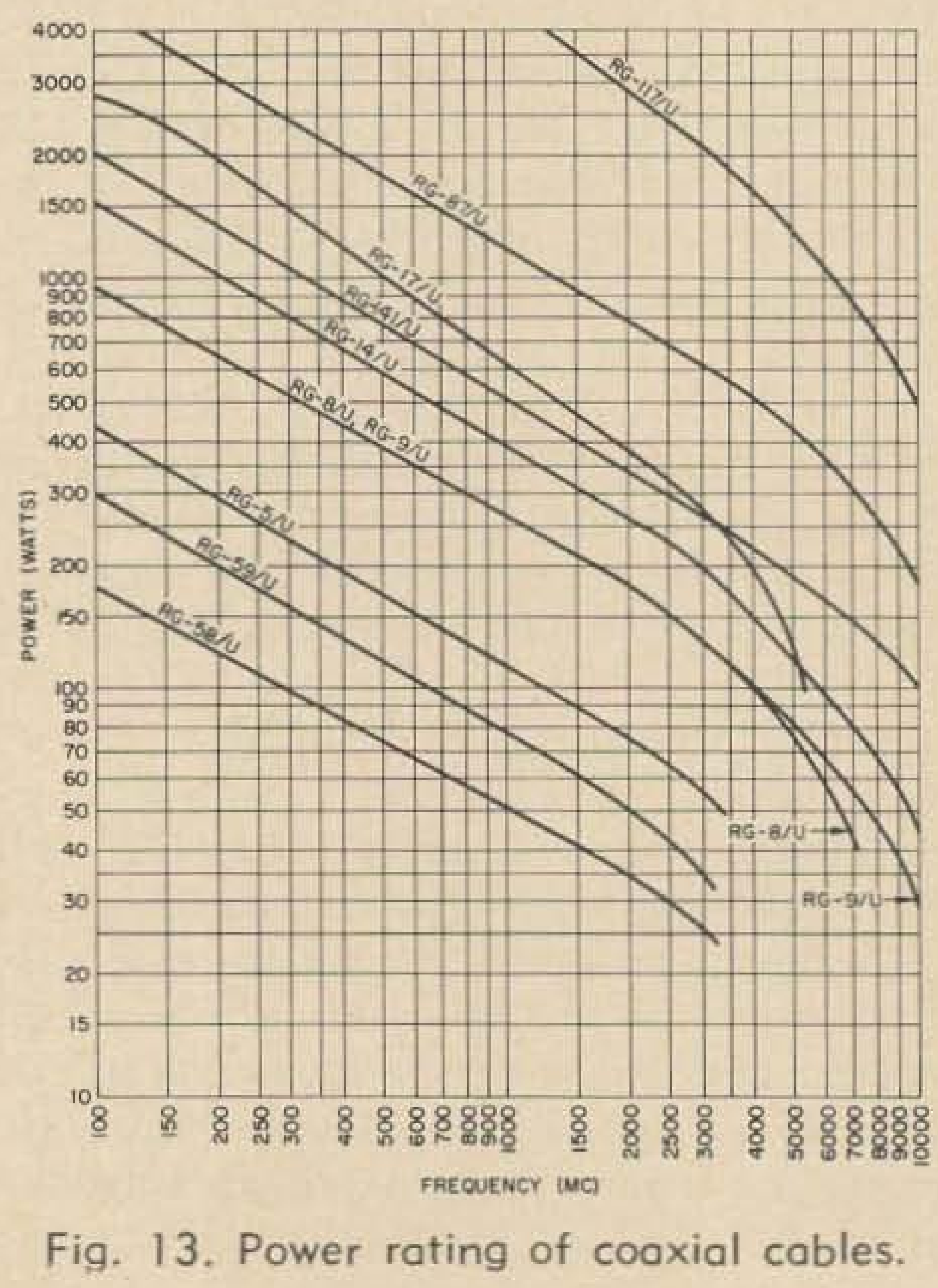


Fig. 13. Power rating of coaxial cables.

rating curves may be plotted if the attenuation curves are known. However, the power curves should not be plotted below 10 mc because electric breakdown rather than thermal limitations will govern.

Since a standing wave ratio along a transmission line multiplies the attenuation of the line, it will also decrease the power rating of the cable. This is because there are larger effective voltages and currents along a line with a standing wave ratio greater than 1:1 and hence considerable more heating of the conductors and dielectric. If it is assumed that the radial transfer of heat from the inner conductor to the atmosphere is the predominate factor, the power rating at other than unity SWR will be changed by a factor equal to the reciprocal of the new SWR; this power derating factor is plotted in **Fig. 15.**

Example If a coaxial cable has a power rating of 1000 watts at a specified frequency for an SWR of 1:1, the power rating with a SWR of 1.6:1 would be approximately 625 watts at the same frequency.

Another factor which derates the power handling capacity of the cable is the altitude. This is because as the altitude is increased above sea level, the less dense atmosphere is a less efficient heat conductor and the power rating must be decreased accordingly. This altitude derating factor is illustrated graphically in **Fig. 16.** Consequently, when considering the maximum operating power of a coaxial line, four factors must be considered: frequency, standing wave ratio, ambient temperature, and altitude.

Example Consider the hypothetical case of high power 432 mc equipment located on top of a mountain under conditions:

Altitude–5000 feet
Ambient temperature–120° Fahrenheit
Standing Wave Ratio–3:1

Assuming RG-8/U coaxial line is used, what is the maximum power that may be safely used?

Looking at the power rating curve in **Fig. 13,** at 432 mc RG-8/U will safely carry 430 watts of rf at sea level at 100 degrees Fahrenheit. Assuming that the station is 5000 feet above sea level, the power rating must be decreased by 7% as shown in **Fig. 16** to 400 watts. Since the local temperature is 120 degrees, the power must be further reduced by 28% (Polyethylene curve in **Fig. 14**) to 288 watts. In as much as the SWR is 3:1, a further reduction of 67% is required, yielding a total power capability under the stated conditions of 76 watts, more than a five to one reduction from the initial rated 430 watts.

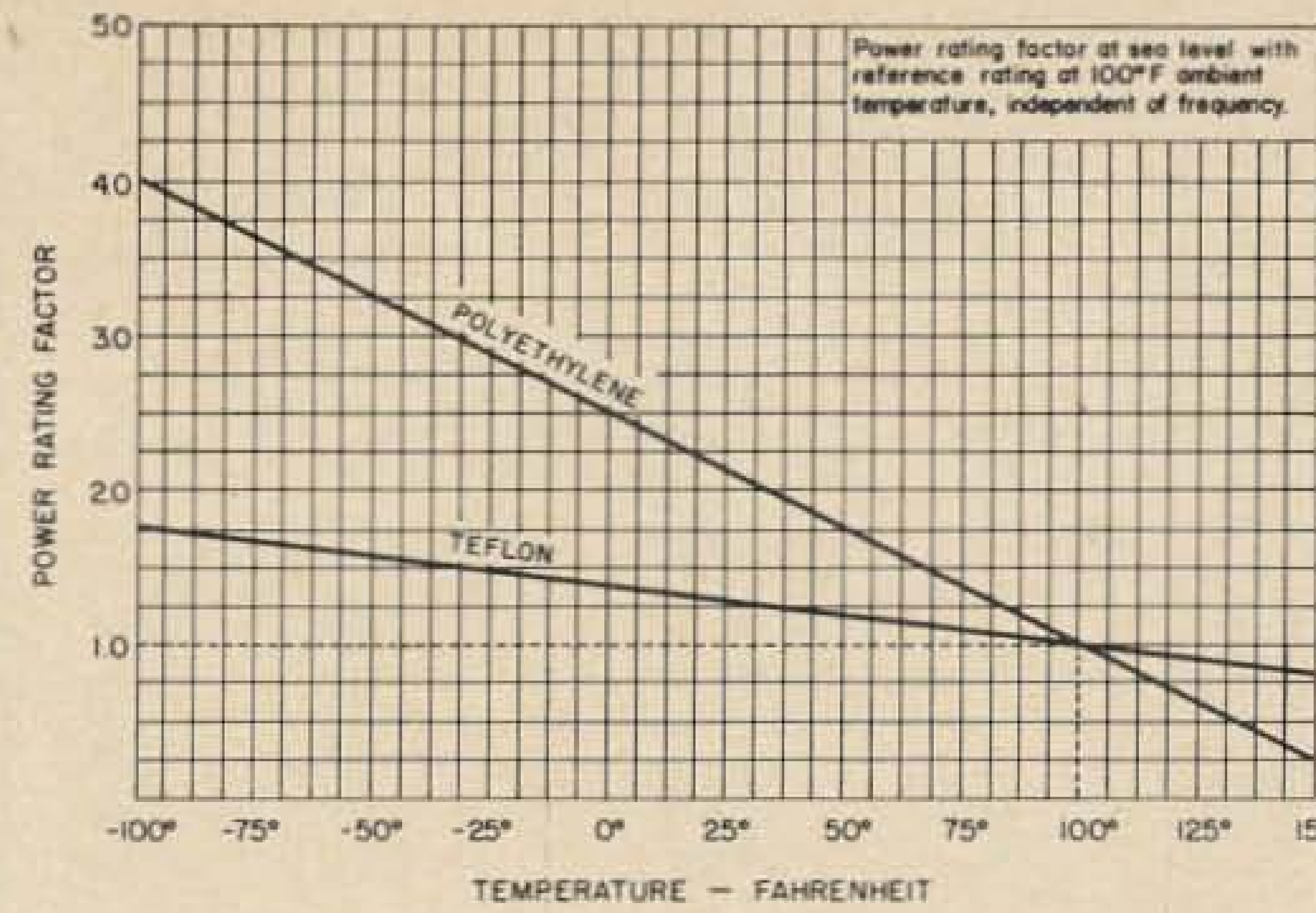


Fig. 14. Power rating factor for coaxial cables.

For higher ambient temperatures or for increased power ratings, Teflon cables are desirable. Teflon has a slightly lower high-frequency attenuation because of the lower dissipation factor, but because of their relatively high cost, Teflon cables are used only when their superior temperature characteristics or improved performance are economical.

Phase temperature characteristic

This term is of particular significance to those amateurs designing phased arrays where the phase relationship between signals traveling on different transmission lines is critical. This term is used to establish the variation in cable length with temperature. The reasons for variation are obvious when considering that all materials expand and contract with temperature. It is interesting to note that flexible braided cable is very poor in this respect, whereas a good quality semiflexible cable will change less than 15 parts per million per degree Fahrenheit.

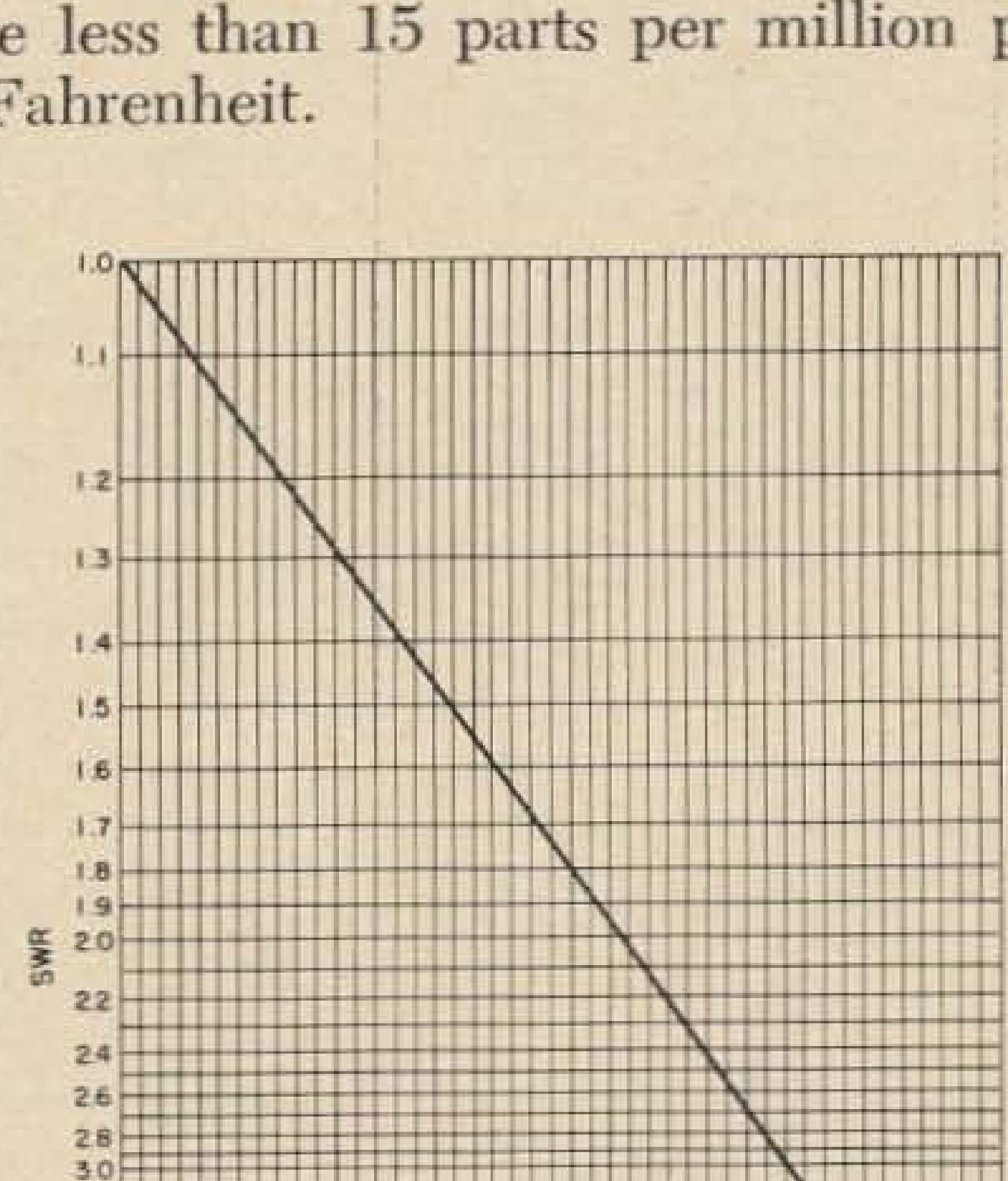


Fig. 15. Effect of SWR on power rating.

Table 3. DB power, voltage and current ratios.

DB	Power Ratio		Voltage or Current Ratio	
	Gain	Loss	Gain	Loss
0.1	1.02	.977	1.01	.989
0.2	1.05	.955	1.02	.977
0.3	1.07	.933	1.03	.966
0.4	1.10	.912	1.05	.955
0.5	1.12	.891	1.06	.944
0.6	1.15	.871	1.07	.933
0.7	1.17	.851	1.08	.923
0.8	1.20	.832	1.10	.912
0.9	1.23	.813	1.11	.902
1.0	1.26	.794	1.12	.891
1.1	1.29	.776	1.13	.881
1.2	1.32	.759	1.15	.871
1.3	1.35	.741	1.16	.861
1.4	1.38	.724	1.17	.851
1.5	1.41	.708	1.19	.841
1.6	1.44	.692	1.20	.832
1.7	1.48	.676	1.22	.822
1.8	1.51	.661	1.23	.813
1.9	1.55	.646	1.24	.803
2.0	1.58	.631	1.26	.794
2.1	1.62	.617	1.28	.781
2.2	1.66	.603	1.29	.776
2.3	1.70	.588	1.31	.763
2.4	1.74	.575	1.32	.759
2.5	1.78	.562	1.33	.752
2.6	1.82	.550	1.35	.741
2.7	1.86	.538	1.36	.735
2.8	1.90	.525	1.38	.724
2.9	1.94	.514	1.39	.716
3.0	1.99	.501	1.41	.708
3.1	2.04	.490	1.43	.699
3.2	2.09	.479	1.44	.692
3.3	2.14	.468	1.46	.684
3.4	2.19	.457	1.48	.676
3.5	2.24	.446	1.50	.667
3.6	2.29	.436	1.51	.661
3.7	2.34	.427	1.53	.654
3.8	2.40	.417	1.55	.646
3.9	2.45	.408	1.57	.638
4.0	2.51	.398	1.58	.631
4.1	2.57	.389	1.60	.625
4.2	2.63	.380	1.62	.617
4.3	2.69	.372	1.64	.610
4.4	2.75	.363	1.66	.603
4.5	2.82	.355	1.68	.596
4.6	2.88	.347	1.70	.589
4.7	2.95	.339	1.72	.582
4.8	3.02	.331	1.74	.575
4.9	3.09	.324	1.76	.568
5.0	3.16	.316	1.78	.562
5.1	3.24	.309	1.80	.556
5.2	3.31	.302	1.82	.549
5.3	3.39	.295	1.84	.543
5.4	3.47	.288	1.86	.537
5.5	3.55	.282	1.88	.531
5.6	3.63	.275	1.91	.525
5.7	3.72	.269	1.93	.519
5.8	3.80	.263	1.95	.513
5.9	3.89	.257	1.97	.507
6.0	3.98	.251	1.99	.501
6.5	4.47	.224	2.11	.473
7.0	5.01	.199	2.24	.447
7.5	5.62	.178	2.37	.422
8.0	6.31	.158	2.51	.398
8.5	7.08	.141	2.66	.376
9.0	7.94	.126	2.82	.355
9.5	8.91	.112	2.98	.335
10.0	10.00	.100	3.16	.316
11.0	12.60	.079	3.55	.282
12.0	15.80	.063	3.98	.251
13.0	19.9	.050	4.47	.224
14.0	25.1	.040	5.01	.199
15.0	31.6	.032	5.62	.178
16.0	39.8	.025	6.31	.158
17.0	50.1	.020	7.08	.141
18.0	63.1	.016	7.94	.126
19.0	79.4	.013	8.91	.112
20.0	100.0	.010	10.00	.100
21.0	125.9	.008	11.22	.089
22.0	158.5	.006	12.59	.079
23.0	199.6	.005	14.13	.071
24.0	251.2	.004	15.85	.063
25.0	316.2	.003	17.80	.056
30.0	1000.0	.001	31.62	.032
35.0	3162.0	.0003	56.24	.018
40.0	10000	.0001	100.00	.010
45.0	31620	.00003	177.80	.006
50.0	10^5	10^{-5}	316.23	.003
55.0	—	—	562.40	.0017
60.0	10^6	10^{-6}	1000.0	.001

Shielding properties

Although it is generally accepted that the coaxial line offers a completely shielded method for rf transmission, this is not necessarily so. Interference and crosstalk can appear between a coaxial line and surrounding equipment due to the radiation of energy through the braid. Although insignificant at the lower frequencies, it can become quite troublesome in the UHF region. This radiation through the shield is attenuated in two ways; absorption by the shield material and reflection due to the impedance discontinuities

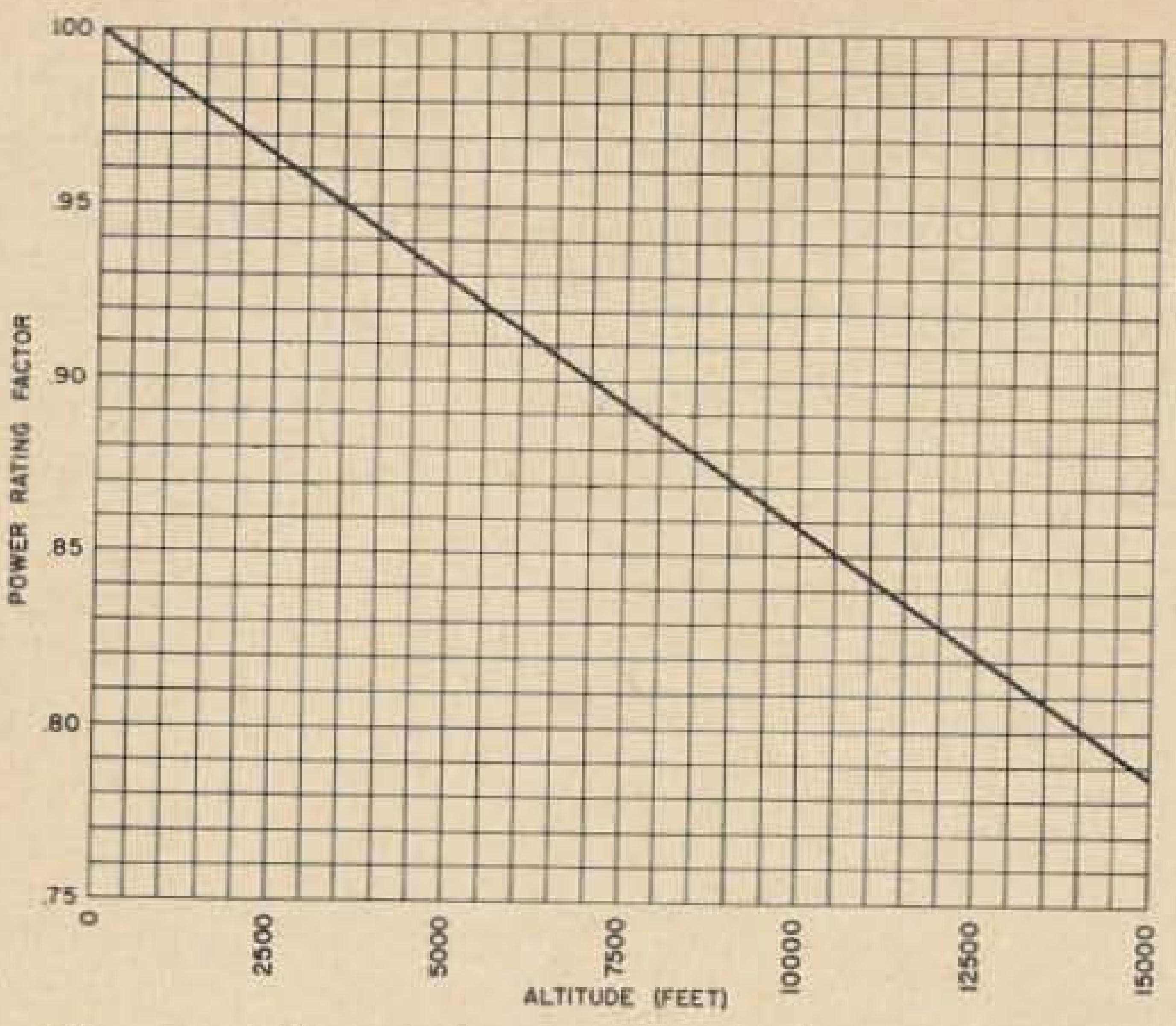


Fig. 16. Effect of altitude on power rating.

where the individual strands of the braid cross one another.

Frequently, the reflection loss from the irregularities of the braid material is greater than the attenuation through the braid. Also, if the braid is constructed from two different materials, the greater the reflections and the more effective the shielding. For instance, the use of copper and steel as a double braid forms a very effective low-frequency shield. Even greater shielding may be obtained by alternately interweaving layers of conductor and insulating materials and this "triaxial" technique is often used in the manufacture of high voltage pulse cables.

Cable standing wave ratio

In the UHF region, the standing wave ratio of a properly terminated flexible coaxial cable may vary between 1.1 and 1.3, occasionally reaching sharp peaks of 1.6 to 1.8. This is because flexible cables exhibit bad resonances at certain frequencies. These resonances are caused by periodic variations in the diameter of the dielectric. Small variations are inherent in the nature of the mechanical extrusion process and are more prevalent in Teflon than in polyethylene. From the standpoint of transmission line theory, gradual variations in cable diameters would cause little reflection. However, abrupt discontinuities in the line that are repeated periodically add up to a very large mismatch at the input end of a long cable at those frequencies for which the discontinuities are spaced by an even number of half cycles.

Cutoff frequency

Although it is not widely appreciated, coaxial cables do have an upper frequency limit. This so-called cutoff frequency is defined as that frequency at which the rf energy within the coaxial structure does not propagate in the proper mode; that is, the frequency at which the line acts more like a piece of waveguide than a piece of coax.

The cutoff frequency is reached when the mean diameter of the coax becomes equal to one wavelength. Practical experience indicates that coax should not be used beyond about 95% of this value because of the extremely abrupt increase in attenuation. This frequency is defined by the following relation:

$$F_c\ (\text{mc}) = \frac{7520}{(d + D)\sqrt{e}}$$

Where: F_c = Cutoff frequency
d = Outside diameter of inner conductor
D = Inside diameter of outer conductor
e = Dielectric constant of insulating material

The cutoff frequency should be of little consequence to the majority of amateur applications since it falls well above 10,000 mc for all but the large diameter cables. It should be noted that the attenuation curves should not be projected into the cutoff region because of the rapid change in slope.

Special cables

In addition to the common types of coaxial line with which most amateurs are familiar, there are several special cables that should be mentioned briefly. One of these is the high attenuation type designed specifically for attenuation pads and loads in instrumentation applications. In order to achieve high attenuation, RG-21/U and RG-126/U use a high resistance number 16 AWG Nichrome wire for the center conductor. Since the majority of attenuation is in the center conductor, the attenuation of these lines is roughly proportional to the square root of the frequency. These cables replace the older RG-38/U attenuating cable which used a lossy rubber dielectric as the attenuating element. In RG-38/U, the attenuation is nearly proportional to frequency.

Subminiature cables which do not have standard RG-/U designations are seeing extensive use in transistorized equipment where size and weight are at a premium. Cables of this type are available in both flexible and semiflexible versions with Teflon, polyethylene and foam dielectrics.

Triaxial cables are available which exhibit very good shielding properties at frequencies up to 10 mc. Although intended primarily for pulse service, they may be used in other applications where noise is a problem.

Table 9. Equivalent international coaxial cables.

USA	British	French	Swedish	Russian
RG-8/U	Uniradio No. 67	KX50MD1	HK-50-7	PK-47
RG-11/U	Uniradio No. 57*	KX76MD1	—	PK-20*
RG-17/U	Uniradio No. 74	—	HK-50-17	—
RG-58/U	Uniradio No. 43	—	HK-50A-3	—
RG-58A/U	Uniradio No. 76	—	HK-50B-3	—
RG-63/U	Uniradio No. 64	—	—	—
RG-133/U	Uniradio No. 78	KX100MM1	—	—

*Similar to but not equivalent

Several manufacturers have special "low-noise" coaxial cables which remain electrically neutral under conditions of shock and vibration. Spurious signals may be generated by standard flexible cable under conditions of extreme flexure; these signals may well be of a higher level than the useful signal being transmitted along the line. The reduction of this inherent noise is obtained by applying a semi-conductive coating between the dielectric and the outer braid.

Although other countries do not have the convenience of coaxial cable standardization that the United States does, most of them have cables that are equivalent or similar to standard RG-/U types. **Table 9** lists British, French, Swedish and Russian coaxial cables and their RG-/U counterparts.

Coaxial cable testing

Accurate testing of coaxial transmission lines normally requires sophisticated laboratory equipment, but some rather simple tests that may be made in the ham shack are useful in determining the quality of a particular coaxial cable in use.

The easiest test is that of isolation between the inner and outer conductors. For this test a 500 volt megohmeter should be used. For good, high quality, unterminated coaxial cable, the isolation between the conductors should be at least 100,000 megohms. If the isolation is less than this, the attenuation of the line will be extremely high, the power rating will be limited and early failure may occur due to voltage breakdown or excessive heat.

Impedance measurement

Another test that is simple to perform, and that is more indicative of cable quality is measurement of the characteristic impedance of the line. For new, high quality coaxial cable, the characteristic impedance should be within one or two percent of that specified by the manufacturer. For example, a 50 ohm line should have a characteristic impedance between 49 and 51 ohms. If the measured impedance is more than two percent off, it is indicative of serious faults within the line. Poor manufacturing processes, contaminated dielectric, and moisture and dirt all contribute to the degradation of cable impedance.

This test is easy to perform and requires only a grid-dip meter and an accurate capacitance bridge or Q-meter. First of all, one end of the cable to be tested is short-circuited with a piece of wire. The grid-dipper is then coupled to the other end of the line and tuned for a dip. Resonant points will be obtained at several different frequencies, but the one lowest in frequency is the one used in this measurement.

Next, remove the short and measure the capacity of the line with the capacitance bridge or Q-meter. For this measurement, several readings should be made and then averaged for best results. Using the capacity of the line and the lowest frequency of resonance, the characteristic impedance of the line may be calculated from the following formula.

$$Z_o = \frac{2.5 \times 10^5}{fC}$$

Where Z_o = Characteristic impedance of the line
f = Lowest frequency of resonance in mc
C = Capacity in picofarads

Example: A length of coaxial cable has a measured capacity of 1377 pf and the lowest frequency of resonance in 3.65 mc.
What is its characteristic impedance?

$$Z_o = \frac{2.5 \times 10^5}{(3.65 \text{ mc})\ (1377 \text{ pf})} = 49.74 \text{ ohms}$$

Attenuation measurement

The most direct method for measuring attenuation is to measure and compare voltages at the beginning and end of a properly terminated transmission line. A vacuum tube voltmeter may be used for this purpose at frequencies up to about 30 mc, but at higher frequencies the two voltage measurements are more difficult to make and a more accurate method should be used. For frequencies up to about 200 mc, a Q-Meter may be used with rather accurate results. The Q-meter is simply a series-resonant circuit with a variable oscillator and a device for indicating the peak voltage or Q across the variable capacitor at resonance.

To use this method of attenuation measurement, the line to be tested is attached to the Q-meter as shown in **Fig. 17**; a shorting switch is shown in the illustration, but any method of shorting the cable will do; a flat piece of copper sheet is excellent for this purpose. The Q-meter is then adjusted to the resonant frequency of the open circuited line; when the line is shorted, the Q-meter should indicate series resonance at the same frequency. If not, a small frequency adjustment may be made to compensate for end effect and other stray effects which cause slight changes in resonance.

Note the relative reading of the voltage indicator on the Q-meter with the line open-circuited and remove the cable from the meter. Substitute standard composition resistors across the Q-meter terminals until the same relative meter reading is obtained. When the equivalent parallel resonant resistance of the cable is determined, the attenuation of the line may be calculated from:

$$a = \frac{8.69\ Z_o}{R_e}$$

Where: a = Attenuation in db
Z_o = Characteristic impedance of the line in ohms
R_e = Equivalent resonant resistance of the line

Since this procedure is not dependent upon the actual values read on the Q-meter and the variable capacitor dial, better accuracy is obtained. This is because even the most expensive Q-meters are rather inaccurate at VHF

Table 4. Free space wavelength.

Frequency (mc)	λ	λ/2	λ/4
3.50	281′ 0.27″	140′ 6.13″	70′ 3.07″
3.75	262′ 3.45″	131′ 1.73″	65′ 6.87″
4.00	245′ 10.73″	122′ 11.37″	61′ 5.69″
7.00	140′ 6.13″	70′ 3.07″	35′ 1.53″
7.15	137′ 6.76″	68′ 9.38″	34′ 4.69″
7.30	134′ 8.84″	67′ 4.42″	33′ 8.21″
14.00	70′ 3.07″	35′ 1.53″	17′ 6.77″
14.20	69′ 3.19″	34′ 7.60″	17′ 3.80″
14.35	68′ 6.50″	34′ 3.25″	17′ 1.63″
21.00	46′ 10.04″	23′ 5.02″	11′ 8.51″
21.25	46′ 3.43″	23′ 1.72″	11′ 6.86″
21.45	45′ 10.25″	22′ 11.13″	11′ 5.57″
28.00	35′ 1.53″	17′ 6.77″	8′ 9.38″
28.50	34′ 6.14″	17′ 3.07″	8′ 7.54″
29.00	33′ 11.00″	16′ 11.50″	8′ 5.75″
29.70	33′ 1.44″	16′ 6.72″	8′ 3.36″
50.0	236.06″	118.03″	59.02″
51.0	231.43″	115.72″	57.86″
52.0	226.98″	113.49″	56.75″
53.0	222.70″	111.35″	55.68″
54.0	218.57″	109.29″	54.64″
144.0	81.97″	40.98″	20.49″
145.0	81.40″	40.70″	20.35″
146.0	80.84″	40.42″	20.21″
147.0	80.29″	40.15″	20.07″
148.0	79.75″	39.88″	19.99″
220.0	53.65″	26.83″	13.41″
222.5	53.05″	26.52″	13.26″
225.0	52.46″	26.23″	13.12″
420.0	28.10″	14.05″	7.03″
425.0	27.77″	13.89″	6.94″
432.0	27.32″	13.66″	6.83″
440.0	26.83″	13.41″	6.71″
450.0	26.23″	13.12″	6.56″
1215.0	9.71″	4.86″	2.43″
1225.0	9.64″	4.82″	2.41″
1250.0	9.44″	4.72″	2.36″
1275.0	9.26″	4.63″	2.32″
1296.0	9.11″	4.55″	2.28″

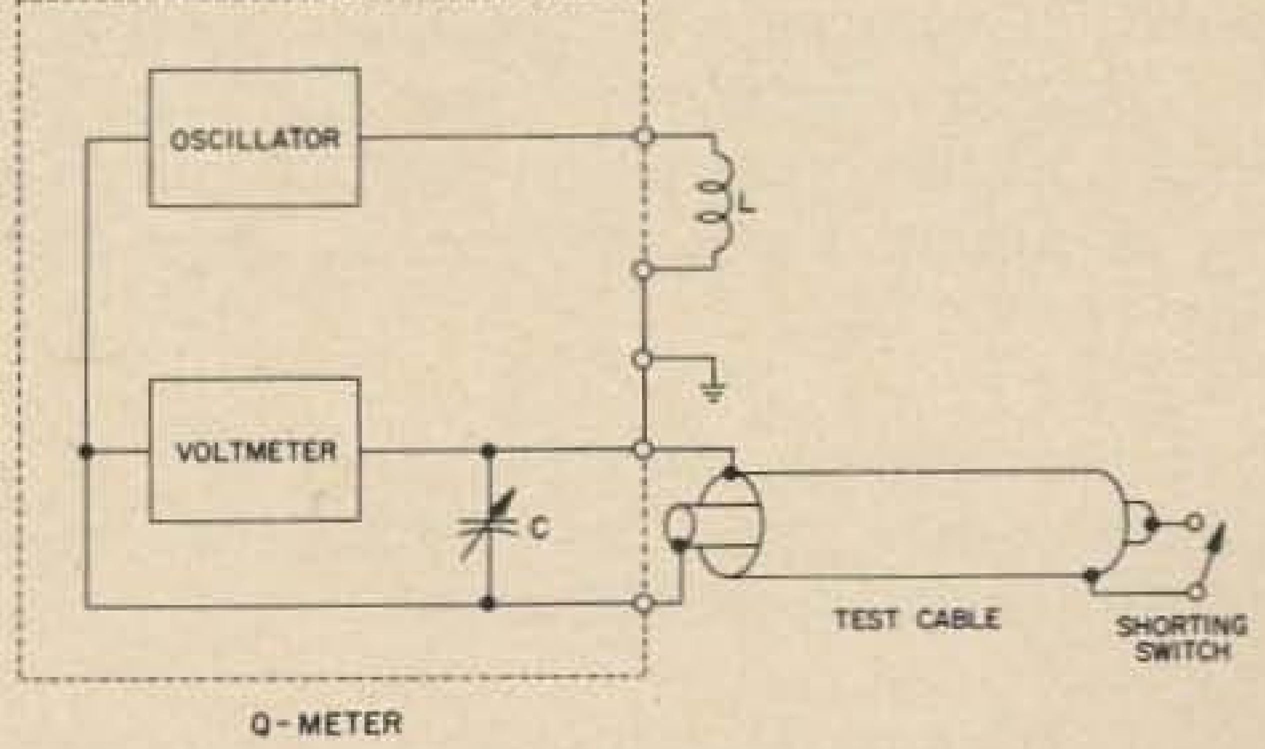


Fig. 17. Test setup for measuring coaxial cable attenuation.

Table 5. Coaxial cable wavelength. Polystyrene dielectric. Velocity of propagation = 0.66.

Frequency (mc)	λ	λ/2	λ/4
3.50	185′ 5.70″	92′ 8.85″	46′ 4.42″
3.75	173′ 1.32″	86′ 6.66″	43′ 3.33″
4.00	162′ 3.48″	81′ 1.74″	40′ 6.87″
7.00	92′ 8.85″	46′ 4.42″	23′ 2.21″
7.15	90′ 9.50″	45′ 4.75″	22′ 8.38″
7.30	88′ 11.11″	44′ 5.56″	22′ 2.78″
14.00	46′ 4.42″	23′ 2.21″	11′ 7.11″
14.20	45′ 8.59″	22′ 10.29″	11′ 5.15″
14.35	45′ 2.85″	22′ 7.43″	11′ 3.71″
21.00	30′ 10.95″	15′ 5.48″	7′ 8.74″
21.25	30′ 6.59″	15′ 3.29″	7′ 7.65″
21.45	30′ 3.17″	15′ 1.58″	7′ 6.79″
28.00	23′ 2.21″	11′ 7.11″	5′ 9.55″
28.50	22′ 9.33″	11′ 4.67″	5′ 8.33″
29.00	22′ 4.62″	11′ 2.31″	5′ 7.15″
29.70	21′ 10.31″	10′ 11.16″	5′ 5.58″
50.0	155.80″	77.81″	38.91″
51.0	152.74″	76.37″	38.19″
52.0	149.81″	74.90″	37.45″
53.0	146.98″	73.49″	36.75″
54.0	144.26″	72.13″	36.06″
144.0	54.10″	27.05″	13.52″
145.0	53.72″	26.86″	13.43″
146.0	53.36″	26.68″	13.34″
147.0	52.99″	26.50″	13.25″
148.0	52.64″	26.32″	13.16″
220.0	35.41″	17.71″	8.85″
222.5	35.01″	17.51″	8.75″
225.0	34.62″	17.31″	8.66″
420.0	18.55″	9.27″	4.64″
425.0	18.33″	9.17″	4.58″
432.0	18.03″	9.02″	4.51″
440.0	17.71″	8.85″	4.43″
450.0	17.31″	8.66″	4.33″
1215.0	6.41″	3.21″	1.60″
1225.0	6.36″	3.18″	1.59″
1250.0	6.23″	3.12″	1.56″
1275.0	6.11″	3.06″	1.53″
1296.0	6.01″	3.00″	1.50″

Table 6. Coaxial cable wavelength. Teflon dielectric. Velocity of propagation = 0.695.

Frequency (mc)	λ	λ/2	λ/4
3.50	195′ 3.73″	97′ 7.86″	48′ 9.93″
3.75	182′ 3.48″	91′ 1.74″	45′ 6.87″
4.00	170′ 10.76″	85′ 5.38″	42′ 8.69″
7.00	97′ 7.86″	48′ 9.93″	24′ 4.97″
7.15	95′ 7.28″	47′ 9.64″	23′ 10.82″
7.30	93′ 7.70″	46′ 9.85″	21′ 3.93″
14.00	48′ 9.93″	24′ 4.97″	12′ 2.49″
14.20	48′ 1.68″	24′ 0.84″	12′ 0.42″
14.35	47′ 7.64″	23′ 9.82″	11′ 10.91″
21.00	32′ 6.62″	16′ 3.31″	7′ 3.66″
21.25	32′ 2.25″	16′ 1.01″	7′ 2.51″
21.45	31′ 10.41″	15′ 11.21″	7′ 1.61″
28.00	24′ 4.97″	12′ 2.49″	6′ 1.25″
28.50	23′ 11.83″	11′ 11.91″	5′ 11.96″
29.00	23′ 6.86″	11′ 9.43″	5′ 10.72″
29.70	23′ 0.22″	11′ 6.11″	5′ 9.06″
50.0	164.06″	82.03″	41.02″
51.0	160.84″	80.42″	40.21″
52.0	157.75″	78.88″	39.44″
53.0	154.77″	77.39″	38.69″
54.0	151.91″	75.96″	37.98″
144.0	56.97″	28.48″	14.24″
145.0	56.57″	28.29″	14.14″
146.0	56.19″	28.09″	14.05″
147.0	55.80″	27.90″	13.95″
148.0	55.43″	27.71″	13.86″
220.0	37.29″	18.64″	9.32″
222.5	36.87″	18.43″	9.22″
225.0	36.46″	18.23″	9.11″
420.0	19.53″	9.77″	4.89″
425.0	19.30″	9.65″	4.83″
432.0	18.99″	9.50″	4.75″
440.0	18.64″	9.32″	4.66″
450.0	18.23″	9.12″	4.56″
1215.0	6.75″	3.38″	1.69″
1225.0	6.67″	3.34″	1.67″
1250.0	6.56″	3.28″	1.64″
1275.0	6.43″	3.22″	1.61″
1296.0	6.33″	3.16″	1.58″

frequencies. On the other hand, tests have shown that standard composition resistors exhibit constant resistance from DC to about 200 mc and the comparison method yields precision of about 5 percent for 50 ohm coaxial cables.

Example: What is the attenuation of a 50 ohm coaxial cable with an equivalent parallel resonant resistance of 91 ohms?

$$a = \frac{8.69 \times 50}{91} = 4.8 \text{ db attenuation}$$

Time domain reflectometry

In military and commercial installations, the time domain reflectometry technique is used to determine the performance of coaxial cable systems. Although this system in its commercial form is much too sophisticated for most amateur installations, it should be mentioned in passing. This technique uses pulse-echo measurements to locate points of impedance change along a coaxial transmission line and has been referred to as a "closed loop" radar system. Here a fast rising voltage pulse is repetitively fed into the transmission line under

Table 7. Coaxial cable wavelength. Amphenol polyfoam dielectric. Velocity of propagation = 0.80.

Frequency (mc)	λ	λ/2	λ/4
3.50	224′ 9.82″	112′ 4.91″	56′ 2.46″
3.75	209′ 9.96″	104′ 10.98″	52′ 5.49″
4.00	196′ 8.58″	98′ 4.29″	49′ 2.15″
7.00	112′ 4.90″	56′ 2.45″	28′ 1.23″
7.15	110′ 0.61″	55′ 0.31″	27′ 6.15″
7.30	107′ 9.47″	53′ 10.74″	26′ 11.37″
14.00	56′ 2.45″	28′ 1.23″	14′ 0.61″
14.20	55′ 4.95″	27′ 8.48″	13′ 10.24″
14.35	54′ 10.00″	27′ 5.00″	13′ 8.51″
21.00	37′ 5.64″	18′ 8.87″	9′ 4.43″
21.25	37′ 0.35″	18′ 6.17″	9′ 3.09″
21.45	36′ 8.20″	18′ 4.10″	9′ 2.05″
28.00	28′ 1.23″	14′ 0.61″	7′ 0.31″
28.50	27′ 7.31″	13′ 9.66″	6′ 10.83″
29.00	27′ 1.60″	13′ 6.80″	6′ 9.40″
29.70	26′ 5.95″	13′ 2.98″	6′ 7.49″
50.0	188.85″	94.42″	47.21″
51.0	185.14″	92.57″	46.29″
52.0	181.58″	90.79″	45.40″
53.0	178.16″	89.08″	44.54″
54.0	174.86″	87.43″	43.71″
144.0	65.57″	32.79″	16.39″
145.0	65.12″	32.56″	16.28″
146.0	64.67″	32.34″	16.17″
147.0	64.23″	32.12″	16.05″
148.0	63.80″	31.90″	15.95″
220.0	42.92″	21.46″	10.73″
222.5	42.44″	21.22″	10.61″
225.0	41.97″	20.98″	10.49″
420.0	22.48″	11.24″	5.62″
425.0	22.22″	11.11″	5.55″
432.0	21.86″	10.93″	5.46″
440.0	21.46″	10.73″	5.37″
450.0	20.98″	10.49″	5.25″
1215.0	7.77″	3.89″	1.94″
1225.0	7.71″	3.85″	1.93″
1250.0	7.55″	3.78″	1.89″
1275.0	7.41″	3.70″	1.85″
1296.0	7.29″	3.64″	1.82″

Table 8. Coaxial cable wavelength. Belden foamcore dielectric. Velocity of propagation = 0.78.

Frequency (mc)	λ	λ/2	λ/4
3.50	219′ 2.37″	109′ 7.19″	54′ 9.59″
3.75	204′ 7.01″	102′ 3.51″	51′ 1.75″
4.00	191′ 9.57″	95′ 10.59″	47′ 11.39″
7.00	109′ 7.18″	54′ 9.59″	27′ 4.80″
7.15	107′ 3.59″	53′ 7.80″	26′ 9.90″
7.30	105′ 1.14″	52′ 6.57″	26′ 3.29″
14.00	54′ 9.59″	27′ 4.80″	13′ 8.40″
14.20	54′ 0.33″	27′ 0.17″	13′ 6.08″
14.35	53′ 5.55″	26′ 8.78″	13′ 4.39″
21.00	36′ 6.39″	18′ 3.20″	9′ 1.60″
21.25	36′ 1.24″	18′ 0.62″	9′ 0.31″
21.45	35′ 9.20″	17′ 10.60″	8′ 11.30″
28.00	27′ 4.80″	13′ 8.40″	6′ 10.20″
28.50	26′ 11.03″	13′ 5.51″	6′ 8.76″
29.00	26′ 5.46″	13′ 2.73″	6′ 7.36″
29.70	25′ 10.00″	12′ 11.00″	6′ 5.50″
50.0	184.13″	92.06″	46.03″
51.0	180.52″	90.26″	45.13″
52.0	177.04″	88.52″	44.26″
53.0	173.70″	86.85″	43.43″
54.0	170.49″	85.24″	42.62″
144.0	63.93″	31.97″	15.98″
145.0	63.49″	31.75″	15.87″
146.0	63.06″	31.53″	15.76″
147.0	62.63″	31.31″	15.66″
148.0	62.21″	31.10″	15.55″
220.0	41.85″	20.92″	10.46″
222.5	41.38″	20.69″	10.34″
225.0	40.92″	20.46″	10.23″
420.0	21.92″	10.96″	5.48″
425.0	21.66″	10.83″	5.42″
432.0	21.31″	10.66″	5.33″
440.0	20.92″	10.46″	5.23″
450.0	20.46″	10.23″	5.11″
1215.0	7.58″	3.79″	1.89″
1225.0	7.52″	3.76″	1.88″
1250.0	7.37″	3.68″	1.84″
1275.0	7.22″	3.61″	1.81″
1296.0	7.10″	3.55″	1.78″

test; impedance changes along the line reflect some of the energy and the reflections are viewed on an oscilloscope. Because the pulse travels down the line at a known speed (determined by the velocity factor of the cable), impedance changes separated in space are separated in time and appear as individual "pips" on the scope. Furthermore, the shape and size of each reflection is indicative of the type of impedance discontinuity present.

This system is particularly useful in large installations where it is desirable to locate physical deformities, breaks and other injuries without complete disassembly and examination. Since this technique indicates the nature of the problem, it is possible to determine such things as impedance discontinuities caused by a tightly squeezed cable clamp or improperly installed connectors. In one case the time domain reflectometry technique showed exactly where to examine a cable in an antenna tower to find a cable injury caused by a rifle bullet. On a large ship a mismatch problem was pinpointed and upon investigation was found to be in the vicinity of steam pipes that had softened the cable dielectric.

Coaxial cable installation

In the installation and use of coaxial transmission lines, there are seven basic rules which must be followed if the most advantageous use of the line is to be realized. These are as follows:

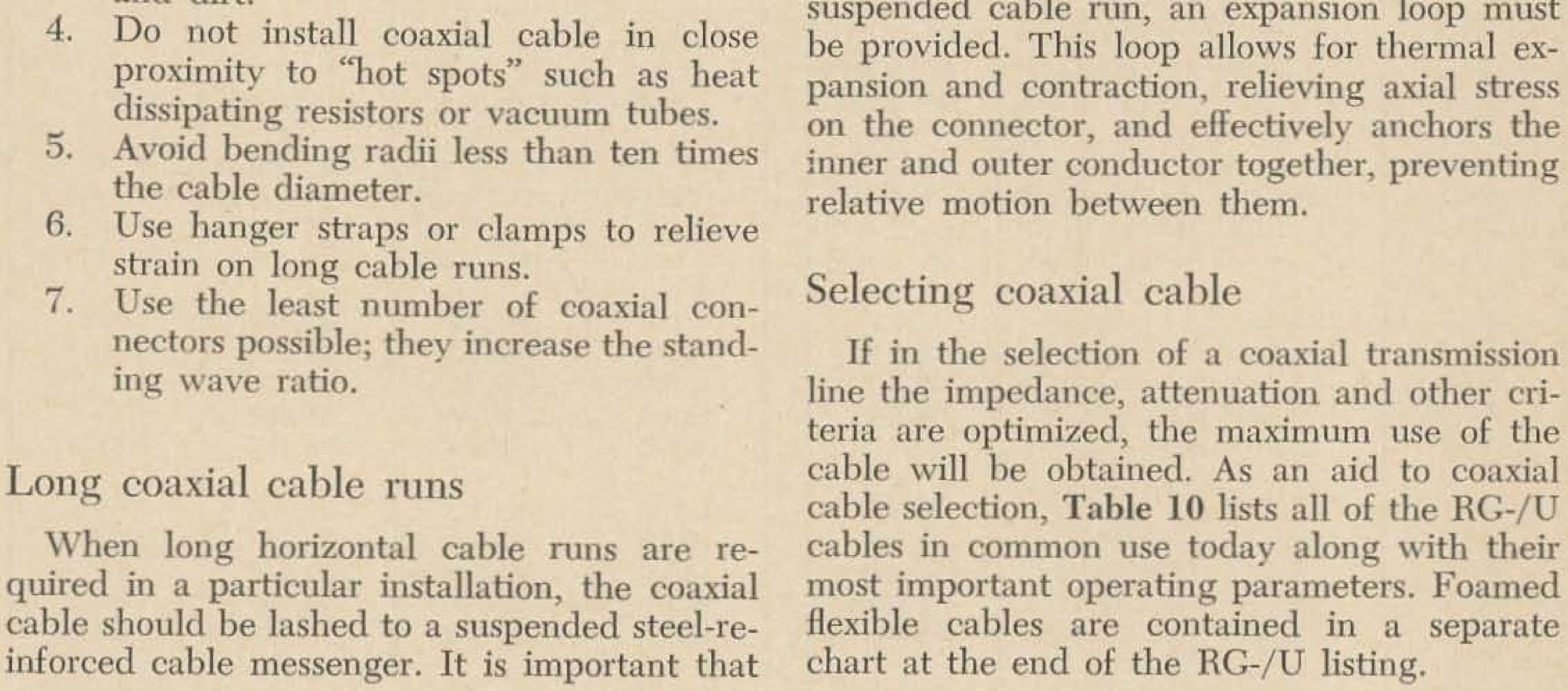
1. Select cables well within their electrical ratings.
2. Do not specify Teflon dielectric cables unless the power ratings or ambient temperature exceeds the safe values for polyethylene.
3. Seal the ends of all cables during storage to preclude damage from moisture and dirt.
4. Do not install coaxial cable in close proximity to "hot spots" such as heat dissipating resistors or vacuum tubes.
5. Avoid bending radii less than ten times the cable diameter.
6. Use hanger straps or clamps to relieve strain on long cable runs.
7. Use the least number of coaxial connectors possible; they increase the standing wave ratio.

Long coaxial cable runs

When long horizontal cable runs are required in a particular installation, the coaxial cable should be lashed to a suspended steel-reinforced cable messenger. It is important that the proper messenger be selected on the basis of length, weight and climatic conditions. For most amateur installations where cable diameters are less than ½ inch in diameter, and where suspension lengths of 150 feet or less are required, steel-reinforced messenger cable with a tensile strength of 80,000 pounds is satisfactory. The coaxial cable is then lashed to the messenger cable with hard AWG #12 aluminum lashing wire. The easiest and most reliable method of lashing is to spirally wind the lashing wire around the coaxial cable and the messenger. Care should be taken so that the lashing is taut and pitch is uniform. When coaxial connectors must be installed along a suspended cable run, an expansion loop must be provided. This loop allows for thermal expansion and contraction, relieving axial stress on the connector, and effectively anchors the inner and outer conductor together, preventing relative motion between them.

Selecting coaxial cable

If in the selection of a coaxial transmission line the impedance, attenuation and other criteria are optimized, the maximum use of the cable will be obtained. As an aid to coaxial cable selection, **Table 10** lists all of the RG-/U cables in common use today along with their most important operating parameters. Foamed flexible cables are contained in a separate chart at the end of the RG-/U listing.



DETERMINE THE LOWEST RESONANT FREQUENCY OF THE CABLE

MEASURE THE CAPACITANCE OF THE CABLE

Fig. 18. Test arrangements for determining coaxial cable impedance.

Table 10. Coaxial cable characteristics.

RG/U Type	Inner Conductor		Dielectric Material	Jacket		Shield		Impedance (Ohms)	Cap. (pf/ft)	Engineering Data	Attenuation in db/100 ft		Max. Opr. Volts RMS	Max. Power Watts @ 50mc
	Mat.	Strand		Mat.	O.D.	Inner	Outer				(100 mc)	(1000 mc)		
4	C	20 AWG	A1	V	0.226	C	C	50.0	30.0	Replaced by RG-58/U	—	—	1900	300
5	C	16 AWG	A1	V	0.332	C	C	52.5	28.5		2.6	9.5	3000	600
5A	SC	16 AWG	A1	NVG	0.328	SC	SC	50.0	28.5		2.4	8.8	3000	600
5B	SC	0.051	A1	NVB	0.328	SC	SC	50.0	28.5	Now designated as RG-212/U	2.4	8.8	3000	600
6	CW	21 AWG	A1	NVG	0.332	SC	C	76.0	20.0		2.8	11.0	2700	600
6A	CW	0.0285	A1	NVB	0.332	SC	C	75.0	20.0		2.8	11.0	2700	600
7	C	19 AWG	A2	V	0.370	—	C	95.0	12.5	Replaced by RG-63B/U	2.0	7.8	1000	—
8	C	7/0.0285	A1	V	0.405	—	C	52.0	29.5		2.1	9.0	4000	1445
8A	C	7/0.0285	A1	NVB	0.405	—	C	52.0	29.5	Now designated as RG-213/U	2.1	9.0	5000	1445
9	SC	7/0.0285	A1	NVG	0.420	SC	C	51.0	30.0		2.0	8.5	4000	1445
9A	SC	7/0.0285	A1	NVG	0.420	SC	SC	51.0	30.0		2.3	8.6	4000	1445
9B	SC	7/0.0285	A1	NVB	0.420	SC	SC	50.0	30.0	Now designated as RG-214/U	2.3	8.6	5000	1445
10	C	7/0.0285	A1	NVGA	0.475	—	C	52.0	29.5		2.1	9.0	4000	1445
10A	C	7/0.0285	A1	NVGA	0.475	—	C	52.0	29.5	RG-8A/U with armor. Now designated as RG-215/U	2.1	9.0	5000	1445
11	TC	7/0.0159	A1	V	0.405	—	C	75.0	20.5		2.1	7.8	4000	1445
11A	TC	7/0.159	A1	NVB	0.405	—	C	75.0	20.5		2.1	7.8	5000	1445
12	TC	7/0.0159	A1	NVBA	0.475	—	C	75.0	20.5		2.1	7.8	4000	1445
12A	TC	7/0.0159	A1	NVBA	0.475	—	C	75.0	20.5	RG-11A/U with armor.	2.1	7.8	5000	1445
13	TC	7/0.0159	A1	V	0.420	C	C	74.0	20.5		2.1	7.8	4000	1445
13A	TC	7/0.0159	A1	NVB	0.420	C	C	74.0	20.5	Now designated as RG-216/U	2.1	7.8	5000	1445
14	C	0.102	A1	NVG	0.545	C	C	52.0	29.5		1.4	6.2	5500	1280
14A	C	0.102	A1	NVB	0.545	C	C	52.0	29.5	Now designated as RG-217/U	1.4	6.2	7000	1280
15	CW	15 AWG	A1	V	0.545	C	C	76.0	20.0		1.58	6.5	5000	1280
16	CT	0.125	A1	V	0.630	—	C	52.0	29.5		1.2	6.7	6000	—
17	C	0.188	A1	NVG	0.870	—	C	52.0	29.5		0.85	4.2	11000	7450
17A	C	0.188	A1	NVB	0.870	—	C	52.0	29.5	Now designated as RG-218/U	0.85	4.2	11000	7450
17B	—	—	—	—	—	—	—	—	—	Cancelled. Assigned new nomenclature as RG-177/U	—	—	—	—
18	C	0.188	A1	NVGA	0.945	—	C	52.0	29.5		0.85	4.2	11000	7450
18A	C	0.188	A1	NVBA	0.945	—	C	52.0	29.5	Now designated as RG-219/U	0.85	4.2	11000	7450

RG/U Type	Inner Conductor		Dielectric Material	Jacket		Shield		Imped-ance (Ohms)	Cap. (pf/ft)	Engineering Data	Attenuation in db/100 ft		Max. Opr. Volts RMS	Max. Power Watts @ 50mc
	Mat.	Strand		Mat.	O.D.	Inner	Outer				(100 mc)	(1000 mc)		
19	C	0.250	A1	NVG	1.120	—	C	52.0	29.5		0.68	3.5	14000	8400
19A	C	0.250	A1	NVB	1.120	—	C	52.0	29.5	Now designated as RG-220/U	0.68	3.5	14000	8400
20	C	0.250	A1	NVGA	1.195	—	C	52.0	29.5		0.68	3.5	14000	8400
20A	C	0.250	A1	NVBA	1.195	—	C	52.0	29.5	Now designated as RG-221/U	0.68	3.5	14000	8400
21	HR	0.0508	A1	NVG	0.332	SC	SC	53.0	29.0		15.0	46.0	2700	—
21A	HR	0.0508	A1	NVB	0.332	SC	SC	53.0	29.0	Now designated as RG-222/U	15.0	46.0	2700	—
22	C	7/0.0152	A1	V	0.405	—	TC	95.0	16.0	Two conductors	3.6	13.7	1000	—
22A	C	7/0.0152	A1	NVG	0.420	—	TC	95.0	16.0	Two conductors	—	—	1000	—
22B	C	7/0.0152	A1	NVB	0.420	TC	TC	95.0	16.0	Two conductor balanced cable. Conductors twisted	—	—	1000	—
23	C	7/0.0285	A1	V	0.650	C	C	125.0	12.0	Two conductors	1.7	7.3	3000	600
23A	C	7/0.0285	A1	NVB	0.650	C	C	125.0	12.0	Two conductors	1.7	7.3	3000	600
24	C	7/0.0285	A1	VA	1.034	C	C	125.0	12.0	Two conductors	1.7	7.3	3000	600
24A	C	7/0.0285	A1	NVBA	1.034	C	C	125.0	12.0	Two conductors RG-23A/U with armor	1.7	7.3	3000	600
29	C	20 AWG	A1	P	0.184	—	TC	53.5	28.5	Replaced by RG-58/U	4.8	18.0	1900	300
33	C	10 AWG	A1	Lead	0.470	—	—	51.0	30.0		—	—	6000	—
34	C	7/0.0285	A1	V	0.625	—	C	71.0	21.5		1.8	7.5	5200	—
34B	C	7/0.0249	A1	NVB	0.630	—	C	75.0	21.5		1.4	5.9	5200	—
35	C	9 AWG	A1	NVGA	0.945	—	C	71.0	21.5		0.7	4.2	10000	7450
35B	C	0.1045	A1	NVBA	0.945	—	C	75.0	21.5		0.85	3.6	10000	7450
36	C	0.162	A1	V	1.180	—	C	69.0	22.0		—	—	13000	—
42	HR	21 AWG	A1	NVG	0.342	SC	SC	78.0	20.0	Replaced by RG-21/U	17.0	54.0	2700	—
54	C	7/26 AWG	A1	V	0.275	—	C	58.0	27.0	Replaced by RG-54A/U	—	—	2500	—
54A	C	7/0.0152	A1	P	0.250	—	TC	58.0	26.5		3.1	12.0	3000	—
55	C	20 AWG	A1	P	0.206	TC	TC	53.5	28.5		4.2	16.0	1900	335
55A	SC	0.035	A1	NVB	0.216	SC	SC	50.0	29.0		4.8	16.8	1900	335
55B	SC	0.0320	A1	PB	0.206	TC	TC	53.5	28.5	Now designated as RG-223/U	4.8	16.8	1900	335
57	C	7/0.0285	A1	V	0.625	—	TC	95.0	17.0	Two conductors	3.0	13.6	3000	—
57A	C	7/0.0285	A1	NVB	0.625	—	TC	95.0	17.0	Two conductors	3.0	13.6	3000	—
58	C	20 AWG	A1	V	0.195	—	TC	53.5	28.5		4.2	16.0	1900	300
58A	TC	19/0.0071	A1	V	0.195	—	TC	52.0	28.5		5.3	22.0	1900	300
58B	C	20 AWG	A1	NVB	0.195	—	TC	53.5	28.5		4.2	15.0	1900	300

RG/U Type	Inner Conductor Mat.	Inner Conductor Strand	Dielectric Material	Jacket Mat.	Jacket O.D.	Shield Inner	Shield Outer	Impedance (Ohms)	Cap. (pf/ft)	Engineering Data	Attenuation in db/100 ft (100 mc)	Attenuation in db/100 ft (1000 mc)	Max. Opr. Volts RMS	Max. Power Watts @ 50mc
58C	TC	19/0.0071	A1	NVB	0.195	—	TC	50.0	28.5		5.3	22.0	1900	300
59	CW	22 AWG	A1	V	0.242	—	C	73.0	21.0		3.8	14.0	2300	—
59A	CW	0.0230	A1	NVB	0.242	—	C	75.0	21.5		4.0	14.0	2300	—
59B	CW	0.0230	A1	NVB	0.242	—	C	75.0	21.0		4.0	14.0	2300	—
62	CW	22 AWG	A2	V	0.242	—	C	93.0	13.5		3.1	10.0	750	—
62A	CW	0.0253	A2	NVB	0.242	—	C	93.0	13.5		3.1	10.0	750	—
62B	CW	7/32 AWG	A2	NVB	0.242	—	C	93.5	14.5		3.1	10.0	750	—
63	CW	22 AWG	A2	V	0.405	—	C	125.0	10.0		2.0	7.0	1000	—
63A	C	22 AWG	A1	V	0.405	—	C	125.0	10.0	Replaced by RG-63B/U	2.0	7.0	1000	—
63B	CW	0.0253	A2	NVB	0.405	—	C	125.0	10.0		1.99	6.4	1000	—
65	F	32 AWG	A1	V	0.405	—	C	950.0	44.0	High impedance video cable used as delay line	—	—	1000	—
65A	F	32 AWG	A1	NVB	0.405	—	C	950.0	44.0		—	—	1000	—
71	CW	22 AWG	A2	P	0.250	TC	TC	93.0	13.5		3.1	10.0	750	—
71A	CW	22 AWG	A2	V	0.250	TC	TC	93.0	13.5		3.1	10.0	750	—
71B	CW	0.0253	A2	PB	0.250	TC	TC	93.0	14.5		3.1	10.0	750	—
72	CW	22 AWG	A2	V	0.630	—	C	150.0	—		—	—	—	—
73	C	20 AWG	A1	C	0.275	C	C	25.0	—		—	—	—	—
74	C	10 AWG	A1	NVGA	0.615	C	C	52.0	29.5		1.4	6.2	5500	1280
74A	C	0.102	A1	NVBA	0.615	C	C	52.0	29.5	Now designated as RG-224/U	1.4	6.2	7000	1280
79	CW	22 AWG	A2	VA	0.475	—	C	125.0	10.0		2.0	7.0	1000	—
79B	CW	0.0253	A2	NVBA	0.475	—	C	125.0	11.0	RG-63B/U with armor	2.0	7.0	1000	—
83	C	10 AWG	A1	V	0.405	—	C	35.0	44.0		2.8	9.6	2000	—
84A	C	0.1045	A1	NVBL	1.000	—	C	75.0	21.5	RG-35B/U with lead sheath in lieu of armor	—	—	10000	—
85A	C	0.1045	A1	NVBA	1.565	—	C	75.0	21.5	RG-84A/U with special armor	—	—	10000	—
87A	SC	7/0.032	F1	FG	0.425	SC	SC	50.0	29.5	For replacement purposes only. Use RG-225/U	—	—	5000	—
89	CW	22 AWG	A2	V	0.632	—	C	125.0	10.0		2.0	7.0	1000	—
93	C	19/0.040	F2	FG	0.710	—	C	50.0	29.0	Replaced by RG-117/U	—	—	10000	—
94	SC	19/0.0255	F2	FG	0.445	C	C	50.0	29.0	Now designated as RG-226/U	—	—	7000	—
94A	SC	19/0.0254	F2	FG	0.500	C	C	50.0	27.0		—	—	7000	—
100	C	19/0.0147	A1	V	0.242	—	C	35.0	44.0		—	—	2000	—
108	TC	7/28 AWG	A1	NVG	0.235	—	TC	78.0	24.5	Two conductors	—	—	1000	—

RG/U Type	Inner Conductor		Dielectric Material	Jacket		Shield		Impedance (Ohms)	Cap. (pf/ft)	Engineering Data	Attenuation in db/100 ft		Max. Opr. Volts RMS	Max. Power Watts @ 50mc
	Mat.	Strand		Mat.	O.D.	Inner	Outer				(100 mc)	(1000 mc)		
108A	TC	7/28 AWG	A1	NVB	0.235	—	TC	78.0	24.5	Two conductors	—	—	1000	—
111	C	7/0.0152	A1	NVGA	0.490	TC	TC	95.0	16.0	Two conductors	—	—	1000	—
111A	C	7/0.0152	A1	NVBA	0.490	TC	TC	95.0	16.0	Two conductors	—	—	1000	—
114	CW	0.007	A2	V	0.405	—	C	185.0	6.8	Special low capacitance	—	—	1000	—
114A	CW	0.007	A2	NVB	0.405	—	C	185.0	6.8	Special low capacitance	—	—	1000	—
115	SC	7/0.028	F2	FG	0.375	SC	SC	50.0	29.5		—	—	5000	—
115A	SC	7/28 AWG	F2	FG	0.415	SC	SC	50.0	29.5		—	—	4000	—
116	SC	7/0.032	F1	FGA	0.490	SC	SC	50.0	29.5	Now designated as RG-227/U	—	—	5000	—
117	C	0.188	F1	FG	0.730	—	C	50.0	29.0	Now designated as RG-211/U	—	—	7000	—
118	C	0.188	F1	FGA	0.795	—	C	50.0	29.0	Now designated as RG-228/U	—	—	7000	—
119	C	0.102	F1	FG	0.465	C	C	50.0	29.0	High temperature	—	—	6000	—
120	C	0.102	F1	FGA	0.525	C	C	50.0	29.0	RG-119/U with armor	—	—	6000	—
122	TC	27/36 AWG	A1	NVB	0.160	—	C	50.0	29.5	Same as RG-58A/U except smaller size and lighter weight	7.0	29.0	1900	—
124	TCW	22 AWG	F2	FG	0.240	—	TC	73.0	20.5	Replaced by RG-140/U	—	—	2300	—
125	CW	26 AWG	A2	NVB	0.600	—	C	150.0	7.8	Special low capacitance	—	—	2000	—
126	HR	7/0.0203	F1	FG	0.280	—	HR	50.0	29.0	High attenuation	—	70.0	3000	—
130	C	7/0.0285	A1	V	0.625	—	TC	95.0	17.0	Two conductors	—	—	8000	—
131	C	7/0.0285	A1	VA	0.710	—	TC	95.0	17.0	RG-130/U with armor	—	—	8000	—
133	C	21 AWG	A1	V	0.405	—	C	95.0	16.2		—	—	4000	—
140	SCW	0.025	F1	FG	0.233	—	SC	75.0	21.0	High temperature similar to RG-59A/U	—	—	2300	—
141	SCW	0.0359	F1	FG	0.190	—	SC	50.0	28.5		—	—	1900	—
141A	SCW	0.0359	F1	FG	0.190	—	SC	50.0	28.5	High temperature similar to RG-58C/U	—	—	1900	—
142	SCW	0.0359	F1	FG	0.206	SC	SC	50.0	28.5		—	—	1900	—
142A	SCW	0.0359	F1	FG	0.206	SC	SC	50.0	28.5	High temperature similar to RG-55A/U	—	—	1900	—
143	SCW	0.057	F1	FG	0.325	SC	SC	50.0	28.5		—	—	3000	—
143A	SCW	0.059	F1	FG	0.325	SC	SC	50.0	28.5	High temperature similar to RG-5B/U	—	—	3000	—
144	SCW	7/0.0179	F1	FG	0.410	—	SC	75.0	20.5	High temperature similar to RG-11/U	—	—	5000	—
146	CW	0.007	F3	FG	0.375	—	C	190.0	6.0	High temperature, low capacitance	—	—	1000	—
147	C	0.250	A1	VA	1.937	—	C	52.0	29.5	RG-19/U with armor	0.68	3.5	14000	8400

RG/U Type	Inner Conductor		Dielectric Material	Jacket		Shield		Impedance (Ohms)	Cap. (pf/ft)	Engineering Data	Attenuation in db/100 ft		Max. Opr. Volts RMS	Max. Power Watts @50mc
	Mat.	Strand		Mat.	O.D.	Inner	Outer				(100 mc)	(1000 mc)		
148	C	7/21 AWG	A1	VA	0.800	—	C	52.0	29.5	RG-8/U with armor	2.1	9.0	4000	1445
150	TC	7/26 AWG	A1	VA	—	—	C	75.0	—	RG-149/U with armor	—	—	—	—
149	TC	7/26 AWG	A1	V	0.405	—	C	75.0	—	Low noise	—	—	—	—
156	TC	7/21 AWG	A1	NVB	0.540	Three braids TC, GS, TC		50.0	30.0		—	—	10000	—
157	TC	19/24 AWG	A1	NVB	0.725	Same as RG-156/U		50.0	38.0		—	—	15000	—
158	TC	37/.0284	A1	NVB	0.725	Same as RG-156/U		25.0	78.0		—	—	15000	—
159	SC	20 AWG	F2	FG	0.195	—	SC	50.0	29.0	Replaced by RG-142/U	—	—	—	—
161	SB	7/38 AWG	F1	N	0.090	—	SC	70.0	20.0	Miniature	—	—	1000	—
164	C	0.1045	A1	NVB	0.870	—	C	75.0	—		0.85	3.6	10000	7450
165	SC	7/0.032	F1	FG	0.410	—	SC	50.0	—		—	—	5000	—
166	SC	7/0.032	F1	FGA	0.460	—	SC	50.0	—		—	—	5000	—
174	CW	7/34 AWG	A1	V	0.100	—	TC	50.0	30.4		9.0	30.0	1500	125
177	C	0.195	A1	NVB	0.895	SC	SC	50.0	—		—	—	11000	—
178	SCW	7/.0039	F1	K	0.079	—	SC	50.0	27.9		—	—	1000	—
178A	SCW	7/.004	F1	K	0.075	—	SC	50.0	27.9		—	—	1200	—
179A	SCW	7/.004	F1	K	0.105	—	SC	75.0	—		—	—	1200	—
180	SCW	7/.0039	F1	K	0.141	—	SC	93.0	15.3		—	—	1500	—
180A	SCW	7/.004	F1	K	0.145	—	SC	95.0	14.5		—	—	1500	—
181	C	7/26 AWG	A1	NVB	0.640	—	C	125.0	12.0	Two conductor	—	—	3500	—
187	SCW	7/0.004	F1	T	0.110	—	SC	75.0	—	High temperature miniature cable	—	—	1200	—
188	SCW	7/0.0067	F1	T	0.110	—	SC	50.0	—	High temperature miniature cable	—	—	1200	—
189	C	0.251	A2	P	0.875	—	SC	50.0	23.0		—	—	3500	—
190	TC	19/25 AWG	D	SR	0.700	GS	TC	50.0	50.0	Low noise pulse cable	—	—	3500	—
195	SCW	7/.004	F1	T	0.155	—	SC	95.0	—	High temperature miniature cable	—	—	1500	—
196	SCW	7/.004	F1	T	0.080	—	SC	50.0	—	High temperature miniature cable	—	—	1000	—
209	SCW	19/0.037	F3	PF	0.750	SC	SC	50.0	—		—	—	3200	—
210	SCW	0.0253	F2	FG	0.242	—	SC	93.0	14.5	Replaces RG-62C/U	3.1	10.0	750	—
211	C	0.190	F1	FG	0.730	—	C	50.0	29.0	Formerly RG-117/U	—	—	7000	—
212	SC	0.0556	A1	NVB	0.332	SC	SC	50.0	29.5	Formerly RG-5B/U	2.4	9.1	3000	600
213	C	7/0.0296	A1	NVB	0.405	—	C	50.0	29.5	Formerly RG-8A/U	2.1	9.0	5000	1445
214	SC	7/0.0296	A1	NVB	0.425	SC	SC	50.0	29.5	Formerly RG-9B/U	2.3	8.6	5000	1445
215	C	7/0.0296	A1	NVBA	0.475	—	C	50.0	29.5	Formerly RG-10A/U	2.1	9.0	5000	1445

RG/U Type	Inner Conductor		Dielectric Material	Jacket		Shield		Impedance (Ohms)	Cap. (pf/ft)	Engineering Data	Attenuation in db/100 ft		Max. Opr. Volts RMS	Max. Power Watts @ 50mc
	Mat.	Strand		Mat.	O.D.	Inner	Outer				(100 mc)	(1000 mc)		
216	TC	7/0.0159	A1	NVB	0.425	C	C	75.0	20.5	Formerly RG-13A/U	2.15	8.4	5000	1445
217	C	0.106	A1	NVB	0.545	C	C	50.0	29.5	Formerly RG-14A/U	1.4	5.6	7000	1280
218	C	0.195	A1	NVB	0.870	—	C	50.0	29.5	Formerly RG-17A/U	0.96	4.4	11000	7450
219	C	0.195	A1	NVBA	0.945	—	C	50.0	29.5	Formerly RG-18A/U	0.96	4.4	11000	7450
220	C-	0.260	A1	NVB	1.120	—	C	50.0	29.5	Formerly RG-19A/U	0.69	3.6	14000	8400
221	C	0.260	A1	NVBA	1.195	—	C	50.0	29.5	Formerly RG-20A/U	0.69	3.6	14000	8400
222	HR	0.0556	A1	NVB	0.332	SC	SC	50.0	—	Formerly RG-21A/U	15.0	46.0	2700	—
223	SC	0.035	A1	NVB	0.216	SC	SC	50.0	29.5	Formerly RG-55A/U	4.6	16.8	1900	335
224	C	0.106	A1	NVBA	0.615	C	C	50.0	29.5	Formerly RG-74A/U	1.4	5.6	7000	1280
225	SC	7/0.0312	F1	FG	0.430	SC	SC	50.0	29.5	Formerly RG-87A/U	—	—	5000	—
226	SC	19/.0254	F2	FG	0.500	C	C	50.0	27.0	Formerly RG-94A/U	—	—	7000	—
227	SC	7/0.0312	F1	FGA	0.490	SC	SC	50.0	29.5	Formerly RG-116/U	—	—	5000	—
228	C	0.190	F1	FGA	0.795	—	C	50.0	29.0	Formerly RG-118/U	—	—	7000	—
235	SC	7/0.028	F2	PF	0.750	SC	SC	50.0	29.5	RG-115A/U with PF jacket	—	—	5000	—
236	C	0.160	A1	See Shield	0.5	Alum. Tube	—	50.0	24.0		0.8	5.4	1000	—
237	C	0.160	A1	P	0.6	Alum. Tube	—	50.0	24.0		0.8	5.4	1000	—
244	C	0.102	A1	See Shield	0.5	Alum. Tube	—	75.0	15.5		0.74	4.8	1200	—
245	C	0.102	A1	P	0.6	Alum. Tube	—	75.0	15.5		0.74	4.8	1200	—
246	C	0.189	A1	See Shield	0.88	Alum. Tube	—	75.0	15.6		0.42	3.0	2200	—
247	C	0.189	A1	P	1.02	Alum. Tube	—	75.0	15.0		0.42	3.0	2200	—

Dielectric Materials

- A1 Solid polyethylene
- A2 Air-spaced polyethylene
- F1 Solid tetrafluorethylene (Teflon)
- F2 Taped tetrafluorethylene (Teflon)
- F3 Air-spaced tetrafluorethylene (Teflon)
- D Layer of synthetic rubber dielectric between thin layers ducting rubber

Conductor and Shield

- C Copper
- CW Copper-covered steel (Copperweld)
- F Formex F
- HR High resistance wire
- GS Galvanized steel
- SB Silver-covered cadmium bronze
- SC Silver-covered copper
- SCW Silver-covered copper-covered steel
- TC Tinned copper
- TCW Tinned copper-covered steel

Jacket Materials

- V Low temperature black polyvinylchloride, contaminating type plasticizers
- NVB Low temperature black polyvinylchloride, non-contaminating type plasticizers
- NVBA Same as NVB, but with armor
- NVG Grey polyvinylchloride, non-contaminating type plasticizers
- NVGA Same as NVG, but with armor
- P Stabilized natural polyethylene
- PB High molecular weight black polyethylene
- PF Polyester fiber impregnated with high temperature lacquer over wrapped or extruded silicone rubber over silicone impregnated fiberglass
- FG High temperature lacquer impregnated fiberglass braid, usually with Teflon tape between shield and jacket
- FGA Same as FG, but with armor
- SR Black synthetic rubber
- T Tetrafluorethylene (Teflon)
- K Kel-F
- N Nylon
- C Copper braid
- Lead Lead sheath

ble 11. Foamed dielectric coaxial cables.

Part No.	RG/U Type	Inner Conductor		Dielectric Material	Jacket		Shield		Impedance (Ohms)	Cap. (pf/ft)	Attenuation in db/100 ft	
		Mat.	Strand		Mat.	O.D.	Inner	Outer			(100 mc)	(1000 mc)
BELDEN FOAM-CORE												
8211	59	CW	22 AWG	FP	PB	0.242	C	—	80	16.3	3.4	10.7
8212	59	CW	20 AWG	FP	PB	0.242	C	—	75	17.3	3.2	13.8
8213	11	C	14 AWG	FP	PB	0.405	C	—	75	17.3	1.5	5.8
8214	8	C	7 x 19	FP	V	0.403	C	—	50	26.0	1.8	6.3
8219	58	C	19 x 32	FP	V	0.195	C	—	50	26.0	4.8	16.1
AMPHENOL POLYFOAM												
521-100	11	C	14 AWG	FP	PB	0.405	C	—	75	16.5	1.4	6.6
521-111	8	C	7 x 19	FP	V	0.405	C	—	50	24.5	1.8	7.2
621-685	62A	CW	0.023	FP	NVB	0.242	C	—	93	14.5	—	—
621-700	59A	CW	22 AWG	FP	V	0.195	C	—	72	17.0	3.4	13.1
621-701	59	CW	22 AWG	FP	V	0.195	C	—	72	17.0	3.4	13.1
621-715	59	CW	22 AWG	FP	PB	0.195	C	—	72	17.0	3.4	13.1

Next month in 73:

Another special book feature—

The Coaxial Connector Handbook

by Jim Fisk WA6BSO

And in the September issue—

Coaxial Accessories

by Jim Fisk WA6BSO

(Continued from page 4)

size, weight, reliability, ruggedness, power drain, ease of circuit construction, and in many cases, simplicity, performance and cost. Yet the 1966 ARRL Handbook gives semiconductors, except for silicon diodes, very short shrift. There is a short chapter on semiconductors in general. Then the receiving chapter mentions and illustrates a transistor mixer for below 20 MHz with a very old transistor, a simple *if* system with older transistors and two rf amplifiers. This 58 page chapter on receiving also contains two transistor construction projects, a four transistor regenerative receiver-code practice oscillator, and a transistorized Selectoject.

The 81 page transmitter section devotes a little over half a page to transistor output circuits. It also describes a simple rf powered keying monitor (a similar device is described in the chapter on monitoring).

The power supply chapter has a number of schematics using silicon diodes, but doesn't even mention zener diodes. There is a long section on VR tubes, even though zeners are far more versatile, smaller, and usually cheaper.

The VHF receiver uses two transistors in the audio section of a 420 MHz unstabilized transceiver.

The VHF transmitting chapter uses IN34 diodes as rf voltmeters for tuning the transmitters.

The mobile equipment chapter is at the same time, most conscious of transistors, and yet most surprising since it uses transistors in at least some of the modulator and power supply circuits, but uses tubes in all the converters, though one does have a transistor mixer and oscillator.

The test equipment chapter includes an excellent pulsed two tone oscillator for SSB and other checks. There's also a field strength meter with a transistor meter amplifier.

The reference chapter on vacuum tubes and semiconductors gives no data on transistors except for the common basing diagrams. The reason is obvious: there are well over 5000 transistors now being manufactured and the ARRL apparently didn't desire to try to choose from among them for recommended devices.

In view of the above uses of transistors in the ARRL Handbook, I don't feel that the most prejudiced reader could state that the ARRL Handbook covers transistors very well. Hence my question.

So I was very happy to have the chance to hear Byron Goodman W1DX, editor of the

Handbook, speak on the role of semiconductors in amateur radio at the ARRL National Convention. His talk answered my question about their treatment of transistors.

W1DX apparently regards transistors as novelties. He seems to feel that people will get over their enthusiasm for transistors one of these days. He didn't mention whether he expects people to go back to tubes or whether he expects something better to come along. Of course, there are better things coming, such as FET's, with many of the advantages of both tubes and transistors, but he didn't mention them in his talk. I guess he just overlooked them.

Here are some of W1DX's points about transistors:

1. The CK722 (the first transistor commercially available to hams) wasn't so great.

2. No transistor front ends are as good as tube ones, as far as he knows. [This would undoubtedly come as a surprise to many engineers.]

3. Good transistors are expensive so hams use them only when they can steal them. [How many tubes can you buy new for 46¢ and even less? Aside from RF power uses, most transistors are cheaper than equivalent tubes.]

4. Transistors are prone to overloading ar intermodulation. [So are tubes if they're n handled properly. Transistor circuits can gi excellent results if designed properly. Als note that the darling of the ARRL these da is the 7360 tube, which they use as a mixer avoid the overload and cross modulation fro more conventional tubes. It costs abo $3.75, roughly the same as an FET that excellent for this use.]

5. Transistors are compact, but this isn too important since equipment can be mad too small for easy tuning–transistors are fin for CB equipment [what a red herring] sinc they're on fixed channels, but not necessar for tunable equipment.

6. Transistor VFO's tend to drift and aren stable. [Sure, if they're not designed properl But it's a lot easier to make low drift transi tor oscillators than tube ones.]

7. Transistor output circuits are weird an unfamiliar looking. [Enough said.]

8. Transistors don't work well in parallel a one tends to hog the current. [Tubes in para lel tend to oscillate, but that can be prevente easily. Likewise, equalizing resistors are use with transistors in parallel.]

9. Varactor triplers are all right for VHF [But there're no practical ones in the HB.]

10. Transistors are all right for *VHF* lo noise amplifiers. [None of those in the HI either.]

11. Silicon diodes are excellent if you'r careful.

12. Transistors are easily adaptable t etched circuits, but etched circuits aren't to practical for individuals. Maybe some da enterprising small manufacturers will mak boards for projects in electronics magazine and sell them. [They have and do. Even QS has had projects like that.]

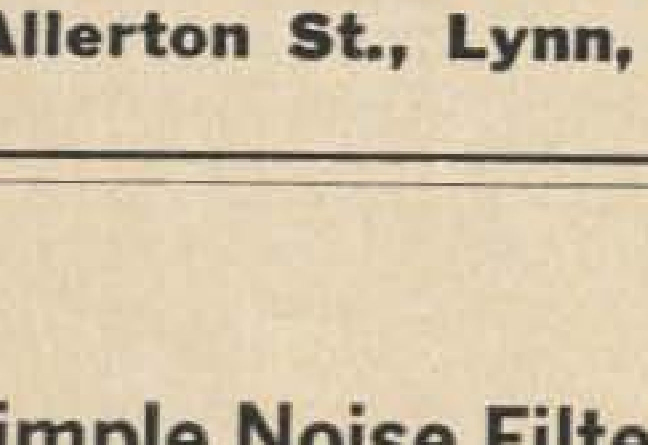
I got the impression that W1DX felt th hams have little reason to use transistors e cept in mobile equipment and that oth equipment using transistors uses them for th novelty value. Is that why Motorola, RC Scott, Raytheon, Davco and others are usin transistors? For novelty?

I don't think so. I feel that hams shoul make every attempt to keep up with mode practice if we are to justify our existence an not to be left behind, ignored and discredite Most amateurs learn their first amateur rad from ARRL books. Will these hams stay b hind the times? Or will they discover mode practices elsewhere? Or will the Handboo be brought up to date? For the sake of ha radio, I certainly hope so.

. . . Pa

Simple Noise Filter

This simple noise filter may be added to your present communications receiver with a minimum of parts (one part). It will provide you with many more hours of operating pleasure if such sounds as high pitched heterodynes and static crashes bother you. The speaker output impedance is 3.2 ohms on the HQ-145 to which this filter was added but should work equally well on receivers of other output impedances.



Almost any old TV horizontal width coil will work. The one I used had a sliding iron core slug and an inductance of approx. 2-17 mH. The screw type would work just as well but the sliding slug type is quicker to adjust. . . . KØT6R

Caveat Emptor?

★ **Price—$2 per 25 words for non-commercial ads; $5 per 25 words for business ventures. No display ads or agency discount. Include your check with order.**

★ **Type copy. Phrase and punctuate exactly as you wish it to appear. No all-capital ads.**

★ **We will be the judge of suiability of ads. Our responsibility for errors extends only to printing a correct ad in a later issue.**

★ **For $1 extra we can maintain a reply box for you.**

★ **We cannot check into each advertiser, so Caveat Emptor . . .**

FACTORYWIRED, PTT, sequence keyed Ranger I, some scratches. Good electrically. Now have transceiver. Bargain at $100. Dean Straw, KH6DKD/1. D4, 386 Prospect Street, New Haven, Conn. 77101

WANTED: Copy of 8 Oct 1956 issue of LIFE magazine Make offer. W5NKG, R. Lent, 5634 Seacomber, San Antonio, Texas 78242.

JACKSONVILLE, ILL. ARC annual hamfest, July 10, 1966. For information. WN90XH, Secretary. 1010 Dayton St. Jacksonville, Ill. 62650.

WABASH VALLEY ARA annual VHF picnic, Sunday July 31. At Turkey Run State Park, about 40 miles north of Terre Haute, one mile off U. S. Route 41 and on Indiana Route 47. Swap tables, eyeball QSO's, entertainment for the ladies. For more information contact K9EBK, Wabash Valley ARA, Box 81, Terre Haute, Indiana. 47808.

HQ170, $200. Heath Apache, $125. SB-10, $50. All in excellent condition. Will deliver 300 miles. W. L. Johnson, W5FPI/6, 205 Mar Vista Drive, Monterey, Calif.

RTTY mod 26 commercial transistorized TU & Osc. Aligned ready to go. My cost $125. HT 32 one owner, excellent $225. Stan Miln K6RMR, 2912 Overland Ave., Los Angeles, Calif. 90064.

CW FILTER, 500 cycles. No receiver alterations, plugs into phone jack. 6 DB gain. $26.50. Guaranteed. Northwest Electronic Repair, 11557 Evanston North, Seattle, Wash.

HALLICRAFTERS SX-117 Receiver. Perfect condition. Manual and original carton. $250. C. McDowell, W7UB, 2455 SW Montgomery, Portland, Oregon.

QSL's Free samples. Self-addressed stamped envelope. Hamprin. Box 235, Troy, Michigan 48084.

QSL CARDS???? Largest variety samples 25¢. Sakkers Printery, W8ded, Holland, Michigan.

6-12-115 Volt Gonset G66B receiver $49. G77A Transmitter $69. Super 6 Converter $9. 80-10 Coil-Whip-Mount $9. K6KUQ, 2812 10th, Arcadia, Calif.

SCR 16 amp prv 1.00, diodes 200/750 ma 10/1.00. RG 13AU coax .07 ft., mixed sfe fuses 25/1.00. glass p. c. board 13 x 7 1.00 tantalex capacitors 75/30v 4/1.00. 5 p.s.t. rotary switch 4/1.00. mixed crystals 10/1.75. Best deals on new ham gear wend and see. used gear wanted. Hirsch Sales So. 219 California Dr. Buffalo, N. Y. 14221.

GONSET SIDEWINDER 6 Meter Transceiver with AC and DC supplies. $350.00 or trade for ??? WA9WP, Vic Mattern, 1200 South Hough Street, Barrington, Ill. 60010.

QSL RUBBER STAMP 3" x 5". Free sample impressions and blank, complete stamp $5.00 P. P. D. Other ham stamps $1.00 up. Wes's Shop W1FP. RFD 1, Amesbury, Mass. 01913.

ALL MAKES of new and used amateur equipment. Write or call Bob Grimes, 89 Aspen Road, Swampscott, Mass. Tel: 617-598-9700 or 617-598-2530.

JULY BARGAINS: Drake 2A $150. TR3 AC supply $485. Globe King 400-D $195. HQ-170 $175. Heath HA-20 $89. Valiant $159. Lafayette HE45A & HE61A $95. NCX-3 $235. NCX-5 $550. Swan 240 $239. Many other bargains. Write for list and trades. Freck Radio & Supply Co. Tenny Freck W4WL, 38 Biltmore Ave., Asheville, North Carolina.

COMPONENTS BARGAINS: Transformers, tubes, meters, capacitors, receiving and transmitting, resistors, fixed, variable, coaxial fittings, switches, tube sockets. Free list. Ken Maas W9AZA, Burlington, Wisconsin, 53105.

CLEANING HOUSE: Keyer $10. B. C. smc VFO with power supply $15. 6mtr. Ameco converter with power supply $40. 20W novice xmtr 80,40 $15. RME 6900 & speaker, like new $225. Lettine 242 (need Mod xfmr.) $15. AR2 rotator & box $15. First check takes any or all. You pay shipping. Harvey Lawrence, WB2GVF RD 2, Bath, N. Y. 14810.

PERFECT HQ-170AC like new $250. Knight T-60 $30. Clyde Freed K7WMM 2317 Lindley Way, Klamath Falls, Oregon 97601.

MOTOROLA new miniature seven tube 455 kc *if* amplifier discriminator with circuit diagram. Complete at $2.50 each plus postage 50¢ each unit. R and R Electronics, 1953 South Yellowsprings, Springfield, Ohio.

CONVERTERS. World's largest selection of frequencies. Ham TV vidicon cameras and parts at low factory-direct prices. See them all now in our full page ad in this issue. Vanguard Labs, 196-23 Jamaica Ave., Hollis, N.Y. 11423.

WE WILL PAY CASH: Wanted, popular, late model unmodified amateur equipment. Highest prices paid for clean, good operating gear. Write Graham Radio, Dept. 10, Reading, Massachusetts.

ARE YOU SINCERE? Are you **really** looking for the best deal on a new or fully guaranteed used unit? Let us convince you with a specific quote that will **really** save you money. Graham Radio, Dept. 10, Reading, Massachusetts.

W6SD 10th ANNUAL HAMFEST PICNIC—Sunday July 24—Door prizes, contests, fabulous program for family—Dollar donation—Write W6SD Hamfest, 2814 Empire, Burbank, Calif. 91504.

THIRD ANNUAL INTERNATIONAL HAM FEST will be held at the International Peace Gardens on the border between North Dakota and Manitoba on Saturday afternoon, July 16 and Sunday, July 17. For further information contact Robert Withey, WAØHUD, Willow City, North Dakota.

WOULD YOU BELIEVE, a Heath DX100B $135.00, National NC-173 $80.00, RME DB-23 Preselector $20.00, First offer over $200.00 gets everything, including a JT30 mike, antenna relay, and crystal calibrator. K3CHJ, Jim Toth, 2201 West Chester Pike, Broomall, ,Penna., 19008, (near Philadelphia)

ELMAC A54H (converted 12 volts), Morrow Converter 5BR, 12 volt Westinghouse dynamotor. $60.00. K2OZM, 9900 Pine Ave. Niagara Falls, New York.

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The model CPR Speech Compressor TRIPLES your average SSB output power; boosts your average AM modulation from 25% to 75%.

- NEW low noise circuits
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- Uses internal battery
- Compression level switch
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10 mfd/ 250 VDC	2 x 45 mfd 350 VDC
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8 mfd 450 VDC	30 mfd 450 VDC
30/10 mfd 300 VDC	80/80 mfd 350 VDC
10 mfd 250 VDC	16/16 mfd 450 VDC
20 mfd 450 VDC	20/10/10 mfd 300 VDC
+ 150 mfd — 150 VDC	40/40/100 mfd 150/150/50 VDC
3 x 10 mfd 450 VDC	125 mfd 450 VDC
50/10/10/60 mfd 350/350/350/25 VDC	+ 150 mfd + 250 VDC
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MIX THEM OR MATCH THEM—ALL @ **$.30** each or **4/1.00**

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R/C Dual 150 mmf Variable Capacitor only **1.85**
RELAY—115 V AC 60 cy 20 ma "Half Wave" **2.00**
with Diode **2.25**

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Add 25¢ for postage

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Formerly William and Cortlandt St.
Now at
81 W. Broadway, Corner Warren
New York City
Six blocks north of old location.

LATEST SBE33 with DC Supply and Mounting plat $225.00. WA2FSD Martin Siegel, 11 Burbury Lane, Grea Neck, New York. Tel: 516 482-2737.

GALAXY V, like new. AC power supply with speake console. DC power supply and complete mobile installa tion including Hustler antenna for 80, 40 and 20. $525 Gerald Boles, 5305 North Drexel Street, Oklahoma City Oklahoma. WI 2-3159.

FREE ZENER DIODE and listing of our capacitors resistors, semiconductors, transformers, and F.M. equip ment. Send self-addressed stamped envelope to: Sura bachi Electronics, 214 E. Brett, Inglewood, Calif. 90302

WANTED: Hallicrafters S-36 VHF receiver; RME DB22A preselector. Write, stating condition and price K3PRE, Edward R. Kowalski, 757 South Third Street Philadelphia, Penna. 19147.

EICO SSB TRANSCEIVER, 752 DC Power Supply, not assembled, 751 AC Power Supply, never on air. $300.00. Milo Heckt, WØTKU, 926 Joy Ave., Rapid City, S. Dak 57701.

WANTED: MILITARY, COMMERCIAL, SURPLUS. Airborne, Ground, Transmitters, Receivers, Testers, Accessories. Especially COLLINS. We pay freight and Cash. RITCO POB 156, Annandale, Virginia (703) 560-5480 COLLECT!

HT-41 $180, NC 183-D $120, Viking Valient $130, BC221 Frequency Meter w/AC Supply $75, Johnson TR Switch $15, Heath Q Multiplier $8, Pair 4- 250th w/Sockets $40 new, 5 URC 4 Transceivers converts tc 2 meters $10 each. I will ship anywhere USA. W8CPZ, 901 East "F" Street, Iron Mountain, Mich. 49801.

TR 150 (80-6 mtrs.) $58, Ameco Converters for 6 and 2 $13 each. Converter power supply $9. Gonset G—76 plus DC supply (both almost new) $160 K2QHT 63 Robir Drive, Hauppauge, New York 516-AN-56479.

GALAXY V Complete with Speaker Console and A.C Power supply, Galaxy 2000 + Linear Amplifier (2 K.W PEP) with A.C. Power Supply, Value $949.00. This equipment has never been used, in original cartons Won at the Dayton Hamvention. Offers over $800.0(will be considered. WA8QEY, J. H. Meixner, 2401 Morningstar Ct., Kettering, Ohio, 45420.

SALE OR SWAP: JOYSTICK Antenna System, excel lent condition. Make offer. Mitchel Katz, W2KPE 147-1] 76th Avenue, Flushing, New York 11367.

APACHE AND MOHAWK Heathkit gear in very goo condition. Factory checked. $325 or best offer. R. Mila sich K9ECK, 405 Price, Calumet City, Illinois.

CLEGG THOR VI complete with both AC & DC Powe Supply/Modulators, two cords, manual, original cartons Two years old, just returned from Clegg factory re aligned perfect. $350.00 FIRM: Shipped charges collec receipt first Money Order. George Haymans WA4NED Box 468, Gainesville, Georgia.

APARTMENT BOUND. Swap excellent 41 ft. E-Z wa crankup tower, Hornet tri-bander, preferably for kilo watt Matchbox. Removal deal only. Blosser, W8DBK Chagrin Falls, Ohio.

DX-100 xmtr, perfect, w/op. manual. $1.00. Dage desig TV camera, w/vidicon, RF, video jeep, tubes, schematics $125. Bert Gathercoal, W9QAP, 50 Westward Ho, North lake, Ill.

DRAKE T4X Txmr., R-4 Receiver, T4X Power Supply Thunderbolt Amplifier—Roy Anderson, Box 2116, Wil liamson, West Virginia 25661.

TECHNICAL MANUALS: ARC-27, CV-116/URR, $3.5(each, BC-1031, FGC-1, ARN-6, $3.00 each. Many others List 10¢. S. Consalvo, W3IHD, 4905 Roanne Drive Washington, D.C. 20021.

MUST SACRIFICE mint HT-37. Original owner, purchased new. First certified check for $275 takes it. Ship express collect. W8EWP, 7229 Saratoga, Reynoldsburg, Ohio 43068.

IOWA 75 METER Phone Net Picnic. Aug. 14, 1966. McHose Park, Boone, Iowa. Contact: Dr. J. H. Robinson, (515) 782-7719.

FEDERATION OF LONG ISLAND Radio Clubs Annual Picnic and Hamfest. July 17 at Hempstead Town Park, Point Lookout, L.I. Contact: W2NOS.

SPRINGFIELD Amateur Radio Club Annual Hamfest. 17 July, 1966 at Clark County Fairgrounds, 4 mi SE of Springfield, Ohio on Route 41.

SOUTHERN COUNTIES Amateur Radio Assoc of New Jersey will hold its annual outing 28 Aug. Egg Harbor Lake, Egg Harbor City, N.J. Contact: W2TUR.

ROGUE VALLEY Amateur Radio Clubs will host the Oregon Amateur Radio Assoc Annual Convention on Aug. 26-27. Speakers, Contests, Swap-shop, Entertainment. Contact: K7WXR, Medord, Ore.

BLUEBOOK prices save money. Take 10% off these prices without trade-ins. KWMI—$299.00; HW12—$119.00; NCX3—$219.00; Galaxy 300—$179.00; Communicator 3/6M—$149.00; NCL2000—$479.00; Thunderbolt —$349.00; 75A4—$479.00; SX99—$99.00; SX117—$259.00; HQ110—$134.00; DX100—$99.00; AF67—$59.00. Hundreds more. Free list. WRL, Leo, WØGFQ, Box 919, Council Bluffs, Iowa.

BUILD W1JJL's popular **CPO-CWM** (code practice oscillator-CW monitor) from the July 1965 73, page 32. The predrilled board with component locations silk-screened on it is only 50¢. The board with all parts mounted on the board is $3 and the unit assembled in an attractive case is a remarkable $7.95. Order today from the Harris Co., 56 E. Main St., Torrington, Conn.

160—2 METERS. HQ-170AC with Ameco 2m. Nuvistor Converter and 6m. preamp—$250. Johnson 250 watt Matchbox with R.F. power meter—$35. WA9NHQ, Bill Gode, 1036 Hillside, Northbrook, Ill.

LINEAR, ANTENNA, PATCH: Hallicrafters HT-31, 600 Watts cw ssb, excellent condition, new 811A'S, 3B28's, $110. New Hy-Gain 80-20 meter doublet, 248BDQ, parts package factory sealed, $22. Johnson phone patch, excellent, $12. Will ship at my expense, manuals included, upon receipt of check. Stan Flegler, K8RPA, 1400 Poxson, Lansing, Michigan, 48910.

NCL-2000, $400, late serial number. Hallicrafters FRR-274/SX73, $150. SBE-34, late, $300. 50' Rohn #25 tower and Ham M rotor, $150. W7WRS, 1708 Valleyview, Las Vegas, Nevada.

AN ASSORTMENT OF 6 ATV EXPERIMENTERS, only $1 while they last. 73 Magazine, Peterborough, N. H. 03458.

25 WORDS FOR $2. Sell or buy through these want ads, a terrific bargain. Caveat Emptor, 73 Magazine, Peterborough, N. H. 03458.

1963 BOUND VOLUMES OF 73. $15 each from 73, Peterborough, N. H. 03458.

COMMUNICATIONS RECEIVERS—an excellent booklet from the RSGB. Limited number available for only 50¢ each.
73 Magazine, Peterborough, N. H. 03458.

NOVICE AND TECHNICIAN HANDBOOK by W6SAI and W6TNS. Limited quantity for only $2.50 each. 73 Magazine, Peterborough, N. H. 03458.

SEND US YOUR zip code. 73 Magazine, Peterborough, N. H. 03458.

INDEX TO ADVERTISERS

Propagation Chart

JULY 1966

J. H. Nelson

EASTERN UNITED STATES TO:

GMT:	00	02	04	06	08	10	12	14	16	18	20	22
ALASKA	14	14	14	7	7	7	7	7*	14	14	14	14
ARGENTINA	14	14	14	7	7	7	14	14	21	21	21	21
AUSTRALIA	14	14	14	14	7#	7	14	7#	7#	7#	14#	14
CANAL ZONE	21	14	14	14	7	7	14	14	14	14	21	21
ENGLAND	14	14	7	7	7	14	14	14	14	14	14	14
HAWAII	14	14	14	7#	7	7	7	7#	14#	14	14	14
INDIA	14	14	7#	7#	7#	7#	14	14	14	14	14	14
JAPAN	14	14	7	7#	7#	7#	14	14	14	14#	14	14
MEXICO	14	14	14	7	7	7	7	14	14	14	14	14
PHILIPPINES	14	14	7#	7#	7#	7#	14	14	14	14	14#	14
PUERTO RICO	14	14	7*	7	7	7	14	14	14	14	14	14
SOUTH AFRICA	7#	7#	7	7#	7#	14		14	14	14	14	14
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ARGENTINA	21	14	14	14	7	7	14	14	14	21	21	21
AUSTRALIA	14	14	14	14	14	7	7	7*	7#	7#	14#	14
CANAL ZONE	21	14	14	14	7*	7	14	14	14	14	21	21
ENGLAND	14	7*	7	7	7	7*	14	14	14	14	14	14
HAWAII	14	14	14	14	7	7	7	14#	14	14	14	14
INDIA	14	14	14	7#	7#	7#	7#	14	14	14	14	14
JAPAN	14	14	14	7	7	7	7	14	14	14#	14	14
MEXICO	14	14	14	7	7	7	7	7	14	14	14	14
PHILIPPINES	14	14	14	7#	7#	7#	7#	14	14	14	14#	14
PUERTO RICO	14	14	14	7*	7	7	14	14	14	14	14	14
SOUTH AFRICA	7#	7#	7	7#	7#	14	14	14	14	14	14	14
U. S. S. R.	14	14	7	7	7	7	14	14	14	14	14	14

WESTERN UNITED STATES TO:

GMT:	00	02	04	06	08	10	12	14	16	18	20	22
ALASKA	14	14	14	14	7	7	7	7	14	14	14	14
ARGENTINA	21	14	14	14	7	7	7#	14	14	21	21	21*
AUSTRALIA	21*	21	21	14	14	14	14	7	7	7#	14	21
CANAL ZONE	21	21	14	14	14	7	7	14	14	14	21	21
ENGLAND	14	7*	7	7	7	7	7	14	14	14	14	14
HAWAII	21	21*	21	14	14	14	14	7*	14	14	14	14
INDIA	14	14	14	14	7#	7#	7#	7#	14	14	14	14
JAPAN	14	14	14	14	14	7#	7	7	14	14#	14	14
MEXICO	14	14	14	7	7	7	7	7	14	14	14	14
PHILIPPINES	14	14	14	14	14	14	7#	7#	14	14	14#	14
PUERTO RICO	14	14	14	14	14	7	7	14	14	14	14	14
SOUTH AFRICA	7#	7#	7#	14	7#	7#	7#	14	14	14	14	14
U. S. S. R.	14	14	7	7*	7	7	7	14	14	14	14	14
EAST COAST	14	14*	14	7*	7	7	7	14	14	14	14	14

Very difficult circuit this hour.
* Next higher frequency may be useful this hour.

Good: 2-4, 7-10, 15-20, 27-31
Fair: 1, 5, 6, 11, 13, 14, 21, 22, 25, 26
Poor: 12, 23, 24
VHF DX: 1, 2, 3, 10, 11, 21, 22, 23, 24, 25

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JULY 1966

60¢—How About That?

Amateur Radio