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These features, so far as we know, are still not available in any competitive linear amplifier at any price: 1, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 17, 18!
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A popular option designed to plug right into the ST-6 is HAL's AK-1 AFSK oscillator. Available assembled or in kit form, the AK-1 is an AFSK oscillator that demonstrates stability and reliability. It provides switch selection of 170 Hz and 850 Hz shift using standard AFSK tones. The AK-1 may also be mounted in its own cabinet for use as an independent unit. Frequencies are set by 15-turn trimmers for ease of accurate tone adjustment. The AK-1 operates on 12 VDC, or directly from the ST-6 power supply.

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HAL Communications Corp.
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  - 425 Hz Disc kit: ____________
  - AK-1 kit: ____________
  - Charge to my Master Charge
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    # ____________
    # ____________
    # ____________
  - Charge to my Master Charge/Interbank # ____________
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September 1975
Recently there has been rising concern over the possible harmful effects to living tissue due to heating by electromagnetic radiation in the frequency range from 10 MHz to 100 GHz. Although microwave engineers have been aware of the potential hazards of working around high-power microwave transmitters for 25 years or more, few people expressed much concern about the possible radiation hazards of lower-frequency equipment. However, from 150 to 1200 MHz the internal body organs are susceptible to damage from rf heating, and the eye is especially prone to damage from radiation above 1000 MHz.

The scientific community is not at all satisfied that there has been sufficient research for formulating rf exposure standards, but based on present knowledge, various governmental and industrial organizations involved in establishing radiation safety standards have recommended exposure limits referred to as Radiation Protection Guide Numbers (RPGN). At the present time the generally accepted RPGN value is 10 milliwatts per square centimeter, and the Occupational Safety and Health Administration (OSHA) has promulgated a standard which limits exposure to power densities greater than 10 mW/cm² of body area.

Authorities generally agree that rf power levels one-tenth the OSHA standard (1 mW/cm²) do not have any noticeable effect. Using this as a basis, what are typical safe distances from a high-frequency amateur antenna?

Since the safe distance from an antenna depends on its radiated power in a given direction, the most direct approach to finding the distance is to use a graph such as that shown in fig. 1. These curves are based on an isotropic radiator so antenna gain (power ratio, not dBi) must be factored in for the practical case. A half-wave dipole, for example, has a power gain of 1.64 over an isotropic (2.14 dBi). Assuming 1000 watts into the antenna, what is the minimum safe distance? The effective isotropic radiated power (EIRP) is 1.64·1000 or 1640 watts and the distance for a power density of 1 mW/cm² is about 24 feet.

Since most dipoles are installed at least 25 feet above ground, they obviously pose little threat at amateur power levels, but what about multi-element beams and stacked arrays? Assuming the array is at the top of a 54-foot tower, and not facing into a building, an EIRP of about 29 kW would be required to produce 1 mW/cm² in the center of the main lobe 100 feet away. With 1000 watts into the antenna, this corresponds to a power gain of 29 or 14.6 dBi.

Few amateur antennas exhibit this much gain, but EME operators who use large arrays or big parabolic reflectors should use caution. A 30-foot dish with only 10 watts input at 432 MHz, for example, is hazardous at distances of less than 18 feet!

Jim Fisk, W1DTY
editor-in-chief
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AN IMPORTANT STORY is still Prose Walker's decision to step down as chief of the Amateur and Citizens Division on July 31st. Deputy Division Chief Dick Everett is presently serving as Acting Division Chief.

In The Long Term the question of who'll be filling Prose's shoes is a tough one. Ideally the job requires an engineer-ham with strong managerial experience — plus appropriate Civil Service status. Though the new chief is likely to come from within the Commission it isn't an absolute must. However, candidates without Civil Service Ratings must establish their qualifications with Civil Service before they can be considered for the post.

CB RESTRUCTURING — DOCKET 20120 — has been partially decided in a recently released Report and Order. Most important change is a sharp relaxation of prohibited communications effectively permitting the hobby use of CB that has already characterized the service legal or not. Also Relaxed are identification procedures, with an operator required to give only his callsign instead of both; the "quiet" period between five-minute series of transmissions has been reduced from five minutes to one minute; inter-licensee communications are now permitted on all 23 channels. Channel 9 continues to be classified as the emergency calling channel, and channel 11 has been designated a general calling channel.

Notable Emissions from this initial Report and Order on the Docket are the expansion to additional channels above the present band and the proposed conversion to all SSB. Though action on these can be expected eventually, it will probably rest to some degree on what happens with Class-E CB.

MANDATORY REVIEW OF LOGGING TAPES for repeaters operating under "automatic control" will not be required as a result of recent FCC decision. Logging tapes must still be made and kept for 30 days, and if any operating problems are reported to the control operator or licensee during that period the tapes must be reviewed and corrective action taken within 72 hours or the system must shut down. This Easing Of Requirements for repeater operators takes most of the sting out of the Commission's Report and Order — mandatory review had been the principle objection raised by the repeater fraternity.

AMSAT MEMBERS not planning to attend AMSAT's annual meeting at the ARRL Convention in September are reminded that their ballots for the Director's election are needed to insure a quorum. The annual meeting is scheduled Sunday, September 14, at Reston, Virginia.

New Two-Color Bumper Sticker Decals are now available from AMSAT. They are being sent free to new members and renewing old members, or sold three for $1 plus SASE from AMSAT, Box 27, Washington, DC 20044.

TV TUNER WITH MEMORY has some interesting design features for Amateur radio applications. Announced in July by General Instrument, the tuner uses a non-volatile memory chip that contains 100 lines of 14 bits each. Each line can be programmed for one TV channel, and when needed the memory information is fed to a 14-bit CMOS D/A converter to produce an analog voltage which is applied to a varactor diode and tunes in the station.

HAM GEAR SHORTAGES have been plaguing dealers for some time and are likely to get worse before they get better. The major cause of the problem is the CB explosion, since many manufacturers — particularly those in the Far East — supply both the Amateur and CB markets and it pays them to put their major effort in the market with the most money.

TYPE ACCEPTANCE OF AMATEUR GEAR is still a hot issue around the FCC. Don't be surprised to see a Notice of Proposed Rule Making come out of the Commission soon. Continued Abuses By CBers using Amateur transceivers and manufacturers building "broadband" linears for the "Amateur Radio market" that just happen to deliver full output with only 4 watts drive (on ten meters, of course) have pretty well forced the FCC to act.
Element for element, our rugged High-Q beam antennas are designed to give you the biggest signal your transmitter is capable of.

Now when you install one of these Swan antennas you can make sure you're running full bore all the time by hooking our new SWR/RF Power meter in the coax.

**Heavy duty 4-element Tribander**
Four elements work on 10, 15 and 20 meters. Optimum spacing for maximum performance. Precision tuned, weatherproof traps. 100-mph winds. TB-4HA. $249.95

**Heavy duty 3-element Tribander**
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**Economy 2-element Tribander**
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**Heavy duty 2-element 40-meter Beam**
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**SWR/RF Power meter** Combination meter measures standing wave ratio and antenna power. Low insertion loss lets you leave it in circuit. 3.5 to 150 MHz. $21.95

All Swan Beam Antennas are Rated for 2000 Watts and designed to use 52 Ohm coaxial feedlines.

### SWAN BEAM ANTENNA SPECIFICATIONS

<table>
<thead>
<tr>
<th>Antenna Model Number</th>
<th>Average Gain</th>
<th>Forward Gain Ratio</th>
<th>Front to Back Ratio</th>
<th>Boom Length &amp; Diameter</th>
<th>Longest Element</th>
<th>Turning Radius</th>
<th>Maximum Wind Survival</th>
<th>Wind Load @ 80 mph</th>
<th>Wind Surface Area</th>
<th>Net Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>TB-4HA 9 dB</td>
<td>24-26 dB</td>
<td>24” x 1.5”</td>
<td>28’-10”</td>
<td>18’-6”</td>
<td>100 mph</td>
<td>148 lbs.</td>
<td>6 sq. ft.</td>
<td>54 lbs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TB-3HA 8 dB</td>
<td>20-22 dB</td>
<td>16” x 1.5”</td>
<td>28’-2”</td>
<td>16”</td>
<td>100 mph</td>
<td>110 lbs.</td>
<td>4 sq. ft.</td>
<td>44 lbs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TB-2A 5 dB</td>
<td>16-18 dB</td>
<td>6.5” x 1.5”</td>
<td>27’-8”</td>
<td>14’-3”</td>
<td>80 mph</td>
<td>80 lbs.</td>
<td>1.8 sq. ft.</td>
<td>18 lbs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MB-40H 4 dB</td>
<td>16-18 dB</td>
<td>15.75” x 1.5”</td>
<td>30’-4”</td>
<td>17’-6”</td>
<td>100 mph</td>
<td>80 lbs.</td>
<td>2.5 sq. ft.</td>
<td>40 lbs.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

305 Airport Road, Oceanside, Calif. 92054
At one time or another most serious six-meter operators have appreciated the value of having a high-power amplifier for extending their communications range — scatter, extended ground wave and aurora contacts are enhanced considerably by the proper use of an amplifier. I decided to build a two-kilowatt PEP linear amplifier around a pair of grounded-grid Eimac 3-500Zs because I have a Swan 250C which easily provides the 100 watt PEP input drive requirement. In addition, I have two other rf power amplifiers using 3-500Zs which have given me trouble-free service for the past several years. A spare pair of tubes that were sitting on the shelf helped convince me to go in this direction.

After acquiring operating manuals from different manufacturers and going through the various amateur magazines, scanning articles and circuits which used 3-500Zs, I built the six-meter kilowatt described here.

The 3-500Z tubes are air-cooled power triodes designed for zero bias operation and are rated to 110 MHz. They are cathode driven with the grids at rf and dc ground. The tuned-cathode input circuit (fig. 1) provides good linearity and minimizes the drive requirements. The filaments are isolated from rf ground with the high-current bifilar rf choke, RFC1. The tuned plate circuit in this amplifier, however, is a bit unusual — the normal pi-network tuning capacitor has been replaced by an inductively-tuned or shorted-turn plate tank coil.

Most circuit losses at 28 MHz and up are due to residual circuit capacitance and much of this undesired effect is due to the pi-network input tuning capacitor commonly used at lower frequencies.
In this circuit the pi-network input capacitance, C5, consists of stray circuit and tube capacitance.

The control relay, K1, which switches the amplifier into the circuit and shorts out the 10k, 10 watt resistor, allowing normal plate and grid current to flow, is operated from a low current dc supply derived from a winding on the filament transformer. External interlocks (not shown here) make it impossible to apply plate voltage without first turning on the filaments and blower.

The two meters on the front panel of the amplifier shown in the photographs are used to read the grid and plate circuits. Since the meters I used had 100-milliampere movements, I used resistance shunts to provide a multiplier of five for the grid current meter (500 mA) and ten for the plate current meter (1 ampere).

construction

The pi-network inductor is wound from ¼-inch (6.5mm) diameter copper tubing and the shorted turn is made from a section of ⅝-inch (38mm) copper water pipe. This slug is moved in and out of the inductor to tune the plate tank circuit to resonance. Construction details for this assembly are shown in fig. 2.* Although I used a simple spinner knob on the inductor tuning screw, a turns-counting dial could be used to provide a logging reference for various operating frequencies.

The grid pins on the 3-500Z sockets are directly grounded to the chassis with ¼-inch (6.5mm) wide copper strap. One end of the strap is soldered to the socket pins and the other end is attached to the chassis with 6-32 (M-3.5) screws and nuts. Make sure that both contact surfaces are clean for low-resistance, trouble-free grounding. The homebrew filament choke consists of 12½ bifilar turns number-2 (2.1mm) Formvar on a ⅜-inch (13mm) diameter ferrite rod (suitable filament choke kits are available from Amidon Associates†).

The shunt-feed rf choke, RFC2, is connected directly across the plate tank circuit, so it must provide good isolation over the entire six-meter band. Hand winding, as described here, is highly recommended as no commercially available rf choke is apt to provide as good performance. The winding is most easily accomplished by feeding two number-20 (0.8mm) wires through one hole in the coil form and winding a bifilar coil of 30 turns, ending at the other hole in the form. Remove one of the bifilar windings and you will have a tight, evenly spacewound winding that makes an excellent six-meter choke. The cold end of the rf choke is bypassed to ground with a 500 pF TV-type doorknob capacitor.

The 500-pF dc blocking capacitors, C3 and C4, are mounted between two

---

*Major components for the shorted-turn inductor are available from Edward A. Stoltzfus, Engineering Machinist, Beacon Light Road, Parkesburg, Pennsylvania 19365.

†Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607. Filament choke kit is $2.50, postpaid.
fig. 1. Six-meter kilowatt uses inductively tuned pi network for high efficiency. In this circuit the pi network input capacitor, C5, consists of tube output capacitance and stray circuit capacitance. Capacitors marked with an M are mica types. Construction of the tuned inductor, L3, is shown in fig. 2.

C1  50 pF compression mica trimmer (ARC-DO 462). Adjust L1 for resonance with C1 compressed 90 percent

C3, C4  500 pF, 5 kV doorknob capacitor (Centralab 8585)

C5  residual circuit and tube output capacitance

C6  250 pF air variable (E. F. Johnson 154-1)

C7  500 pF, 10 kV doorknob capacitor (TV type)

Cn  Neutralizing capacitor, copper strap ½" (13mm) wide by 3½" (89mm) long

CR1  Silicon diode, 600 PIV, 1 A

K1  110 Vdc relay, 3 pole, double throw (Potter & Brumfield KA14DG or Heath 69-55)

L1  3 turns no. 14 (1.6mm), airwound, ¼" (13mm) diameter, 5/8" (16mm) long

L2  2 turns no. 18 (1.0mm) insulated wire, ½" (13mm) diameter, placed between turns of L1 (note polarity)

L3  3½ turns ¼" (6.5mm) copper tubing, 3" (76mm) long, 2-1/8" (54mm) inside diameter. Tuning slug details are shown in fig. 2.

PC1,2  Parasitic suppressors. Each consists of three 50 ohm, 2 watt resistors shunted across ½" (13mm) wide copper plate strap, install as close to the plate cap as possible (see photo)

RFC1  12½ turns no. 12 (2.1mm) Formvar, bifilar wound on ½" (13mm) diameter, 3½" (89mm) long ferrite rod (Amidon Associates filament choke kit)

RFC2  30 turns no. 20 (0.8mm) enamelled wire, space wound on 3/4" (19mm) round, 3-3/4" (95mm) long ceramic or Teflon rod. Drill holes for wire ends ½" (13mm) and 2-3/4" (70mm) from top or rod

T1  dual secondary transformer, 5 Vac at 30 amps (filaments), 120 Vac (relay K1 dc supply)

brass plates, one of which is attached to the top of RFC2. The other plate is connected to the pi-network inductor L3 (see photo of the rf compartment).

The amplifier is built on a homemade chassis made from 3/32-inch (2.5mm) thick aluminum sheet and is 1-3/4 inch (4.5cm) high, 12 inches (30.5cm) wide and 13 inches (33cm) deep. The front and rear panels are 1/8-inch (3mm)

10 september 1975
thick aluminum, 8 inches (20.5cm) high by 13 inches (33cm) wide. The inner right- and left-hand panels are 1/16-inch (1.5mm) thick aluminum, 7 ½ inches (19cm) high by 13 inches (33cm) long. These two panels can be made from perforated stock or solid sheets can be drilled to provide for ample air intake and exhaust to cool the plate and filament seals.

The rf compartment is 10 inches (24.5cm) wide, 8-3/4 inches (22cm) deep and 6 inches (15cm) high. The top cover for this compartment is made from perforated aluminum sheet and should be installed at all times to protect the operator from the lethal voltages which are used to operate this equipment.

The bottom cover is 1/16-inch (1.5mm) thick aluminum, 13 inches

---

**fig. 2.** Construction of the tuned pi-network inductor, L3. This arrangement requires a minimum of machine work and uses readily available materials.
(33cm) wide by 14 inches (35.5cm) deep with ½-inch (13mm) lips formed on two sides to provide a mating surface for the top cover. The U-shaped top cover is also made from perforated aluminum. The trim around the raw edges on the top and bottom covers is car door protective edging that is available from most department and automotive stores; it is very easy to work and cut with simple hand tools. The vox connector and power plugs are all brought out on the rear panel along with the input and output coaxial connectors.

Cooling air must be provided to maintain the plate seals of the 3-500Zs below 225°C and the filament seals below 200°C. Many 3-500Z power amplifiers are designed around a system of air-system sockets and chimneys, along
with a centrifugal blower. The noise generated by the blower motor and air movement through the cooling system, however, is very distracting. Extensive tests by Eimac have shown that for CW and ssb operation at legal amateur power limits the 3-500Zs may be adequately cooled by a lateral air blast blown against the tubes by a small, properly positioned rotary fan.²

The arrangement of the cooling fan in the six-meter kilowatt is shown in fig. 3. The fan is mounted in the rf compartment wall, between the tubes, in line with the center of the glass envelopes, and blows cooling air across the envelope and plate caps (use a good heat-dissipating plate connector such as the Eimac HR6). The Johnson 122-275-1 ceramic tube sockets are mounted off the chassis about 1/8 inch (3mm) to allow air flow around the base of the tubes to cool the filament pins.

<table>
<thead>
<tr>
<th>Table 1. Typical operating data for the 3-500Z in rf linear amplifier service, class B (two tubes).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dc plate voltage</td>
</tr>
<tr>
<td>Zero signal plate current (mA)</td>
</tr>
<tr>
<td>Single tone dc plate current (mA)</td>
</tr>
<tr>
<td>Single tone dc grid current (mA)</td>
</tr>
<tr>
<td>Two-tone dc plate current (mA)</td>
</tr>
<tr>
<td>Two-tone dc grid current (mA)</td>
</tr>
<tr>
<td>PEP useful output power (watts)</td>
</tr>
<tr>
<td>Intermodulation distortion products (dB)</td>
</tr>
</tbody>
</table>

With this arrangement maximum plate dissipation of about 450 watts per tube is achieved for the 3-500Z. While this is about 10 percent short of the maximum rating, dissipation is sufficiently high that the pair of tubes will easily handle the maximum amateur power limit for CW or ssb operation under normal operating conditions. For continuous operation (RTTY or ssTV, for example) the power input must be reduced to about 750 watts.

neutralizing

The neutralizing capacitor, CN, is formed from a 0.032-inch (0.8mm) thick copper strip, 1/2-inch (13mm) wide and 3½-inches (89mm) long into an L-shape with the foot of the L about 3/8-inch (10mm) long. The foot is drilled for mounting to the threaded stud of a small ceramic feedthrough bushing. The feedthrough bushing is centrally located between the two 3-500Zs and in line with the socket mounting holes toward the rf choke (see photograph). This capacitor is adjusted to lean in toward the center line of the tubes.

Inductor L2 is inserted between the turns of L1, the input circuit coil, and adjusted until the amplifier is neutralized (stabilization occurs when maximum grid current, maximum output power, and output power distortion products meet specifications).
and minimum plate current all are reached at one setting of the plate tank circuit). With the amplifier turned on but with no drive signal, grid current should be zero. I used an insulated rod to adjust L2 through a small hole in the bottom compartment. The neutralizing capacitor should be adjusted with the power turned off.

Two views of the power amplifier which show the various pieces of metalwork which were used in its construction.

**Tune up**

Before applying any voltages to the amplifier, carefully check all the wiring. Then install the two tubes and use a grid-dip oscillator to approximately set the tuned cathode circuit and pi network output circuit to the desired operating frequency. I used 50-ohm resistors across the input and output coaxial fittings during the grid-dipping operation and made sure that all relay contacts were closed.

After the amplifier has been cold tuned with the grid-dip meter, remove the 50-ohm resistors and connect the six-meter exciter to the input and a dummy load (or antenna) to the output. A monitor scope or relative power meter (an SWR bridge works well) will provide a good output indication during initial testing of the amplifier.

First tune up the exciter for full normal CW output with the amplifier switched out of the line. Reduce exciter output, apply power to the amplifier and tune the amplifier for maximum output with reduced B+. Gradually increase the excitation and high voltage to get the feel of a very smoothly tuning six-meter power amplifier.

For CW operation with a 2500-volt power supply tune the plate circuit and adjust the exciter drive for a plate current reading of about 400 mA (about 125 mA grid current). I am using a power supply with a tapped primary which I can switch from 2300 volts for CW and tuning, and then to 2800 volts for SSB operation.

I usually tune for maximum output with the lower voltage and then switch to the higher voltage for SSB. Apply SSB drive from the exciter and advance the microphone gain control for an average plate current reading of 350 mA. An occasional voice peak may boost this up to 600 mA. A monitor scope will show you more than any plate meter can be expected to, and should be used at all times when you are running high power. The manufacturer's operating data for the 3-500Z is published in most handbooks and should be consulted as a guide for proper use of these tubes in amateur service.

**References**

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tunable

RC notch filter

Discussion of an

RC notch filter

which can be tuned with a single variable resistor

Of the host of RC notch filters that have been devised, the twin-T (also called parallel-T) has enjoyed the greatest popularity by far. This is surprising because, in order to make this circuit adjustable or tunable, three components, either resistors or capacitors, must be varied simultaneously. To make matters worse, these three components don’t all have the same value as shown in the basic circuit of fig. 1. One of the resistors is one-half the value of the other two, and one capacitor is twice the value of the others. Therefore, an adjustable twin-T notch filter requires a three-gang potentiometer, and the tracking and alignment problems can be troublesome if not expensive.

There is another circuit, however, which has performance comparable to the twin-T, but which can be tuned over a wide frequency range by means of a single potentiometer. Although this circuit has been around for about 20 years, it has seldom appeared in the electronics literature and is not widely used.

To my knowledge, this tunable notch filter first appeared in print in 1955 when it was mentioned by Henry P. Hall of the General Radio Company in the September issue of IRE Transactions on Circuit Theory. He discussed it further in the July, 1961, issue of the General Radio Experimenter. That same year, General Radio brought out its Type 1232-A Tuned Amplifier and Null Detector; this instrument used Hall’s tunable notch filter as a feedback element around an amplifier to produce a continuously tunable, narrow-band audio amplifier. General Radio still markets this instrument for about $700.

fig. 1. The twin-T notch filter is difficult to tune because three components must be varied simultaneously.
In the October, 1969, issue of *EEE Magazine*, Ralph Glasgal, in his article, "Tunable RC Null Networks," referred to the circuit as a "bridged differentiator." These articles are the only ones on this circuit of which I am aware. The following sections describe my own investigations.

![fig. 2. Basic circuit for a tunable RC notch filter which requires only one variable resistor.](image)

**the circuit**

Fig. 2 shows the basic configuration of Hall's tunable notch filter. The tuning pot is composed of R1 and R2, R1 being the resistance between one end of the pot and the wiper, and R2 the resistance between the other end of the pot and the wiper. The other resistor in the circuit must have a value equal to six times that of the pot. All three capacitors have the same value, which simplifies things if you want to match them for best performance.

The null frequency equation in fig. 2 may be solved for different values of R1 and R2, and the results plotted to show how the notch frequency changes as the wiper is moved from one end of the pot to the other. Fig. 3 shows the result if the pot is assumed to be linear. When the wiper of the pot is at its mid-position (50 per cent of rotation) the notch frequency has its lowest value, and very little change in null frequency occurs in the middle section of the pot. As the wiper approaches either end of the pot, however, the null frequency begins to increase quite rapidly and would theoretically become infinite at the ends of the pot.

From the curve of fig. 3 it can be seen that, in a practical tuned notch filter, the tuning pot need only cover a relatively small percentage of the range shown. In other words, if the actual pot were used with fixed series resistors so that the pot covered only the range from 1 to 10 per cent, the relative frequency range would be from 10 to 3.3, or a 3 to 1 frequency range. Fig. 4 shows a schematic of how this would be implemented. Once the value of the pot has been selected, the values of the

![fig. 3. Relative notch frequency of the circuit shown in fig. 2 vs the rotational position of the potentiometer wiper.](image)
three resistors may be calculated from the relationships shown.

It can be shown that the lowest notch frequency is given by

\[ f_n = \frac{27700}{\text{CR}} \]  

(1)

where \( f_n \) is in Hertz, \( C \) is in microfarads, and \( R \) is the resistance of the pot in ohms. The highest frequency to which the notch may be set is equal to three times the value given by eq. 1.

practical examples

As a starting point, I had on hand a 20k pot and some 5 per cent, 2000 pF dipped-mica capacitors. These components would give a lowest notch frequency of

\[ f_n = \frac{27700}{(0.002)(20 \times 10^3)} \approx 693 \text{ Hz} \]

The highest notch frequency should be three times this value or about 2079 Hz.

Using the resistor relationships of fig. 4, the circuit design was completed as shown in fig. 5. It was necessary to connect resistors in series to arrive at some of the values shown, and the pot had a tolerance of at least ±10 per cent. Fig. 6 shows the response of this filter with the tuning pot set at each end of its rotational range. Depth of the notch varies, but is greater than 50 dB in all cases; at 1160 Hz, the notch depth is 54 dB. Actual notch frequencies at the ends of the pot match the calculated values reasonably well, and the tuning range is slightly over 3 to 1.

![Fig. 4. Relationship of resistance values for a 3:1 notch-filter tuning range.](image)

![Fig. 5. Notch filter which tunes from 693 to 2079 Hz. Performance of this circuit is plotted in fig. 6.](image)

![Fig. 6. Frequency response of the notch filter of fig. 5 with the potentiometer set at each end.](image)
fig. 7. Tunable notch filter for 60 Hz can be used to minimize hum pickup from the ac line (circuit tunes from 40 to 120 Hz).

Optimizing Notch Depth

Greatest notch depth will result when the ratios of component values approach the exact theoretical design values. In this regard, there are two requirements: the capacitors should all be exactly equal in value, and the large-value resistor connected from input to output should be exactly six times the resistance in the variable-resistance branch of the network.

Capacitors may be matched by measuring them on a capacitance bridge or a direct-reading capacitance meter and selecting those most nearly equal in value. An easy way to optimize the resistance ratio is to replace the resistor connected between the input and output with a trimpot and fixed resistor, or simply a trimpot, as shown in fig. 8; the trimpot can then be set for the deepest notch. Since changing this resistance also affects the notch frequency, it will be necessary to repeatedly adjust first the trimpot and then the tuning pot until the notch can no longer be improved.

fig. 8. Notch depth may be optimized by using a trimpot to set the series resistance to exactly 6R. Notch depth of the 60 Hz filter in fig. 7 was increased from 44.5 to 57 dB using this simple technique.

fig. 9. Tunable bandpass audio amplifier uses RC notch circuit as the feedback element. Tuning range of this circuit is 700 to 2000 Hz. Frequency response at 1000 Hz is plotted in fig. 10.

Once the trimpot has been set, however, it needs no further adjustment when the tuning pot is set to another frequency.

As an example of what this optimization can mean, the 60 Hz notch filter of fig. 7 was first built as shown with unmeasured ceramic disc capacitors and 5 per cent resistors; at 60 Hz it had a notch depth of 44.5 dB. By selecting capacitors with equal values and replacing the 333k resistor with a 500k trimpot, I was able, by careful adjustment, to increase the notch depth to 57 dB.

Tuned Amplifier

The tuned notch filter can be used as
the feedback element with an op amp to produce a continuously tunable narrow-band audio amplifier. I used the circuit of fig. 5 in conjunction with a 741 op amp to build a tunable bandpass audio amplifier which will tune from about 700 to 2000 Hz. This circuit is shown in fig. 9. With the tuning pot set for a center frequency of 1000 Hz, the 3 dB band-

cause the bandwidth is quite narrow as it stands.

Although I used plus and minus 12-volt power supplies for the 741 op amp, two 9-volt batteries should work okay; battery drain should be about 1 mA or less with a 2000 ohm load.

I have found that trying to increase the tuning range of this amplifier by in-

width is 23 Hz, the 6 dB bandwidth is 39 Hz, and the 10 dB bandwidth is 68 Hz. At 1000 Hz, the voltage gain of the circuit measured 36 dB.

Fig. 10 shows the frequency response of this circuit when tuned to 1000 Hz. High-frequency rolloff is quite good, being about 43 dB down at 2000 Hz, so this circuit can convert a 1000 Hz square wave into a very nice sine wave. Low-frequency response flattens out, however, to a value determined by the ratio of the 1.33 megohm resistor to the 1 megohm input resistor. Some highpass filtering would improve the low-frequency skirt considerably, however. No attempt was made to optimize this notch circuit as described previously be-

creasing the value of the tuning pot and decreasing the value of the 200k resistor results in self-oscillation when the pot is set near its low frequency extremity.

This article contains everything I know at the present time about this tun-
able notch filter circuit and its applications. I hope I have presented enough information for those interested to make good use of this valuable but little known circuit. All data was taken using a 600-ohm audio generator and an ac vtm with an input resistance of 10 megohms. If readers have questions or can further enlighten me on these cir-
cuits, I would be pleased to hear from them.

fig. 10. Frequency response of the tunable bandpass audio amplifier when tuned to 1000 Hz. Bandwidth at -3 dB points is 23 Hz; at -30 dB the bandwidth is approximately 773 Hz.
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optimization
of the
phase-locked
RTTY terminal unit

The original design concept of the phase-locked loop RTTY terminal unit included totally automatic and universal operation requiring a minimum of adjustment. The initial design would copy any afsk shift between 150 and 100 Hz, operate at data rates up to 110 baud, and automatically track a drifting signal. Another publication described a modified autostart system that incorporated an anti-CW feature.

Since the original article was published there have been two distinct developments in amateur RTTY operation:

1. Wide shift (850 Hz) has almost completely disappeared from the high-frequency amateur bands with the exception of some operation on 80 meters (and, of course, wide shift is still the rule on two-meter fm).

2. The continued use of 60 wpm for 95 per cent of amateur RTTY operation, even with the availability of 75- and 100-wpm speeds.

This latter development is undoubtedly because of the vast amount of 60-wpm teleprinter machines available and the fact that most RTTY operators can’t type more than 60 wpm.

With these two developments in mind, and in response to requests from readers, I’ve attempted to optimize the detector circuit to decrease the required minimum input-signal-to-noise ratio of 6 dB (for 99 per cent correct copy). In consideration of users having commercially made printed-circuit boards, one constraint was placed on the modifications: no printed-circuit changes would be necessary — only parts substitutions, deletions, and parts value modifications would be used.

modifications

For the phase-locked loop detector (fig. 1) changes are shown circled. In the original loop, the lowpass filter capacitor, C7, was selected to give a loop bandwidth of approximately 400 Hz. This value was selected in compliance with Shannon’s rule for operation at the highest data rate of 110 baud: $110 \text{ baud} \div 2 = 55$, $55 \text{ Hz} \times 7 = 385$ Hz, or the required minimum loop bandwidth. But for 45-baud (60 wpm, 5 level), a 22.5-Hz signaling rate results, thus requiring a loop bandwidth of only 157.5 Hz. A 180-Hz loop bandwidth was used because 0.22 $\mu$F was the nearest standard value capacitor to the design value for C7. To complement the preceding change, the phase-locked loop output RC ladder filter cutoff frequency was also lowered by increasing the value of C8, C9, C10 and C11 from 0.01 to 0.022 $\mu$F.

The sbp position of the mode switch, S1, is now used for 170-Hz shift, and the vco frequency-set pot, R5, is adjusted for a natural vco frequency of 2210 Hz at TP-2 with no audio input applied to the TU. This new frequency setting allows the vco to swing symme-
trically to either side of its natural frequency, thus reducing the probability of the loop unlocking on noise.

The normal position of the mode switch, S1, is used for 850-Hz shift and its pot, R6, is adjusted for a natural vco frequency of 2550 Hz at TP-2, as in the original article. Other shifts, such as 425 or 85 Hz, can be copied simply by adjusting the receiver frequency so that the shift is centered on the appropriate vco natural frequency.

In the tracking comparator, an RC network consisting of R11 and C12 is

C12 has been changed to a 0.33 µF mylar, and R11 has been changed to 1 megohm to maintain the same time constant. To take advantage of the higher impedance presented by this RC network, U2 has been changed from a NE5741T to a NE536T, an fet input op amp. The minimum detectable shift was measured at 40 Hz with an input-signal-to-noise ratio of 10 dB and a noise bandwidth of 3 kHz.

The tracking comparator output lowpass filter cutoff frequency has been decreased to 30 Hz to optimize the

used to produce a signal-derived reference voltage for the noninverting input of U2. The RC time constant was selected to be 2.5 times that of the longest space condition at 60 wpm, which is the blank key having a space duration of 132 milliseconds. Accordingly R11 and C12 were selected to give a time constant of 330 milliseconds. However, the leakage path through electrolytic capacitor C12 limited the minimum detectable shift to approximately 150 Hz. Thus

section for the 22.5-Hz signaling rate used with 60 wpm, 5-level RTTY. To accomplish this frequency change, capacitors C16 and C17 were increased from 0.033 to 0.068 µF. Also affected was resistor R14, which was deleted to produce a higher voltage to the input to the Schmitt trigger, U3, so that its operation on marginal signals would be improved. The noise rectifier in the noise squelch circuit was changed. The output filter capacitor, C15, was in-

fig. 1. Circuit modifications to the phase-locked loop RTTY terminal unit for improved performance. New circuit values are circled. All resistors are 5%, ½ watt unless otherwise specified.
increased from 10 to 39 μF to provide a longer time constant, which reduced the effects of static crashes.

**Experimental Procedure**

The phase-locked loop\(^2\) TU was connected to a test setup (fig. 2). A Wave-tek model 134 function generator was used to generate a 22.5-Hz square wave to simulate a 60-wpm, 5-level RTTY signal. This signal was fed through an attenuator to the voltage-controlled generator input of a Wavetek model 132 function and noise generator. This latter instrument could simultaneously generate both a signal as well as random noise in a front-panel controlled, calibrated ratio. In these tests the signal used was an afsk sine wave shifted 170 Hz between 2125 and 2295 Hz, and a random noise sequence of \(2^{20} - 1\) was used at a maximum noise clock frequency of 48 kHz, thus ensuring that a random noise sequence could not repeat in a time period of less than 21.85 seconds.

Noise clock frequencies of 48, 45 and 39.3 kHz were used to produce upper noise bandwidths of 3, 2.81, and 2.46 kHz so that the signal-plus-noise bandwidth was always centered on 2210 Hz, which is the shift midpoint and the natural frequency of the phase-locked loop\(^2\) vco. A lower bandwidth limit of 10, 1610, and 1960 Hz was imposed by the use of a Krohn-Hite dual electronic variable filter with both sections connected in series for highpass operation. These instrumentation methods gave simulated receiver bandpasses of 3000, 1200 and 500 Hz respectively.

All tests were started at a 10 dB s/n ratio, which was then reduced until the output of the Schmitt trigger (fig. 3, Channel 4) exhibited excessive jitter or failed to follow the afsk keying signal (fig. 3, Channel 1). This s/n ratio was considered to be the minimum usable input signal for a given simulated receiver bandpass. The test results were: 0 dB minimum s/n for a simulated receiver bandpass of 3 and 1.2 kHz. For 500 Hz, it was -3 dB.

**Conclusion**

Figs. 3A, 3B and 3C illustrate the input and output waveforms for the test setup and TU with input s/n ratios of zero and -3 dB and simulated receiver bandpasses of 3, 1.2, and 0.5 kHz. These figures represent a 6-dB improvement for the worst case and a 9-dB improvement for the best case over the original design.

Comments, contribution of ideas, and criticism are welcome from users of phase-locked loop terminal units.
A. 3-kHz noise bandwidth; signal-to-noise ratio, 0 dB.

B. 1.2-kHz noise bandwidth; signal-to-noise ratio, 0 dB.

C. 500-Hz noise bandwidth; signal-to-noise ratio, -3 dB.

Center frequency, 2200 Hz; dispersion, 200 Hz/cm; sweep speed, 5 sec/cm; vertical sensitivity, 200 mV/cm.

fig. 3. Input and output waveforms from test setup show improvements of 6 and 9 dB over original design for worst- and best-case conditions.

Channel 1: afsk keying voltage; horizontal, 10 ms/cm; vertical, 50 mV/cm.
Channel 2: signal + noise at 3 kHz bandwidth; horizontal, 0.2 ms/cm; vertical, 100 mV/cm.
Channel 3: PLL vco at TP-2: horizontal, 0.2 ms/cm; vertical, 10 V/cm.
Channel 4: Schmitt trigger output: horizontal, 10 ms/cm; vertical, 10 V/cm.
acknowledgement

I'd like to express my gratitude to the Wavetek Corporation for making a Model 132 VCG/noise generator available for this and other research work in the biomedical field. The work reported here was greatly simplified by the use of this instrument.

references

3. Digital Communications Corp., 185 Devonshire, Suite 900, Boston, Massachusetts 02110.

toroidal coil inductance

Toroidal inductors are being used more and more in amateur communications equipment because of their small size, high Q and self shielding properties. Michael Gordon's article makes it relatively easy to determine the number of turns to wind a coil on a particular core. He includes numerous core constants and a helpful equation necessary to achieve a specific inductance. Fig. 1 contains much of that information in graphical form and was developed for builders who tend to shy away from using mathematical formulas. To determine the required number of turns on a particular toroid core, simply locate the desired inductance, L, on the vertical axis, draw a horizontal line through L to where it intersects the appropriate core line, and read off the number of turns, N, on the horizontal axis, beneath the intersection point.

The graph of fig. 1 can be expanded to include more core types and a greater number of turns if desired. Fortunately, Gordon's expression \( N = K\sqrt{L} \) plots as a straight line on log-log graph paper; therefore, by using paper with more cycles, a more complete nomograph can be obtained. I constructed the original graph by rearranging the above formula into the form \( L = \frac{N^2}{K^2} \), where K is one of the core constants, and then solved the equation for L when N is 20 and 100. This gives two points which can be connected by a straight line.

The dashed line shows actual measured values for an Amidon T50-2 core. Four test coils were wound using number-26 (0.4mm) enamel covered wire. A commercial Q meter was used to measure Q, and the inductance was calculated from the resonant frequency formula. The small discrepancy noted between the measured and calculated inductance values could have been due to connecting lead length and Q-meter accuracy.

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More Details? CHECK-OFF Page 110
single sideband
speech splatter

An informative discussion of nonlinear ssb operation and what to do about it

If you've listened on the low-frequency end of the 20-meter phone band when two or three rare DX stations are coming through, you've probably noticed a steady, noise-like signal between the DX stations. Under good conditions the noise may be S2 or S3; more likely it's S9 or more. This steady noise seems to come from no particular station; in fact it seems to emanate from all stations of the band. The noise is caused by splatter.

When only one station is causing splatter, it's a good bet the operator will be told his transmitter is at fault. Sometimes this brings an apology and an immediate resolution; often it brings a protestation of innocence based on the equipment in use: "My so-and-so off-the-shelf rig has super automatic level control; it can't be me." A cop-out response? Perhaps not. The fellow in question may not understand the causes and cure of splatter.

This article presents some hints on the causes, cure, and source of splatter interference and what can be done about it to help alleviate the noise problem in the congested amateur phone bands.

source of splatter

Splatter comes from a single source; in fact a rather simple one. There is a relationship between the way a signal changes and the bandwidth it occupies. The relationship is easily described mathematically, but this does not lead to a good understanding of the process. For this discussion let's look at some
special types of signals and use these as analogies.

A simple example of a signal with a high rate of change is a pulse of width $\Delta t$, corresponding to a dot of a CW signal or to an ideal radar pulse. With respect to time, the signal is off for a long period, then on at constant strength for a period $\Delta t$, then off again for a long period. With respect to frequency, the relative strength of this signal varies with frequency; its spectrum is shown in fig. 1. Most of the signal energy is contained in the bandwidth defined by $f = 1/\Delta t$.

For example, suppose the pulse represents a dot with a width of 50 milliseconds and a dot speed of 24 words per minute. Most of the energy will be contained within a band 20-Hz wide. If the pulse is from a radar, having a width of 0.2 microsecond, most of the signal energy will be contained within a band 5-MHz wide. On a relative basis, the shape of these two signals is the same.

Both of these signals have additional peaks extending outward from this central band, as shown in fig. 1. These additional components are the source of key clicks on CW signals and the typical buzz of a radar signal when a receiver is tuned well away from center frequency. The components extend far from the center frequency.

For a perfectly rectangular pulse, the magnitude of the components is defined by the relationship $(\sin X)/X$. This relationship is called the aperture function and is the envelope of the spectrum amplitude for a single square pulse. The $X$, in this case, is $\pi T_0 f$, where $T_0$ is the pulse duration (seconds) and $f$ is the frequency (Hz) at which it is desired to know how much signal amplitude exists. If the pulse duration is 0.1 second and you want to know how much splatter exists at, say, 100 Hz from center frequency, then

$$\pi (0.1)(100) = 10\pi$$

and

$$\frac{\sin 10\pi}{10\pi} = 0$$

There is no splatter at all at exactly 100 Hz from center frequency. However, if you ask about splatter 5 Hz from center frequency,

$$\pi (0.1)(5) = 0.5\pi$$

and $(\sin \pi/2)/\pi2 = 1/\pi2 = 2/\pi = 0.636$, or about two-thirds the signal you'd hear exactly on frequency.

The influence of this idealized signal extends over the entire band, from dc to infinitely high frequencies. The change in signal strength with frequency is slow. For example, if the maxima have a strength of 100 mV at 10 kHz from the center of the CW signal, they will have a strength of 50 mV at 20 kHz from the signal, 25 mV at 40 kHz, etc.

For a given pulse width and amplitude, the only way we can change the signal spectrum is to change the rate of change of the signal or rise time. This affects the strength of components far
from the center frequency of the signal without changing the main part of the signal very much. For example, suppose the pulse were changed from a perfect rectangle to the triangle of fig. 2. The energy distribution is now described by the relationship \( \frac{(\sin X)}{X}^2 \), but the

peak amplitudes far from center frequency decrease twice as fast as before. If the maxima are 100 mV at 10 Hz from center frequency, they will be 25 mV at 20 kHz; 6.25 mV at 40 kHz, etc. The energy very close to the center frequency is identical for the triangle and the rectangle. Other wave shapes can show greater reduction of the “far-out” components.\(^1\)

This modification of wave shape and its effect on far-from-center frequency components is the principle of the key click filters used in CW. Note that the shaping can’t stop key clicks — all it can do is reduce their strength and, in particular, reduce the strength of the components relatively far from the signal. For the 20-wpm signal, clicks beyond a few hundred Hz can be brought to the noise level or below.

The important point of this discussion is that any signal that goes on and off will spread across a band of frequencies. How far it spreads and how much energy occurs at each frequency is determined by the interval between on and off, the rate of change of the signal during the on period, and the maximum amplitude the signal reaches.

**ssb signal generation**

Now let’s apply these principles to ssb phone signals. We’ll ignore some “fine structure,” such as the effect of turning the transmitter on at the beginning and off at the end of a transmission. What we want to look at is how a signal supposedly contained within the speech bandwidth can appear many kHz from this nominal band: in other words, we want to know where splatter comes from. To do this let’s look at how the signal is formed and processed.

Fig. 3 shows, in block diagram form, an elementary single-sideband transmitter. Audio and carrier are processed by the modulator to produce a double sideband suppressed-carrier signal. The modulator also produces distortion products at twice the frequency of the carrier, three times its frequency, etc. However, all of the signal outside the passband of the filter is rejected; therefore, only speech products lying between about 300 and 2400 Hz, plus the small amount of distortion that lies within this range, are passed on to the following amplifiers. At the output of the filter the signal is free of widespread spurious components: it is splatter-free.

This nearly ideal signal is then amplified and finally transmitted. If the amplifiers are linear, no energy will exist outside the passband. That is, the amplifier output signals must bear a direct relation-
ship to the input signals. Each amplifier must follow the law

\[ e_{out} = k(e_{in}) \]

The transfer function of the amplifier must look like fig. 4. Unfortunately, most amplifiers don’t attain this ideal relationship and this is where the trouble comes from. In looking at this, let’s again remember we’re not interested in “fine structure;” that is, distortion close to the transmitted signal or regeneration of the rejected sideband, or things of that kind. We want to know the source of splatter.

**splatter due to flat-topping**

One characteristic of practical amplifiers is that they saturate. The output reaches some maximum level then doesn’t increase further. Instead of being linear they have the relationship shown in fig. 5. The effect on a typical signal is shown in fig. 6; it becomes amplitude-limited and is usually called flat-topped. The effect of flat-topping is the same as if the transmitter were putting out an ideal signal plus a negative-going pulse that cancels the top of the signal (fig. 7). The transmitter is now transmitting its intended signal and is also transmitting a radar-like pulse. Flat-topping generates splatter. Since speech waveforms last for relatively short periods, and since only the tip of the wave is cut off, the radar-like pulse formed by peak clipping has a very short duration. Therefore, it spreads a long way from the desired signal and repeats at each voice peak, generating the sound amateurs call “buckshot”.

![Fig. 5. Input-output relationship of an amplifier which saturates.](image)

![Fig. 6. SSB two-tone test with saturation.](image)

Note that the signal close to the center frequency is perfectly good. Don’t ask the station you are working if you are splattering; he can’t tell since he hears a perfectly good signal. It’s the station well removed from the center frequency who hears the splatter.

**splatter due to bias-off**

Another characteristic of practical amplifiers is the tendency to ignore small signals. For a small input they show no output for a time. The transfer function tends to look as in fig. 8, which causes the bottom end of the signal to be clipped. Again, this is equal to a normal signal plus a distortion term. In audio amplifiers, where push-pull operation is common, this clipping is called crossover distortion. It also exists in single-ended amplifiers and is the result of improper bias adjustment—the bias is set too high—often in an attempt to reduce the tube idling current. This form of distortion is less likely to cause trouble than that from positive peaks, since only a small part of the signal is affected. However, evidence indicates that the importance of this form of distortion has recently in-
creased as power companies lower line voltage or allow poorer line voltage regulation. These acts reduce the plate voltage (unregulated) but usually don’t affect the bias voltage, since it is regulated. Effectively, the reduced line voltage increases the bias on the tube and therefore increases this type of distortion.

**splatter due to parasitics**

Another characteristic of practical amplifiers is a tendency to oscillate, often at a frequency far from that at which they are designed to work. Sometimes this parasitic oscillation starts at a specific plate voltage and dies out when the voltage increases beyond this level or when it decreases below this level again. The effect on the input-output relationship can be as in fig. 9. Either of these oscillations will create splatter as the parasitic turns itself on and off. Very similar effects can appear if the amplifier is merely unstable instead of oscillatory. This action causes the amplifier output to increase beyond its normal value, then level off, or perhaps even drop back to normal.

Problems of these types are very common when amplifiers are first tuned up. They may arise again because of components that become defective or change values: more commonly, they arise when an amplifier isn’t adjusted properly or if it’s operated with voltages appreciably different than those for which it was adjusted. It’s likely that the really bad cases of splatter are due to such parasitic oscillations or instability.

**splatter due to level control**

Let’s go back to the flat-topping situation, which is the most common problem. A number of automatic means of preventing flat-topping have been developed. Most work by detecting a particular level of signal at the final amplifier and feeding the signal back to an earlier amplifier to reduce the gain. This scheme is called automatic level control, ALC, or overdrive detection. The intent of these systems is to reduce the value of $k$ in the linear input-output relationship, $e_{out} = k(e_{in})$, to the point where linear operation is maintained — by keeping all peaks below the overload point.

---

**fig. 7. Flat-topping as the sum of an ideal signal plus pulses.**

**fig. 8. Input-output relationship of an amplifier with crossover distortion.**
Unfortunately there can be some problems with these automatic circuits. It takes a finite time for the overload signal to be detected, fed back, and for it to reduce the gain of the earlier stage. This time delay can also introduce a problem, as shown in fig. 10. The relatively sudden decrease from the initial value of \( k \) to a second value is just as effective in producing splatter as any other change of equal rate and magnitude. An associated splatter source may be the click of the vox relay pulling in: it’s gone before the ALC circuits can act, but it can still produce splatter.

Some transmitters incorporate circuits to prevent these sudden changes from occurring. There may be several gain-controlled stages, or several control sources, with different time constants. These complex circuits definitely help prevent the rapid changes shown in fig. 10; however, even they can’t cope with the results of a wide-open gain control. The transmitter struggles zealously but just can’t prevent splatter from occurring.

**splatter due to the receiver**

To be complete, we should note that receivers also include some linear stages, and can have almost identical problems. Problems arise if these stages are overloaded, unstable, or if the automatic gain control circuit time constants don’t match the rate of change of a particular signal being received. Splatter reports can be generated in the receiver, so that a false report is perfectly possible. If you’re told you’re splattering, it’s in order to ask about the precautions against receiver overload, assuming your transmitter is operating linearly.

**detecting your own splatter**

Many stations are equipped with an oscilloscope or monitor. This is by far the best way to operate, but it’s necessary to be cautious. A scope won’t show all splatter problems. Example: suppose two transmitters are operating. One is an ssb transmitter with two-tone modulation. The second is an a-m transmitter 100 percent modulated by the unfiltered output of a full-wave rectifier. As seen on a monitor scope, what is the difference between these two signals?

![Figure 9: Input-output relationships of an amplifier with parasitic oscillations.](image)

The answer is that, to casual inspection, there is absolutely no difference. Both look like the ideal signal of fig. 7. Even detailed inspection of the envelope will not show any difference. The only way a scope can detect the difference is to look at the rf waveform. When this is done, a phase reversal will be found at each zero crossing of the envelope for the two-tone test: the rf wave of the a-m signal doesn’t show this reversal. This very small difference won’t show up on any of the usual types of signal monitor; yet the difference as seen by outside receivers is enormous. The two-tone ssb signal is clean while the recti-
fier-output modulated a-m signal spreads to many, many times the frequency of the modulating sine wave.

Fortunately this situation is artificial but it does show that casual observation of the scope is not enough; some attention to detail is necessary. The first point to watch for is flat-topping, usually the only item observed. Sharp peaks of the voice signal are a good indication that splatter is not occurring from flat-topping. However, splatter due to parasitics or to instability can cause a pattern that resembles, very closely, the sharp peaks of a voice pattern. It takes careful examination of the signal, and, in particular, examination of the rate of rise around the midpoints of the signal, to detect splatter-producing parasitics. The type of splatter that arises from sharp changes at the lower signal levels is also detectable on the scope, but also only by careful observation. The rule should be, inspect the entire signal, not just peaks.

Many operators with stations using transmitters incorporating automatic level control (ALC) eliminate the scope and place their dependence on the automatic circuits. As long as the circuits are working properly and the transmitter is adjusted properly, this is satisfactory. The circuits do work if given half a chance; however, the practice of turning the gain fully open is responsible for much splatter. The gain control should be set to give ALC action as recommended by the instruction book.

Stations using transmitters without ALC and no scope have a special problem. It's almost impossible to detect splatter generation by reading the meters on the transmitter. About the only automatic way of preventing splatter is to choose an exciter that can't overdrive the amplifier. In most cases, this means limiting the exciter power to about one-tenth to one-twentieth the power of the final amplifier. If the final is to run 1000 watts input, the exciter should run no more than 50-100 watts input.

references

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There has been a tremendous increase in ssb activity on 432 MHz since the launch of Oscar 7 in late 1974. However, many amateurs who are communicating through Oscar's 432-to-144-MHz translator are using only 5 to 15 watts ssb output on 432 MHz so they must use complex, high-gain antennas to hold a good signal through the satellite. Few 432-MHz power amplifier designs have appeared in print, and because of mechanical considerations, vacuum-tube amplifiers are difficult to build at this frequency. This article describes a two-transistor, 100-watt PEP, solid-state linear amplifier which solves many of these problems. The components used in the amplifier, for the most part, are readily available.

*RF Power Circuits Engineering, Motorola Semiconductor Products Division, 5005 East McDowell Road, Phoenix, Arizona.*
The transistors used in this power amplifier are the new high reliability Motorola MRF306s. The MRF306 is a 28 volt, 60 watt, 225 to 400 MHz power transistor and is unique in that it is internally matched for broadband use. Internal matching is nothing more than extending the matching network to the actual chip inside the package. This is accomplished by incorporating the bond wires and additional MOS capacitors as tuning elements between the base lead and the transistor die (fig. 1). The ladder network transforms the input impedance of the device in a controlled manner so it represents a low loaded Q at the frequency of use, hence the name, “Controlled Q Transistor.”

Gold metalization is used inside the MRF306 to provide high reliability, ruggedness, and long life. The device can withstand a load vswr of 30:1 at all phase angles at 60 watts CW output. This kind of ruggedness offers burnout protection against hazards such as a forgotten antenna connector or even a mislaid screwdriver!

**theory of operation**

The power amplifier described here is essentially a narrowband, parallel amplifier that can be tuned from 420 to 450 MHz. For conventional ssb use, a push-pull configuration should be employed; in this case, however, both transistors are being driven at less than what they are capable, and operate in the class AB linear mode. Fig. 2 is a spectrum display of a two-tone test I ran on the amplifier. The center frequency is 432 MHz, the two tones are spaced 500 kHz apart, and power output is 100 watts PEP. The drive level is approximately 10 watts PEP.

As you can see, the 3rd and 5th order intermodulation products are down 28 dB. IMD responses greater than −30 dB can be attained by running the amplifier at lower power levels (see fig. 3), but since 100 watts is intended to be the “worst-case” condition, I chose to demonstrate its response there. I might add that you should always pay very close attention to the linearity of any amplifier, especially when operating in crowded bands or when using one of the OSCAR satellites. When you operate an amplifier too close to the saturation point of the curve, you not only increase the incidence of spurious emission, your ssb signal also becomes mushy and distorted.

This power amplifier can also be used on CW and fm. When I first built the amplifier I biased it into class C, and was able to drive and sustain 140 watts of output power for more than 30 minutes (I cheated a bit by using a fan because the ambient temperature of the heatsink can rise above 80°C). If you wish to use the amplifier for either CW or fm, and not on ssb or a-m, you can replace the class AB bias circuit with a ferrite bead and a four-turn inductor from the base of each device to ground as shown in fig. 5A. The devices can be driven further into class C by placing a 2.7 ohm, ¼ watt resistor between the inductor and ground (fig. 5B). This resistor is required only if you desire greater efficiency or have a greater drive level capability.

**construction**

The amplifier is built on 1/16 inch (1.5mm) thick double-clad G10 epoxy-
glass printed-circuit board. I normally design with 1/16 inch (1.5mm) thick glass-teflon board, but at $135 a sheet it's a bit expensive for amateur radio projects. Epoxy-glass circuit board is somewhat lossy at 432 MHz, but is still quite acceptable for amateur use considering the cost differential.

However, it is imperative that you use double-sided board. It is also important that the ground on the bottom side be tied closely to the ground pads on the top side. This is accomplished by using either eyelets or plated-through holes from one side to the next. If you don't have eyelets you can do it by drilling holes through the board with a number-50 (1.8mm) drill; you then place number-18 or -20 (1.0 or 0.8mm) wire through the holes, solder both ends, and trim them off flush with the circuit board. I recommend that you make such a connection under each Unelco capacitor. As for the holes for the transistor flanges, a good drill, a file, patience, and a little elbow grease are all that is necessary.

The Unelco metal-clad mica capacitors have a dual purpose. Not only are they important to the input and output networks, they also serve as supports for the transistor leads. The Unelco capacitors are a bit expensive, but at these frequencies they cannot be replaced by anything other than porcelain chip capacitors such as those manufactured by ATC.

The transistors should always be screwed down to the heatsink (thermal compound underneath) before soldering the leads as it is possible to crack or break off the ceramic cap of the device. (The clearance holes in the flange are made for 4-40 [M3] screws.) Once this is done, the base and collector leads can be connected to the microstrip with 2 to 5 mil (0.05 to 0.10mm) thick copper or brass strap. Be sure that the width of the strap does not exceed the width of the microstrip.

The Arco variable mica trimmers work surprisingly well at uhf. Piston variables are better suited for uhf work, but here again the price tag is prohibitive. When you look at the bottom of the Arco variables you will notice that there are two small grounding tabs on each side. These tabs must be soldered to the ground plane to reduce the amount of lead inductance inherent in the capacitor. Be careful, when installing the capacitor, to make sure it doesn't short out the microstrip.

The collector and base biasing circuits are best placed between the two devices in the center of the board (see fig. 6). The 580 pF feedthrough capacitor, C12, is mounted on a piece of 0.7x0.4 inch (18x10mm) copper strap.

![fig. 3. IMD performance of the 100-watt 432-MHz power amplifier vs output power (Vcc = 28 Vdc, quiescent collector current = 100 mA).](image)
fig. 4. Schematic diagram of the solid-state 100-watt linear amplifier for 432 MHz. This amplifier may also be used on fm or CW by replacing the class AB bias circuit with a ferrite bead and inductor as shown in fig. 5.

A 0.192 inch (5mm) hole is drilled through the strap for insertion of the capacitor and a small right-angle bend is placed in the strap so it can be soldered upright on the board.

The 1 \( \mu F \) tantalum capacitor, C13, is connected on the side which is electrically closest to the power supply. The 0.1 \( \mu F \) disc capacitor, C11, is connected on the other side of the feedthrough. The collector chokes L3 and L4 come straight off the feedthrough to a point on the collector leads as close as possible to the cap of the devices.
bias circuit

As you may or may not know, the \( h_{FE} \) (dc current gain) of transistors will vary from device to device but will always stay within a prescribed tolerance. As a result of some laborious experimentation, I have determined that the biasing scheme used in this amplifier will keep the MRF306s biased between 20 and 50 milliamps of quiescent collector current. This variation in quiescent current has little or no effect in IMD performance but does have a small effect on gain.

The placement of the 1-ohm wire-wound resistors, R3 and R4, is not as critical as that of the collector chokes; it is still advisable, however, to have the bias brought in as close to the transistor package as possible. Remember, too, that the 1-ohm wirewound resistor acts as an rf choke. Carbon varieties will not work in this application.

It is necessary to use approximately 100 nH of inductance in series with the 6.8 ohm resistors, R5 and R6, as they are carbon-composition resistors. The junction point of diode CR2, resistors R2, R3 and R4, and capacitor C10 use the isolated tab of the Unelco capacitor as a standoff. The anode lead of the zener diode, CR1, may be soldered directly to the circuit board. The cathode lead then serves as a tie point for

fig. 5. Power amplifier can be operated in class C for fm and CW by connecting a ferrite bead and inductor from the base of each device to ground as shown in (A). The devices can be driven further into class C by adding the 2.7 ohm series resistor as in (B). Inductor L1 is 4 turns no. 22, 1/8" (3mm) inside diameter.

fig. 6. Component placement for the 432-MHz power amplifier. Full-sized printed-circuit board is shown in fig. 7.
resistors $R_1$ and $R_2$. The other end of resistor $R_1$ is connected directly to $+28$ volts.

Finally, the 100 pF series capacitor in the output, $C_9$, is mounted by placing it on its side on the microstrip with its isolated tab connected to the BNC output connector. This capacitor prevents and sufficient voltage regulation to prevent gross $V_{cc}$ fluctuations during load and no-load conditions, as encountered during modulation. Fig. 8 is a basic block diagram of a simple power supply that meets these requirements for this amplifier.

The transformer should provide from 26 to 35 volts with a current rating of 10 amps or greater. If you thumb quickly through practically any surplus parts catalogue you will find many suitable transformers at very reasonable prices. The bridge rectifier is anything capable of 10 amps. I recommend using the MDA962-1. A Motorola MPC1000 voltage regulator IC, followed by a large capacitor, will provide excellent regulation.

Tune-up of the amplifier is not as tricky as it may seem, although it will require a little caution at first. It is advisable, if you have a means of varying the drive level, that you begin by applying only 3 to 5 watts to the input. It is very important that you get the

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**fig. 7.** Full-sized printed-circuit layout for the 100-watt linear power amplifier. Component placement is shown in fig. 6.

WA7CNP

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collectors loaded to a "ball park" point before you start pouring on the coal.

When you first begin tune-up, adjust the input trimmers until you see a small deflection of output power. Then immediately adjust the output trimmers for peak output, ignoring the input match for the moment. The best way to adjust the output is to adjust C8 for a peak before adjusting C7 and C19. Capacitors C7 and C19 should be adjusted so that both Q1 and Q2 are equally sharing the load. Once you have a reasonably good collector load established, you can go ahead and do the same to the input match.

You will notice that, as output power increases, the output circuit will require small amounts of adjustment. This is because the required collector load impedance changes slightly as power increases. A small decrease in capacitance will probably be required on all the output trimmers as output power comes up. Alternately adjust the input and output circuits until you have reached your desired operating point (around 100 watts output).

The collector current should be between 6 and 8 amps depending upon the operating frequency. Capacitor C8

---

**fig. 8.** Basic block diagram of a regulated 28-volt supply for the 100-watt solid-state power amplifier. The Motorola MPC1000 is a positive voltage regulator designed to deliver up to 10 amps dc.
may be adjusted for slightly better efficiency but be careful not to drive the amplifier above 100 watts PEP output as severe flattopping will occur in the output waveform.

I hope you find this amplifier to be a useful tool in extending the capabilities of your 432 MHz station. There are many ways that this amplifier can be made to work even better, but it was my desire to make it as simple and inexpensive as possible without seriously degrading performance.

A lot of the technology employed in solid-state power devices and amplifier design is new to amateur radio (and to industry as well) but as soon as technical publications and education programs can get geared up to this new technology, this type of work will become more and more commonplace. It should be the job of amateurs who are familiar with this technology to show the rest how it is done, and also to be the first ones to improve its implementation.

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**Fig. 9.** Plot of drive vs output power for the 100-watt 432-MHz power amplifier operating in class AB (Vcc = 28 Vdc). Note that the knee of the curve is just above 100 watts output; this corresponds to the rolloff in IMD performance shown in fig. 3.

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Ham radio
The continuing increase in the popularity of autopatches, on both two meters and 450 MHz, coupled with the large number of hand-held fm transceivers now available, has generated the need for a truly compact tone encoder. With the introduction of a single-chip IC for this purpose, the handie-talkie Touch-Tone is now a practical achievement and for less than $35 you can enjoy all the benefits of your autopatch while operating portable with a handie-talkie.

The Motorola MC14410 is a complementary mos IC and is functionally a 2-of-8 tone encoder or Touch-Tone. It is available in both plastic and ceramic packages, but for amateur purposes there is no reason to pay the premium for the ceramic package. Designed for 4.4 to 6 volts, it will withstand moder-
ate over-voltages. As it requires only 4 to 5 mA, it has little effect on the total current drawn by the radio and can be switched with the T-R key. The IC is complete within itself except for a 1-MHz crystal and the necessary components to limit voltage and match the output to the radio.

Unlike many other hybrids available today, the MC14410 is not susceptible to rf interference, so close proximity to the transmitter is no problem. The board shown here was designed to slide into the PL area of an Omni-housing Motorola HT220 radio. Fortunately, it is small enough to be tucked away in some corner of almost any fm transceiver. The crystal can be remoted on pigtails, and does not have to be mounted on the printed-circuit board, but can be located wherever space is available.

construction

Any good PC board material can be used for the circuit board. Since the solder pads are small, a board with good adhering foil is necessary; the phenolic materials seem to lack this attribute. Use a number-64 (0.9mm) drill and a high-speed drill motor to avoid tearing the pads. The IC should be soldered in last to avoid any possible static build-up on the MOS devices. Use a soldering iron, not a gun. Pins 1 and 7 are clipped off as they are not used.

Very flexible, fine gauge wire is advised for the board-pad leads; the leads should be approximately 2-1/2 inches (6.5cm) long. Solder all the wires to the board first; Teflon insulated wire is easier to work with because the insulation doesn’t melt at soldering temperatures. The double pad on pin 11 of the IC is for the fourth column tone if you have a 4x4 keyboard — it was not needed here.

As shown on fig. 1, the 1-μF capacitor, C1, must be a nonpolarized unit. An alternative is to use two 1-μF electrolytics in parallel with reversed polarity. Since the output is approximately 25 kilohms to ground, the capacitor can be tied directly into the audio line.

A zener diode, CR1, is used to limit the voltage to the IC at high battery conditions; it should be picked so that \( V_{bat} - V_z = 7 \) volts. For the HT220, since the battery goes to approximately 16 volts at full charge, a 9-volt zener is used. Then, when the battery is low, there will still be 4.5 volts (13.5 - 9 = 4.5 Vdc) available for the encoder.

fig. 1. Schematic diagram of the miniature Touch-Tone encoder for the HT220 fm handle-talkie.
The Chomerics ER-21623 pad pins must be clipped to approximately 1/8 inch (3mm) so they will clear the components of the HT220. Remove the fuse in the HT220 front cover from its clip while cutting the slots for the pins. An Xacto saw works well after pilot holes have been drilled; a Dremel Mototool could also be used. Extreme neatness isn't necessary as the Chomerics pad will completely cover the slots after it is epoxied into place.

The four plastic pins at the corners of the pad should be cut off and filed flush with the case. Fit thin pieces of cardboard around the pin areas to support the pad (see fig. 4). The pad is then epoxied to the front of the radio. Be sure to roughen the plastic of the radio with fine sandpaper to insure a good bond. Also, be careful to only epoxy the four edge rails of the pad. A little goes a long way, and epoxy can seep around the inside edges of the pad and make it inoperative.

After the epoxy has hardened, you are ready to put it all together. The pins of the pad should be tinned using a good clean hot iron. Do not overheat the pins as they will come free internally from the pad, resulting in erratic or no operation. The eight wires from the circuit board can then be soldered to the keyboard. The B+ supply, ground and audio are picked up as shown in the photograph. The difficult part is stuffing all those wires in. A gentle loop between the front cover and main circuit board will suffice, and there don't appear to be any detrimental effects from having the eight wires right next to the radio circuitry.

The output potentiometer, R4, should be adjusted to produce a 4 to 5 kHz final frequency deviation when one key is depressed. This assumes, of course, that the radio's modulation causes a similar deviation during normal voice operation. Note that the microphone is live, so use precautions while dialing.

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how to use milliammeters

A discussion of meter shunts and other techniques to adapt surplus panel meters to the operating requirements of your own circuits

It is not necessary to determine the meter resistance to apply this ancient trick, although that is not particularly difficult, and meter shunts can be satisfactorily made with readily-available materials. For example, on a recent rig I shunted a 60 mA meter to read 600 mA, a 200 μA meter to read 20 mA and a 100 μA meter to read 10 mA. The basic test setup for current-meter shunting is a variable current source and a calibrated meter, either a small battery, with a series variable resistor, or an adjustable current-limiting power supply such as the Heath HP-28 which can be set at the desired full-scale current.

For milliammeters, shunt resistances are often very small: a 10 mA meter, for example, is likely to have about 2.5 ohms internal resistance and a 200 mA meter, about half an ohm. In the resistance ranges desired, copper wire makes quite satisfactory shunts.

meter shunt theory

For full-scale meter readings there will be an IR drop across the meter. If it is desired that the meter read full scale when the total circuit current is higher, the shunt must have whatever resistance required.
will pass all the additional current at the same IR drop. For example, a 10 mA meter with 2.5 ohms internal resistance will have an IR drop of \((0.01 \times 2.5 = 0.025 \text{ volt})\). If you wish the meter to read full scale when the circuit current is actually 100 mA, the shunt must pass 90 mA at 0.025 volt, which calls for a 0.278 ohm shunt \((0.025V \div 0.09 \text{ mA} = 0.278 \text{ ohm})\). A standard-value 0.27 ohm resistor will do the trick.

It is not difficult, however, to zero in on the right shunt value without knowing the internal resistance by taking a random length of small copper wire, placing it in series with the constant-current source, connecting the meter to one end and tapping it (with a needle-tipped probe) along the shunt wire until the meter reads full scale. Number-30 enamel wire, for example, has about 0.1 ohm per foot (3.28 ohm per meter) and the resistance and current-carrying capacity of other wire sizes appear in the ARRL Handbook. Thus, 2.8 feet (85.3cm) of number-30 wire wound in a small coil would make a suitable shunt for the previous example.

A lot of trial and error can be saved, however, by some simple calculations. Start by making a trial shunt, erring on the low resistance side if you have limited control over your constant-current source. Here is how it went shunting a 60 mA meter to 600 mA. With about 3 inches (76mm) of resistance wire, 60 mA in the circuit produced a meter reading of 15 mA, meaning that 45 mA was being passed by the shunt. As the IR drop across the meter and the parallel shunt is the same, two Ohm's law expressions can be stated in terms of three unknowns: the meter resistance, \(R_m\), the test shunt resistance, \(R_s\), and the common voltage across the meter and shunt, \(E\).

\[
\begin{align*}
E &= 0.045 R_s \\
E &= 0.015 R_m \\
R_s &= 0.333 R_m
\end{align*}
\]

When this meter is used in the 600 mA circuit the required current division between the meter and the shunt is 60 mA through the meter and 540 mA through the shunt. Using the same set of equations, the relationship of the meter resistance to the desired shunt resistance, \(R_s\) is calculated as follows:

\[
\begin{align*}
E &= 0.540 R_s' \\
E &= 0.060 R_m \\
R_s' &= 0.111 R_m
\end{align*}
\]

Since the meter resistance, \(R_m\), is an unchanging value, the desired shunt resistance, \(R_s'\), compared to the test shunt resistance, \(R_s\), is:

\[
\frac{R_s'}{R_s} = \frac{0.111 R_m}{0.333 R_m} = 0.333
\]

This is the same as saying that the wire in the desired shunt should be exactly one-third the length of the wire in the test shunt. The unknowns are still unknowns, but the desired result has been achieved.

When shunting sensitive milliammeters or microammeters, a low-range resistance decade is nearly essential because the resistance values are too high for lengths of copper wire. Alternatively, a small-value potentiometer can be used as a variable shunt, the value set for full-scale reading at the desired circuit current and then measured with an ohmmeter.

The approximate shunt values can be estimated by noting that 1 mA meters typically have about 30 ohms resistance; 500 \(\mu\text{A}\) instruments, about 90 ohms; 100 \(\mu\text{A}\), 500 ohms; and 50 \(\mu\text{A}\), about 2500 ohms. (If a decade resistance box is used, be sure it has shorting contacts or the full circuit current will instantaneously go through the movement during switching!) With this technique, the actual value of the desired shunt is determined and it is possible to select series or parallel combinations of stan-
standard-value resistors that will closely approximate the desired shunt value.

Note that decade resistance boxes can be constructed with only four resistances by using the Mallory type 154L switch, which automatically arranges a 1-ohm, two 2-ohm and a 5-ohm resistor so as to provide the entire decade range. In the one-tenth to one ohm range switch contact resistance is not likely to be serious. Such a decade will be very convenient if you plan to design shunts for very many meters.

There is less chance of blowing out meters accidentally in test set-ups if you wire the shunt in series with the current source and tap the meter around the shunt, rather than the other way round.

You will probably find that resistance wire is a bit hard to come by, and generally bare wire intended for heating elements is all that can be found. Standard Scientific Supply* carries Chrome-A resistance wire (80 percent nickel and 20 percent chromium) which has the best temperature/resistance relationship. Its resistance characteristics are listed in table 1.

critical damping resistance

If a meter is heavily shunted, the movement will be severely damped by self-induced current, and this may be undesirable in applications such as measuring the plate current of a linear, or VU instruments. The amount of damping can be reduced by putting a small resistor in series with the movement and shunting the combination of that resistor with the movement.

An interesting experiment with a sensitive high-quality meter is to vary the shunt resistor with a potentiometer and observe how the needle oscillates before finally coming to rest. The largest resistance for which the needle approaches the final setting without overswing is called the critical damping condition. With more resistance there will be a slight overswing, and with less resistance the final setting will be approached more slowly.

In amateur applications there is no particular need to achieve critical damping, but it can easily be approximated by making the series combination of the shunt and resistance in series with the coil equal to the critical damping resistance.


<table>
<thead>
<tr>
<th>B&amp;S gauge</th>
<th>diameter (mm)</th>
<th>resistance per foot (ohms)</th>
<th>resistance per meter (ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>0.0400&quot; (0.102mm)</td>
<td>0.406</td>
<td>1.332</td>
</tr>
<tr>
<td>20</td>
<td>0.0320&quot; (0.81mm)</td>
<td>0.635</td>
<td>2.083</td>
</tr>
<tr>
<td>22</td>
<td>0.0253&quot; (0.64mm)</td>
<td>1.017</td>
<td>3.337</td>
</tr>
<tr>
<td>24</td>
<td>0.0201&quot; (0.51mm)</td>
<td>1.610</td>
<td>5.282</td>
</tr>
<tr>
<td>26</td>
<td>0.0159&quot; (0.40mm)</td>
<td>2.570</td>
<td>8.432</td>
</tr>
<tr>
<td>28</td>
<td>0.0126&quot; (0.32mm)</td>
<td>4.100</td>
<td>13.451</td>
</tr>
<tr>
<td>30</td>
<td>0.0100&quot; (0.25mm)</td>
<td>6.500</td>
<td>21.325</td>
</tr>
</tbody>
</table>

meter multipliers

Voltmeters can also be multiplied using additional series resistors, and low-current milliammeters or microameters can be easily converted to voltmeter use. In this use, it is well to operate far below the wattage rating of the shunts because the temperature coefficient of standard carbon resistors is not the best. In addition, the maximum voltage across any one resistor should be kept below about 400 volts.

One of the best uses for shunts is for multi-circuit metering of equipment where different current or voltage ranges are desired for each circuit. In such configurations it is very useful to mount the shunts on the switch — generally a non-shorting type. You must watch the voltages on the various circuits, and on the meter as well. Current production panel meters from Weston and other firms built to government

Specifications are tested at 3000 volts (actually 2600 volts rms) between the movement and the case, but very old meters with metal zero-adjust screws should be used in high-voltage circuits only with great caution.

If a multiplier resistor is used to expand the range of a voltmeter which is switched off the multiplier, leaving the multiplier resistor floating, it will assume the full voltage potential which may be more than the switch insulation can stand. A better approach is to run the multiplier to ground, taking the voltage off a tap on the multiplier resistor. With this arrangement, the voltage across the switch contacts will be far less.

**Ayrton Shunt**

You can easily convert a sensitive meter into a multirange milliammeter with a few standard-value resistances and a switch using the configuration known as the Ayrton shunt shown in fig. 1. The values given will yield full-scale readings of 10, 100 and 1000 milliamperes within a few percent from a 1 mA meter with 50 ohms internal resistance. If your meter has less internal resistance, add enough resistance in series to bring it up to that value. A

To make a rough way to measure internal meter resistance is to adjust a constant-current source through a resistor to bring the meter to full scale, and then add enough resistance in parallel to bring the meter to half scale. The added resistance then equals the meter resistance.

Meters are sometimes found with non-linear movements, and they can be particularly useful in some applications (and of course internal resistance cannot be found in the manner just described).

---

**Fig. 2.** This wide range rf wattmeter uses surplus non-linear “antenna current indicator” meter used in Command Set transmitters.

Many amateurs have such meters in their junkboxes which were salvaged from war surplus Command Sets, a 2½-inch (64mm) meter with a zero-to-ten indication labelled, “antenna current indicator.” Half-scale of this meter is about 5 milliamperes, but it is very sensitive at the low range and very insensitive at the high range. Built into the rf wattmeter shown in fig. 2, a scale reading of 1 corresponds to 40 milliwatts on my instrument, 5 corresponds to 1.6 watts, and 9 corresponds to 17 watts. This wattmeter is for 75-ohm systems but a similar arrangement could be built for 50 ohms (I often use 75-ohm coax, as low-loss 75-ohm CATV cable is often available on the surplus market.

If you cannot find a non-linear meter you can achieve the same result by shunting any meter with diodes and add-
ing enough series resistance to the movement to bring the combined IR drop to about the contact potential of the diode. Table 2 gives the full-scale IR drop of a common (and typical) series of panel micro/milliammeters. Since silicon diodes start to conduct at about 0.6 volt, nonlinearity is achieved by adding enough series resistance to the movement at \( R_y \) in fig. 3 so that the combined IR drop is in this general range.

If too large a resistance is added the meter will not reach full scale; if just enough resistance is added so that full scale can be achieved the reading will be very nonlinear, and by adding less the linearity is improved. In fact, merely adding a protective diode alone will produce some degree of non-linearity, although it is not likely to be noticeable except in microammeters.

Parenthetically, meters are protected only up to the point where the shunting diode blows out, and with high-current diodes available so inexpensively on the surplus markets, it makes sense to use a 10-ampere diode in any setup (such as an experimental bench supply) where short circuits are occasionally possible. These diodes need not be heatsinked.

Nonlinearity of the opposite sort can be achieved by putting zener diodes in series with meters, and some very odd curves of current versus needle deflection can be obtained by various combinations of zeners and shunt diodes. All of these effects, of course, ruin the original scale calibration.

Zener diodes in series with milliammeters result in expanded-range volt-

\[ \text{fig. 3. Simple circuit for non-linearizing meter movements uses semiconductor diode (see text).} \]

meters. For example, a 150 volt, 10 watt zener such as the 1N3011, in series with a 1N4007 and 100-ohm resistor, spreads out 100 to 130 volts over the entire scale of a 50 mA meter. The amount of resistance determines the amount of compression. Lower voltage zeners — typically just above the target voltage — are very useful for expanded scale monitors of battery packs and transmitter filament voltages. The additional series diode is only necessary when monitoring ac.

**summary**

Liberal use of meters can be one of the design features where the home builder can outshine the commercial source. Good quality panel meters are still in abundant supply in surplus and at flea markets, often at very low prices. Changing scales and ranges is not very difficult for many types, though it is not possible to open up the newer hermetically sealed-instruments. The more odd-ball the scale, of course, the lower the selling price.

**bibliography**

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More Details? CHECK-OFF Page 110
magnet-mount mobile antenna

This simple, magnet-mount vhf antenna is useful for temporary mobile operation where a permanently mounted antenna is not available.

A magnet-mount antenna is an indispensable item for anyone currently working vhf fm on 144, 220, or 450 MHz. When used in conjunction with a cigarette lighter adapter to provide 12 Vdc for the fm rig, it permits mobile operation from almost any vehicle at a moment's notice. Thus, from an emergency standpoint, you are not restricted to a vehicle already equipped with a vhf antenna. In addition, the magnet mount is useful for those who do not wish to cut a hole in their car to operate mobile.

Unfortunately, commercially available magnet-mount antennas are expensive, and up to now it has been difficult to obtain magnets with the right surface area, the right holding power, and the right price. This article describes a very simple quarter-wave magnet-mount antenna which can be built in about a half hour for any of the three vhf bands mentioned. The total cost of the antenna, not including coaxial cable, is less than $6.00. All parts are readily available, and the magnets can be obtained locally.*

The magnet-mount antenna is really too simple for words; fig. 1 shows a drawing of the antenna. It simply consists of a good quality magnet, a 1\(\frac{1}{2}\) inch (38mm) long 6-32 or 8-32 (M3.5 or M4) flat-head screw, three nuts, a lock washer, coax connectors, and a cable clamp.

construction

To build the antenna, connect a female uhf chassis connector to the magnet as shown in fig. 1. Run the coax under the cable clamp (or tape the coax to the screw if you don't have the clamp), and connect the inner conductor to the center of the coax connector and the shield to the flange. Take a piece of brazing rod of the proper length (see fig. 1), and solder it to the male uhf connector. Use some silicone

*If you can't find a local source, the 1\(\frac{1}{2}\) inch diameter magnets are available for $3.95 plus postage from George Allen Engineering, 8C Farmstead Lane, Windsor, Connecticut 06095. Connecticut residents add 6% sales tax.
bathtub caulking such as that made by GE to fill up the male connector to provide a good seal. The brazing rod can be obtained from any welding supply house.

In regard to the magnet, use round button or shallow pot Alnico magnets or equivalent of 1¼ or 1½ inches (32 to 48mm) diameter. Magnets of this size provide enough holding power, while smaller magnets won’t hold well and will blow off your car at high speeds. Note that when your antenna is not being used, make sure that the “keeper,” the small metal piece provided with the magnet, is placed across the poles of the magnet. The use of the keeper prevents loss of magnet power.

tuning

Although this simple magnet-mount antenna will give you good results, it is not quite as efficient as a quarter-wave antenna permanently mounted on your car. In most cases, however, you probably couldn’t see the difference between the magnet-mount antenna and one that is permanently mounted. In regard to feedline matching, it is difficult with this type of antenna to get the swr down to 1:1. However, this really doesn’t matter since your feedline is very short and the overall losses will be small.

To tune the antenna, place the antenna on the center of the car roof or trunk and connect an swr bridge in the line between the transmitter and the antenna. Start snipping off pieces of brazing rod by 1/8 inch (3mm) at a time until the swr falls between 1.5:1 and 2:1. At this point the antenna is tuned, and the only remaining thing to do is to put some silicone seal or tape on the end of the antenna to protect against injury. Note that the swr may vary when the antenna is used with different cars.

performance

I have been doing quite a bit of traveling in the last six months and have been taking this antenna with me. It is convenient to use, works well, and has yet to come off a car roof at speeds up to 80 mph. I have been using the antenna on all sorts of rental cars and have had no problems except where the car has a vinyl roof. In those cases I place the antenna on the trunk. The magnet won’t hold well through the thickness of the vinyl.

In practice, I place the antenna on the center of the roof or trunk and run the coax through a window, leaving the window slightly open so as not to damage the cable. I connect the coax to my rig and I’m on the air! It does not appear to be necessary to protect the car paint from the magnet. I have been using these mounts for four years and have yet to scratch the paint with a bare magnet.

I hope that this short article gives you the incentive to build this simple antenna; it’s handy either for daily use or to keep in the closet for use in that emergency when you can’t use your own car.
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<table>
<thead>
<tr>
<th>BAND</th>
<th>BANDWIDTH</th>
</tr>
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<tbody>
<tr>
<td>160</td>
<td>50</td>
</tr>
<tr>
<td>80</td>
<td>200</td>
</tr>
<tr>
<td>40</td>
<td>entire band</td>
</tr>
</tbody>
</table>

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300-Hz crystal filter for Collins receivers

Recently a number of 455-kHz Collins crystal filters with a 6-dB bandwidth of 300 Hz have become available on the surplus market.* These filters, which were built to military specifications, have a 60-dB bandwidth of 1200 Hz and maximum insertion loss of 5 dB, are designed for a source and load impedance of 2000 ohms, and do not require any resonating capacitors† (mechanical filters for Collins receivers are designed for terminations of 50 kilohms or greater and require external capacitance to resonate the transducer coils). If the crystal filter is not terminated with 2000 ohms, passband ripple will be on the order of 6 dB or more and spurious response will seriously degrade skirt selectivity.

Since the filters in Collins receivers are isolated by dc blocking capacitors, the required terminations for the crystal filter are most easily provided by simply connecting 2200-ohm resistors across the input and output terminals. Be sure to remove the 100 pF resonating capacitors from the circuit, however, as they will cause excessive passband ripple and unwanted spurious response. When terminated with 2200-ohm resistors passband ripple is nil and the skirts roll off smoothly to 80 dB or more.

Unfortunately, however, this simple resistive loading results in a serious impedance mismatch which manifests itself as 10 to 12 dB of additional circuit loss. Increasing the terminating resistors to 3900 ohms will reduce the loss about 3 dB, but passband ripple starts to suffer. A better solution is to drive the crystal filter with the simple emitter follower circuit shown in fig. 1. This circuit, which requires only 10 mA of current, reduces circuit loss to 3 dB or less and provides the filter with the required source impedance.

The emitter follower can be built on a small section of perforated circuit board which is supported by the input and output wiring. Power is derived from the screen circuit of the mixer tube. Make sure that the emitter follower is properly isolated with dc blocking capacitors as any dc voltage on the filter transducers will damage them (the filter switch has shorting contacts, so any voltage on the switch may damage adjacent filters as well). However, if you follow the circuit shown in fig. 1, which is completely isolated, you will have no difficulties.

Installation of the filter in 75S3B and later model S-line receivers requires only a length of number-20 (0.8mm) tinned bus wire, a lockwasher, and a 4-40 nut. The filter is installed below the chassis, on one side of the filter shield compartment, as shown in fig. 2.* The Collins 300-Hz crystal filters, X455KF300, with data sheets, are available from Gary Fertik, W1EBC, 40 Pilgrim Trail, Woodbury, Connecticut 06798. Price is $49.95, postpaid.

†The Collins 300-Hz crystal filters, X455KF300, with data sheets, are available from Gary Fertik, W1EBC, 40 Pilgrim Trail, Woodbury, Connecticut 06798. Price is $49.95, postpaid.

Jim Fisk, W1DHY, Ham Radio Magazine, Greenville, New Hampshire 03048
(installation suggested by WA8OBG). Three holes are required: two for the electrical terminals and one for the mounting screw. Since these holes are below the chassis the filter installation does not deface the receiver. The filter is symmetrical so either end may be used for the input or output.

**Collins 75A4**

Owners of Collins 75A4 receivers should be particularly interested in the 300-Hz crystal filter as the narrowest bandwidth filter designed specifically for this receiver has a 3-dB bandwidth of 500 Hz, and these filters are very difficult to find on the open market. Although there are two methods of installing the 300-Hz crystal filter in the 75A4, the installation shown in the photograph is recommended because it provides maximum isolation between the input and output (this same method is also recommended for Collins type-FA mechanical filters).

Turn the 75A4 upside down on your bench (front panel forward) and remove the bottom cover. The three filter sockets are in the front right-hand corner next to the selectivity switch. The crystal filter is installed in the shield which crosses the three filter sockets. Two 1-inch (25mm) deep slots must be cut in the shield as shown in fig. 3. Use sharp tin snips and place rags underneath the work area on both sides of the shield to catch any debris. After cutting the slots, bend the tab toward the rear of the receiver so it forms a 90-degree angle with the shield. A hole for the filter mounting screw is drilled in the center of the tab, ¼ inch (6mm) from the end (the threaded stud on the other end of the filter is not used).

After the tab is finished, temporarily set the filter in place to check for clearance between the top of the filter and the bottom cover of the receiver (if you follow the dimensions shown in fig. 3, the top of the filter should be approximately flush with the top of the shield). Locate the input and output wires to filter socket A (underneath switch S2) and their respective connection points on the switch wafers (note that one of the wires is grounded). Remove the two 100-pF resonating capacitors. Install the emitter follower circuit shown in fig. 1 between switch S2 and the crystal filter. The emitter follower common is con-

---

*In some Collins 7553B receivers there is sufficient clearance under the filter shield on the top of the chassis that the crystal filter can be installed in the existing crystal-filter sockets. Although the terminals of the X455KF300 will not fit the sockets, short lengths of no. 20 (0.8mm) wire can be soldered to the filter terminals and plugged into the sockets.*
nected to the grounded terminal on the rear wafer of S2; the input coupling capacitor, C1, is connected to the other switch terminal which goes to filter socket A. Install two short lengths of number 20 (0.8mm) bus wire to each of the connection points on the front wafer of switch S2. (If you don’t want to include the emitter follower, connect bus wires to the rear wafer as well.)

Connect a 2200-ohm resistor across the output terminals of the crystal filter and install the filter on the mounting tab using a lockwasher and 4-40 nut. Wire in the emitter follower and solder the two bus wires to the output terminals. Total installation time should be two hours or less.

Since you have the bottom of the receiver open, this is a good time to apply some contact cleaner (such as GC Electronics Tunerlube) to each of the switch contacts. It’s also a good idea to dab some silicone grease on the switch detent mechanisms. If your 75A4 is like most, the only lubrication the receiver has ever seen was applied at the factory, and that’s pretty well dried up. A little switch care now may save an expensive replacement problem later.

An alternative method is to mount the crystal filter on a small L-shaped bracket which is attached to the chassis with the screw which holds the left-hand end of the filter shield (next to the i-f gain control). In this case the filter connections are made to filter socket C. However, this method is not recommended because the connecting wires are quite long and lowered input-output isolation degrades the high skirt selectivity of which the filter is capable.

**operation**

If another mechanical filter is installed in filter socket A, it must be moved to socket B or C. Operation of the 75A4 with the sharp 300-Hz filter requires some practice to gain full advantage of its high skirt selectivity. The setting of the passband tuning control is quite critical and for best results should be set so that CW signals peak at a pitch of about 700 Hz. When you tune in a signal with a broader filter, set the main tuning for a 700-Hz note before switching the sharper 300-Hz filter into operation. If the signal is tuned for a higher or lower note (assuming the passband tuner is set for 700 Hz), the receiver must be retuned slightly to find the signal. With a little practice, you’ll find that the narrow bandwidth and high skirt selectivity of this filter do an excellent job of cutting interference or digging into the noise for weak signals.
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Dear HR:

Due to the rather large response to my article on Touch-Tone decoders which appeared in the December, 1974, issue of *ham radio*, I have decided to offer printed-circuit boards for sale to those individuals who might want them. I am also putting together some kits for those builders who have a hard time finding all the necessary components. All the parts and materials are top quality, commercial grade and ICs will be pre-tested to ensure performance. A set of boards is $12.95, and a kit, including boards and toroids, is $37.50.

John F. Connors, W6AYZ
Electromedics
3295 Brookdale Drive
Santa Clara, California 95051

---

Dear HR:

A small number of the transceivers built from the ssb transceiver article in the August, 1974, issue of *ham radio* suffer from apparent AGC instability. The symptoms are generally motor-boat ing at certain signal levels.

The problem is not, in fact, due to the AGC but to instability caused by I-F feedback through the unused transmitter section of the circuit. It may easily be cured by connecting a single 0.1-µF capacitor with low RF resistance between the transmitter section power supply line and ground (as near as possible to the SL610C amplifier). Installing this capacitor does not remove the necessity of grounding the transmitter power line during reception and vice versa.

I apologize to anyone who has been inconvenienced by this fault, but the majority of these transceivers are not affected and the problem has only recently been brought to my attention.

Brian D. Comer, G3ZVC
Plessey Semiconductors

---

Dear HR:

I have been following the articles concerning direct-conversion receivers and find the communication between Madey and Shubert regarding the Phase II receiver in the June, 1974 *comments*...
section most interesting. The diagram of a quadrature-phased local oscillator I have been working on for use in a 3.5- to 4-MHz receiver is shown in fig. 2. As the timing diagram (fig. 1) demonstrates, the design is free of asymmetry errors since it is responsive to the negative-going transition of the clock waveform, and the clock may exhibit any periodicity it wishes, within device limitations. The circuit was intended for use with MC1496-type product detectors and has provision for switching the phase of the local oscillator to effect sideband reversal rather than performing the task at audio and having to accept a compromise in unwanted sideband rejection.

Douglas K. Beck, K6ZX
Sunnyvale, California 94086

Collins 75A4 mods

Dear HR:

Recently, when the avc failed in my Collins 75A4, the usual changing of tubes had no effect. Actually, a small amount of avc action remained — the S-meter needle rose slightly off zero with very strong signals. The trouble proved to be R86, a 39k resistor. Both R86 and R87 had suffered severe overheating — R86 had changed in value from 39k to approximately 3k, causing overheating of R87 and eventual failure of the avc.

My 75A4 manual lists R86 as a half-watt resistor. However, a friend has a later 75A4 manual, and it shows a rating of one watt (the serial number of my receiver is in the 2500 series). If you experience avc failure in your 75A4, first check R86 and, if you're working on the receiver anyway, make sure that R86 is a one-watt resistor.

Incidentally, I cannot recommend too highly the 75A4 mixer mods described by W6ZO in *Ham Notebook*. I installed them over a year ago and have been extremely pleased with the results. I also changed the first rf amplifier from a 6DC6 to a 6GM6 as recommended by W2VCZ, and recommend that, too, as it increases gain and sensitivity. However, I would not plug in the 6GM6 without first installing the W6ZO mixer modifications.

Bob Locher, W9KNI
Deerfield, Illinois 60015

September 1975
Heath HM-2102 wattmeter mods

Dear HR:

With reference to the item on the Heath HM-2102 wattmeter by VE6RF,* the following additional information might also be of some interest. It was interesting to read how one amateur solved the problem of calibrating his Heath HM-2102 below an SWR of 1.5:1. In my case the problem was solved in a slightly different manner.

In my initial calibration, using a Bird Termaline wattmeter, the minimum SWR null was about 1.3:1. This was within the specified limits called for in the Heath instruction manual and, for all practical purposes, should have sufficed. However, in actual tests erroneous readings were obtained, often below the 1.3:1 reference level. An inspection of the schematic shows that C3 in series with C4 (the trimmer) will produce a capacitance of 1.99 to 5.56 pF. The total capacitance would then have to be changed to either a value lower than 1.99 pF, or higher than 5.56 pF. A 2 pF capacitor placed across C3 showed that the null could not be brought down to less than 2:1. Obviously the total capacitance of C3 and C4 had to be decreased instead of increased.

Cutting the long lead from C3 to the circuit board and inserting several values of capacitance in series with C3 showed an immediate improvement in the null. In my case a 10 pF capacitor brought the null down to a 1:1 SWR. The total range of all three capacitors in series is now 1.66 to 3.57 pF. Replacing C3 with a capacitor of about 4 pF would probably have produced the same results. Since the capacitors in this circuit form an ac voltage-divider network, changes in this circuit will also affect the wattmeter reading so the wattmeter will also have to be recalibrated.

In my case no thought was given to changing capacitor C16 since this appears to be a bypass for frequencies outside the desired range of 50 to 160 MHz. Changes here could influence the sensitivity of the bridge and may even bypass energy at the wanted frequencies.

In addition to the above, I found two other slight modifications to be useful. The first concerns wattmeter calibration. According to the instruction manual, power calibration is performed with the wattmeter in the 25-watt range; no provision is made for calibrating in the 250-watt range. However, after calibrating the wattmeter on the low range using 20 watts of power, switching to the high range showed a meter reading of about 16 watts. An examination of the schematic shows that if R8, a 68k resistor, is replaced by a fixed resistor and potentiometer in series, a second calibration can be made on the 250-watt range which is quite accurate. In my case R8 was replaced by a 51k, 1/4-watt fixed resistor in series with a small 25k potentiometer.

The last modification was for convenience more than anything else. In order to locate the remote chassis closer to the coax feedline, the short piece of five-conductor cable supplied with the kit was replaced with similar cable about 6-feet (1.8m) long. One end of the cable was connected inside the cabinet in accordance with the instructions, but the other end was terminated in a small five-pin plug instead of being connected directly to the remote chassis. A matching five-pin socket was mounted on the chassis off to one side of coax connector A. Short leads were then run from the circuit board to the five-pin socket. To prevent RF from reaching the indicator unit through the cable, the ferrite beads supplied with the kit were mounted at the socket instead of on the circuit board. Now the indicator unit and remote chassis can be easily separated.


B. T. Ring, K3VNR
Riverdale, Maryland
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September 1975
non-synchronous impedance transformer

In matching one impedance level to another, as in antenna work, the usual device is a quarter-wavelength transformer section whose characteristic impedance is the geometric mean of the two impedances to be matched (fig. 1). When it is necessary to match one transmission line to another, and particularly in coaxial line applications, obtaining a length of line of the proper intermediate characteristic impedance may present a major problem.

The non-synchronous transformer shown in fig. 2 offers a way out of this dilemma. It is composed of two abbreviated lengths of transmission line of the same characteristic impedances as the impedances being matched. The procurement problem is therefore greatly simplified. As indicated in fig. 2, the transformer section length can be seen to vary according to the impedance ratio. For example, if a 2:1 impedance transformation ratio is required, each section of the transformer would be 28° 8', making the total length about 56½ degrees, or in terms of wavelength, 0.156 λ.

It must be pointed out that the non-synchronous transformer is not always interchangeable with the quarter-wavelength version. The quarter-wavelength transformer will match an infinite number of impedance pairs, as long as their geometric mean is equal to the characteristic impedance of the transformer. The non-synchronous transformer, on the other hand, will match only the impedance pair for which it was designed. Within these limits, however, the non-synchronous transformer compares very favorably in

\[ z_1 \rightarrow z_2 \rightarrow z_1 \rightarrow z_2 \]

\[ \theta \cdot \cos^{-1} \sqrt{\frac{z_1}{z_2} + \frac{z_2}{z_1}} \cdot \frac{\lambda}{2} \]

fig. 2. The non-synchronous transformer consists of two lengths of transmission line of the same characteristic impedance as the impedances being matched, with length varying according to the impedance ratio.
bandwidth as well as impedance-matching characteristics, and should find ready application in coaxial impedance-matching networks.

Henry Keen, W5TRS

drilling aluminum

The following hint for working with aluminum, which may not be common knowledge, was given to me by ham friends in Portugal: apply a drop or two of alcohol when drilling aluminum. It not only makes the work easier but results in a much cleaner cut.

Ralph Cabanillas, Jr., W6IL

metric conversions for screw and wire sizes

Here’s a conversion chart you can use for plugging in metric values for machine screws and wire sizes. *Ham radio* articles have been including metric equivalents for dimensions of physical quantities such as area, length, mass, temperature, and volume. We have wanted to include metric equivalents for machine screws and wire but have only recently been able to obtain equivalent data for this hardware from the International Standards Organization (ISO). The ISO standard has not yet been adopted by all countries, but these tables will at least give overseas readers an idea of what size the author specified in the nearest metric standard.

Jim Fisk, W1DTY

short circuit

In DJ2LR’s excellent article on crystal oscillators in the June, 1975, issue of *Ham radio*, there was an error in fig. 5 (10k pot incorrectly shown). The correct schematic is presented below.
High-current power supplies are an absolute requirement in commercial two-way radio shops and are now on the verge of becoming a requirement in the ham shack. Most of the new solid-state equipment being released for the amateur market is designed for 12-volt operation, either mobile or from a fixed station 12 Vdc supply. The 12-volt ac supply has been a problem in the past because well-regulated, high-current supplies tend to be complex and expensive to build while commercially available supplies are even more expensive and are frequently in short supply. VHF Engineering has recently announced two inexpensive solid-state 12 Vdc power supply kits which are simple to build and can be used in either commercial or amateur applications. Two models are available, the PS12C for 12 amps, and the PS24C for 24 amps.

The circuit for both power supplies consists of a full-wave dc current source feeding a capacitive filter network and an IC voltage regulator. The IC regulator controls a set of pass transistors and keeps the output voltage consistent to within 2% over a load range of from zero to 20 amps (zero to 10 amps in the PS12). Large heat sinks are provided to dissipate the heat produced by the pass transistors. The 12-amp supply is rated at 10 amps continuous or 12 amps for 50% intermittent duty. The 24-amp supply is rated at 20 amps continuous or 24 amps for 50% intermittent duty. Current limiting prevents damage to the supply in the case of an accidental short circuit. The output voltage of both supplies may be adjusted over a nominal range from 12 to 15 volts. The supplies may be used as general purpose, variable voltage supplies by replacing the voltage controlling resistor with a 10k potentiometer.

The VHF Engineering high-current power supply kits are complete with all parts, computer grade capacitor, epoxy glass circuit boards, styled case, and complete instructions. Average construction time is one evening or less. The 12-amp supply kit, model PS12C, is priced at $69.95 ($85.95 wired and tested). The 24-amp supply kit, model PS24C, is $99.95 ($114.95 wired and tested). For more information, write to VHF Engineering, 320 Water Street, Binghamton, New York, 13902, or use check-off on page 110.
The new six-ounce HP-21 from Hewlett-Packard is the smallest and lowest priced model in HP’s line, and is designed primarily for scientists, engineers and students. The HP-21 has all of the trigonometric and logarithmic functions of the HP-35. In addition, the user can calculate in either degrees or radians; convert from polar to rectangular coordinates and vice versa; format and round the display in either fixed or scientific notation; and perform register arithmetic (+, -, $\times$, $\div$) with the contents of the HP-21’s single addressable memory.

The new calculator has five fewer keys (30) than other HP pocket models, but since several keys serve dual functions, the HP-21 is able to perform more functions and operations than the HP-35. Like other HP pocket calculators, the HP-21 features the company’s RPN logic system with a four-memory stack that holds intermediate answers and automatically brings them back when needed in a calculation.

The HP-21 comes with an owner’s handbook, soft carrying case and an ac adapter/recharger that allows the calculator to be operated on ac while its batteries are recharging. Optional accessories include a security cradle and a reserve power pack (with batteries). The HP-21 will be sold through leading col-

In it you’ll find hundreds of quality consumer electronic products. Amateur radios, CB radios, scanners, antennas, masts, towers, rotors, tools, components, electronic kits, technical books, test gear, digital watches, calculators, portable radios, televisions, microphones, speakers, audio equipment, high fidelity, stereo systems, tape recorders, and much, much more. If it’s electronic and it’s quality, TECO has it.

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525-MHz uhf prescaler

The new Pagel model 525 uhf prescaler divides frequency by ten to extend the range of any 50 MHz or higher counter to the vhf and uhf bands. The unit also contains a 20 dB preamp for the unscaled 1 MHz to 50 MHz range to improve frequency counter sensitivity to 5 millivolts rms or better. Sensitivity is 50 mV rms at 500 MHz, and 30 mV rms below 400 MHz. A through-line feature with an internal signal sampler can be used with transmitters up to 100 watts (requires an external 50-ohm dummy load). This feature can be used to perform simultaneous power and frequency measurements and is a great time saver.

The model 525 operates from the 117 Vac line or battery power (8 to 15 volts) and may be used for portable or mobile use. Price is $159. For more information, write to Pagel Electronics, 6742-C Tampa Avenue, Reseda, California 91335, or use check-off on page 110.

evervelope detector

The Modset recently introduced by David R. Corbin Manufacturing is an envelope detector which can be used with an oscilloscope to provide a clear, hum-free display of the transmitted audio waveform from ssb and a-m transmitters. The Modset is built into a rugged, machined aluminum box, and includes input and output impedance matching and an overload protection circuit.

The Modset accepts any input signal from a few milliwatts to 25 watts peak power and operates over the frequency
range from 200 kHz to 30 MHz; to 50 MHz with slight reduction in output level. Higher power levels can be monitored by using a short whip antenna or probe instead of the 50-ohm direct coupling. Output level is 0.1 to 10 volts (relative to input power), dc reference plus recovered audio to 10 kHz. The unit is priced at $29.50.

For more information, write to David R. Corbin Manufacturing, Post Office Box 44, North Bend, Oregon 97459, or use check-off on page 110.

keyer chip adds dash memory

A companion to the 8043 keyer-on-a-chip has been announced by Curtis Electro Devices. Called the 8044, this new cmos IC offers dash memory in addition to the features found on the 8043. These are dot memory, dot, dash and space completion, instant start, key debouncing filters, iambic operation, internal sidetone, weight control and practically zero power dissipation.

An exact pin-for-pin equivalent to the 8043, the 8044 yields a top performance one-IC electronic keyer capable of running on 5 to 12 volt supplies. Usual power supply is a 9-volt transistor radio battery. The 8044 may be plugged into any keyer designed around the 8043 such as that described in the April, 1975, issue of Ham Radio.

The keyer kits are offered. The 8044-1 contains the 8044, a printed-
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This new book by Noel M. Morris provides all of the essential electrical and electronic formulas required by students, technicians and professional engineers. The rapid growth of electronics technology has made it practically impossible to memorize all the formulas which are required. This book contains all the basic equations in the fields of electronics, electrical engineering, control systems, measurements, logic, telecommunications and mathematics. Sections include electrostatics and electromagnetism, complex numbers, ac and dc circuits, transients, amplifiers and oscillators, modulation and transmission lines. The SI system of units is used throughout.

This book assumes that the reader is familiar with each of the formulas, so it does not provide any typical examples or information describing how to use them. However, for the serious worker who frequently needs this information, this valuable book provides it all in one place. 26 pages, softbound, 8½ x 11½ inches, $2.95 from Halstead Press, a Division of John Wiley & Sons, 605 Third Avenue, New York, New York 10016.
tracking voltage regulators

Three new dual tracking voltage regulator ICs are now available from National Semiconductor. Called the LM125, LM126 and LM127 (LM325, LM326 and LM327 for commercial temperature range), the regulators are designed to provide balanced positive and negative output voltages at currents up to 100 milliamps. Input voltage can be as high as ±30 volts, and there is a provision for external adjustable current limiting.

The LM125 provides tracking outputs of ±15 volts making it ideal for op amp power supplies. It features output voltages balanced to within 1% and line and load regulation of 0.06%. The LM126 provides ±12 volt outputs balanced to within 1% and features line and load regulation of 0.08%, while the LM127 has +5 and -12 volt outputs which are compatible with most mos circuits.

For more information, contact National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, California 95051, or use check-off on page 110.

stepped drill bit

The Unibit, a versatile single flute step drill that does the work of thirteen conventional twist drill bits, is now available. The first Unibit model, designed to fit any three-jawed ⅜" (6.5mm) chuck, is intended primarily for use with hand-held electric drills. It has a starting diameter of 1/8" (3mm)
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This keyboard produces a standard ASCII coded output that is compatible with TTL, DTL, RTL and MOS logic systems. You have the option of wiring the kit for normal typewriter style output in both upper and lower case letters, or all upper case format. All common machine control commands such as "line feed", "return", "control", etc. are provided on the keyboard. Four uncommitted or extra keys are available for your specific use requirements. Two of these have isolated output lines to the connector for special functions such as "here is".

Keyswitches are standard, full travel style with gold plated contacts for long troublefree service. Requires +5 Volts and -12 Volts.

KBD-3 Keyboard and Encoder Kit $49.50 ppd

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and each of twelve succeeding steps removes material in 1/32" (0.8mm) increments up to 1/2" (12.5mm) diameter. Each step penetrates material up to 1/8" (3mm) thick.

The Unibit is made of industrial grade high-speed steel, heat treated and tempered to assure maximum strength for long wearing, rugged use. It exhibits superior characteristics when drilling thinner gauges of sheet metals such as steel, copper, brass and aluminum as well as most plastics and wood. Starting a hole with the Unibit is a snap because its single flute design eliminates skidding and the need for center punching. Chatter and vibration are also kept to a minimum. Its design geometry also helps prevent the Unibit from penetrating softer material too fast and "hogging-in."

Many other operations, considered difficult with conventional twist drills, can be conveniently accomplished using the Unibit. Its unique cutting edge angle automatically de-burrs a hole, eliminating a time consuming countersink tool change. The Unibit allows for sizing or aligning and reaming operations, drilling intersecting holes as well as enlarging a slot or a square into a round hole. In addition, the Unibit is available with a special non-slip key on its shank that prevents it from spinning in the chuck.

The newest Unibit drill, Model II, enables the drilling of eight round holes, sizes 9/16-inch (14.5mm) to one-inch (25.5mm), with a single bit. The Unibit II requires a starting diameter of 1/2-inch (12.5mm) or larger and removes material in 1/16-inch (1.5mm) increments in eight steps.

Designed for use with any 1/2-inch drill chuck, Unibit II works equally well with hand-held electric drills as well as drill press equipment. The Unibit II is made of industrial grade, high speed steel, heat treated and tempered to assure maximum strength for long wearing use. It's patented design features a single flute to assure smooth penetra-
tion of materials and, unlike conventional twist drills, it is easily sharpened without special tools. Unibit II is extremely versatile and allows the user to perform many operations including intersecting holes, making round holes from slots, hole de-burring and a "hole-opening" reamer.

Unibit literature, information and prices are available by contacting the Unibit Corporation, Box 331, Department 2, Wyoming, New York 14591, or by using check-off on page 110.

how to use ic logic elements

Just released and completely illustrated, this new book by Jack Streater is designed to help the engineer or technician who has not previously used or designed digital logic circuits meet the challenge of digital ICs in electronics. The practical problems and limitations of connecting IC logic elements into logic systems to accomplish the required result are thoroughly covered.

The first two chapters cover binary, BCD, and decimal number systems and Boolean algebra with its applications to simple switching circuits. The next two chapters discuss gates and gate combinations, and the following chapter explains bistable elements and their uses. Then the logic families (RTL, DTL, TTL, ECL, CTL or CML, MOS and diode logics) are discussed and compared.

Another chapter is devoted to off-the-shelf logic elements—breadboarding, testing, troubleshooting and locating sources of data on integrated circuits. The final chapter includes experiments to aid in understanding the operation of logic circuits. A glossary of digital terms has been included as an appendix.

Soft cover, 160 pages, $4.50 from HR Books, Greenville, New Hampshire 03048.

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September 1975
A revolutionary "new generation" transceiver. It's completely solid-state and totally broadbanded to eliminate preselector tuning. And the output can be instantly switched from 100 watts to 1 watt. The true digital readout offers resolution down to 100 Hz and outstanding tuning accuracy. Receiver intermodulation distortion has been minimized and there are very few active devices ahead of the highly selective crystal filter. Adjacent channel overload is negligible, yet sensitivity is better than 1 µV (.6 µV typical) and front-end overload is dramatically reduced. The "104" is 12 VDC-powered for mobility and the optional HP-1144 fixed station supply fits inside the 33-604 speaker cabinet. An optional noise blanker can be installed in the "104" and an optional 400 Hz crystal filter improves CW selectivity.

Kit SB-104, 31 lbs., mailable .................................. 669.95*
Kit SBA-104-3, 400 Hz CW crystal filter, 1 lb., mailable ................................. 36.95*
Kit SBA-104-1, Noise blanker, 1 lb., mailable ................................ 28.95*
Kit SBA-104-2, Mobile mount, 6 lbs., mailable .................................. 36.95*
Kit HP-1144, Fixed station power supply, 28 lbs., mailable .......................... 89.95*

SB-634 station console combines 5 convenient accessories
The "634" performs 5 important functions—a 10-minute digital 1D timer with visual or visual and audible indicators an RF wattmeter that reads 0-2000 or 0-2000 watts with ±10% accuracy, an SWR bridge, a hybrid phone patch that can be used manually or with VOX control, and a 24-hour digital clock that runs independently of all other functions. It's a must for every well-equipped station.

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Kit SB-614, 17 lbs., mailable .................................. 139.95*

SB-644 remote VFO
Designed exclusively for the SB-104, it provides split transmit and receive control and you aren't frequency-limited in any way—transmit at one end of the band, receive at the other. The "644" even has two crystal positions for fixed-frequency control. The "644" has a linear dial, but the exact frequency is displayed on the "104"s digital readout. The display automatically changes when switching from transmit to receive.

Kit SB-644, 10 lbs., mailable ................................ 119.95*

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<table>
<thead>
<tr>
<th>Freq. Range (MHz)</th>
<th>MMa 50</th>
<th>MMa 144</th>
<th>MMa 220</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nom. Gain</td>
<td>20dB</td>
<td>16dB</td>
<td>15dB</td>
</tr>
<tr>
<td>N.F. (typical)</td>
<td>2.5dB</td>
<td>2.8dB</td>
<td>3.4dB</td>
</tr>
<tr>
<td>Power 12V D.C. at 20mA typical</td>
<td>$29.95</td>
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<td>$34.95</td>
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For instance, just plug in our 510-X crystal oscillator when you want extra frequency coverage. If your kind of traffic calls for separate transmit and receive frequencies, our 508 VFO is made for your station. Want VOX? Plug in the Swan VX-2 and start talking. Or hook up our FP-1 telephone patch in minutes.

And when you're ready for that big jump to all-the-law-allows, our 2000-watt P.E.P. input Mark II linear amp is waiting in the wings.

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Get started on your dream rig today. See the 700CX at your nearest Swan dealer or order direct from our factory.

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117-XC 110V AC Power Supply ....... $159.95
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The Logic Probe is a unit which is for the most part indestructible in trouble shooting logic families: TTL, DTL, RTL, CMOS. It delivers the power it needs to operate properly and it requires no power. The Logic Probe can detect high frequency pulses to 45 MHz. It can't be used at MOS levels or circuit damage will result.

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96 MORE DETAILS? CHECK-OFF PAGE 110

September 1975
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More Details? CHECK-OFF Page 110

September 1975
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AC/DC lead

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Type MM330 by National utilizes P-channel low-threshold enhancement mode devices and ion implanted depletion region devices. Provides logic circuit for 4½ digit DVM. All logic for four decade counters, a divide by four counter, a divide by two counter for range-blanking, latches for all counter stages, an output ROM to generate BCD to 2a complement BCD of the latches and a module 4 counter to sequentially present each of 2a decade latches. Not BCD compatible. Includes a 4a digit DVM, ideal with only Litronix ½ single, 1½, 2½ and digit displays. 16-pin DIP

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More Details? CHECK—OFF Page 110

98 september 1975
flea market

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SALE: Communicator VFO, Global VFO, HyGain 6-2 antenna, reasonable. WAZEU, 110 Lafayette St., Copiague, N. Y. 11726.


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RECIPIROCATING DETECTOR, write Peter Meacham Associates, 19 Loretta Road, Waltham, Mass. 02154.

For Further Details, Check off Page 110.
FREE BARGAIN CATALOG. LEDs, ztals, microphones, headsets, ICs, relays, ultrasonic devices, precision trimmer capacitors, unique components. Chaney's, Box 15431, Lakewood, Colo. 80215.

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