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ham radio

magazine

SEPTEMBER 1974

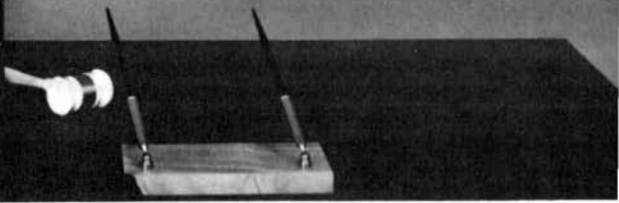
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for
1296
MHz**

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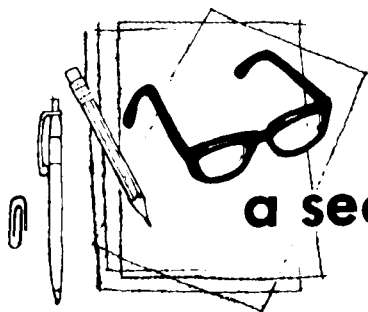
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a second look

by Jim
Fisk

As you look through this month's issue of *ham radio*, you'll see that two new sections have been added. The first, *stop press* on page 6, is a monthly summary of late news and happenings which affect amateur radio. In the jargon of the newspaper world, *stop press* means exactly that. If a hot story breaks while your morning paper is still coming off the presses, or if a big story takes a dramatic new turn, the presses grind to a halt so the new story can be added. If the story is big enough to justify a *stop press* edition, it's usually big enough to require a complete remake of the front page, banner headlines and all. Nor does the task stop there—room has to be found on the inside pages for stories crowded off the front page, re-edited to fit the available space, less important news items cut to the bone, and others discarded. Such a last-minute, crash effort is obviously expensive, so you don't see *stop press* editions every day, the editors opting instead for their regular early and late editions.

For a monthly magazine such as *ham radio*, however, a *stop press* edition in newspaper terms would be a practical impossibility. A crash effort to get WA6UAM's 1296-MHz article into this issue, for example, started the middle of May, immediately after it was first introduced at the West Coast VHF Conference. Nevertheless, it is possible, with proper planning, to insert whole pages a few hours before the magazine goes to press. Such is the case of *stop press* in this

issue. With this technique, *stop press* is dated only by the slowness of second-class mail—typically three to four weeks. For immediate, up-to-date coverage of amateur radio news, in much more detail than can be presented within the limited confines of *stop press*, subscribe to *HR Report* (see page 98), our bi-weekly newsletter which more and more amateurs are depending upon to stay current with fast-breaking news from the FCC, ARRL and industry.

Some readers may be concerned that *stop press* is the beginning of an editorial swing to the non-technical aspects of amateur radio. Such is not the case—*ham radio* will continue to bring you the latest technical and construction information available, as we have in the past. But with a World Administrative Radio Conference scheduled for 1979, restructuring of the amateur service probably only a matter of time, and the many new proposals being offered by the FCC, it is imperative that the amateur community be well informed. *Stop press* is a small step in that direction.

The other new section in this issue is *pr bandstand* on page 76, a one-shot chance for our advertisers to blow their own horns. If you like the idea, we'll do it again next year. Our regular *new products* section, displaced temporarily by the *bandstand*, will return next month.

Jim Fisk, W1DTY
editor-in-chief

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FCC ORDER RELAXES LOG KEEPING, and from now on NO mobile logs and only minimal fixed-station logs are required of amateur stations. Fixed (and portable) stations must maintain log book, but must record only contacts involving third-party traffic or during which an operator other than the station licensee was at the controls.

ANY EXTRA-CLASS LICENSEE COULD REQUEST PREFERRED CALL, even a two-letter call that previously required 25 years as a licensed amateur, under FCC Docket 20092. Extra Class licensees would also be permitted to hold as many "preferred" (one-by-three) calls as they had additional stations, although only one two-letter call would be permitted.

ARRL NATIONAL CONVENTION OPENED JULY 19, and for three days New York's Waldorf Astoria resembled the DX pileup on Kingman Reef. Weather was perfect, and show management estimates over 4000 attendees showed up.

Banquet Tickets Were Gone early Saturday afternoon, and commercial exhibitors were almost all enthused, as the three exhibit halls were well filled almost all the time they were open. Despite the high level of activity in the exhibit halls, however, the many forums all attracted substantial support too.

ARRL Band Plans for 50- and 450-MHz bands were announced at Repeater Forum. In brief, 6 meters will be low in, high out, on 20-kHz centers; 450 will be high in, low out, on 50-kHz centers. Auxiliary links, ATV and satellite communications are all accomodated on 450.

FCC CHAIRMAN RICHARD WILEY provided one of the weekend's high points with his ringing pro-amateur radio speech. Anyone who came with reservations about the new chairman's feelings toward the amateur service lost them quickly -- he's been looking us over pretty closely, and is, for the most part, enthused about what he's seen.

After Reviewing Recent Amateur-Related FCC Activities he touched on amateur restructuring (still evolving, and amateur inputs welcome) and Class-E CB (not yet decided one way or the other). He and the other FCC staffers then fielded questions from the floor: License fees -- will probably be reduced, perhaps to as low as half the present schedule. 160 meters -- should see some restrictions lifted soon in some areas as Loran A begins to be phased out. Codeless license -- very probable part of restructuring, but only above 144 MHz and placed so as to offer little disturbance to existing amateur operations.

IMPORTANT NEW FCC ACTIONS highlighted the FCC Forum. FCC has just issued Notices of Proposed Rulemaking which would: lift the restrictions on repeater linking; lift restrictions on repeater crossbanding; and clarify commemorative callsign procedures.

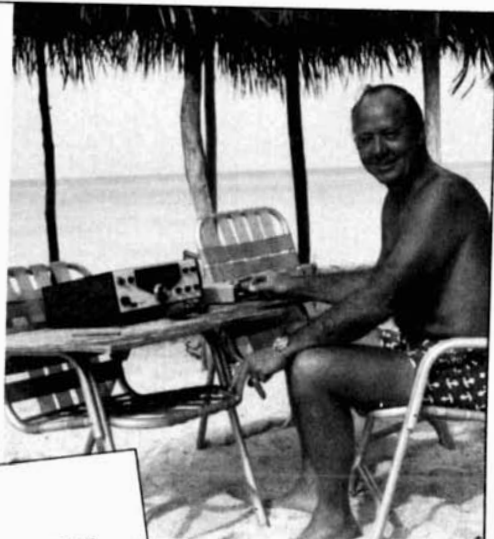
NEAR RESTRUCTURING OF CB by FCC is provided by three items released July 24. Most far-reaching is Docket 20120, a Notice of Proposed Rule Making that greatly expands Class D (27-MHz) CB. 27.23 to 27.54 MHz segment would be added, with 26.96-27.31 to present AM and SSB only on 5-kHz channels! Restrictions on permitted communications would also be eased. This NPRM seems to neatly avoid or at least effectively put off action on the 220-MHz Class-E band. Hmmmm...

The Second Shoe Dropped on CB July 24 is Docket 20118, which would prohibit the sale, lease, offer for sale or lease, or importation of RF power amplifiers capable of amplifying signals in the 20-40 MHz range! The only noteworthy exception to the ban is for multiband amplifiers specifically designed for amateur use.

Low-Power CB Handie-Talkies Will Move near 50 MHz if FCC Docket 20119 goes through. Commercial hand-held units not requiring operating licenses would be moved from 27 MHz to 49.91-49.99 MHz, and would require type acceptance by the FCC.

W5BWQ OF AUSTIN, TEXAS, is ham radio's most happy fellow, having recently taken delivery of a 1974 Chevy Vega, plus a car full of Swan amateur gear including an SS-200 Solid-State HF Transceiver and an FM-2XA Two-Meter FM Transceiver. All of this was his reward for winning HR's 1974 sweepstakes. Now it's your turn -- next year.

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PRESIDENT

February 4, 1974

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I have just returned from a three week trip to the Cayman Islands during which time I operated the Triton II using a vertical trapped antenna with a ground radial system in the ocean.

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Since returning from the Islands, I have operated the Triton II during the CW and phone ARRL DX Contest as part of our multi-station operation with great success.

My congratulations to you and your Engineering Department for developing what I consider one of the finest pieces of equipment I have ever operated.

You probably better remember me under my old call number of W2SAI rather than my current call number of K3MBF.

I look forward to seeing you in person soon.

Very truly yours,

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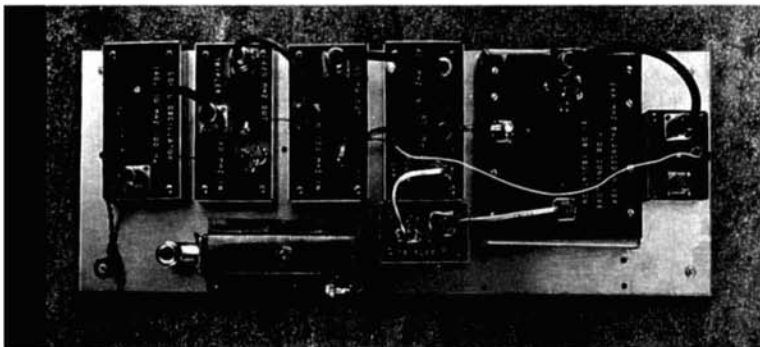
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President

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easy-to-build ssb transceiver

for 1296 MHz

Complete description
of a simple
sideband system
for the amateur
23-cm band —
the same technique
can be used
for the other
uhf bands

The simple microwave ssb system presented here was used to achieve Northern California's first recent two-way ssb communications on 1296 MHz, between WA6UAM and K6UQH, on April 14, 1974.* Aside from any precedent which may have been established, the method used to transmit and receive microwave ssb represents a significant breakthrough in that it is simple, straightforward, in-

expensive and readily reproducible by any uhf enthusiast. Neither specialized tools nor elaborate test equipment is required to build this equipment — equipment that provides the capability for line-of-sight ssb contacts on the amateur 23-cm band.

Fig. 1 shows the scheme generally used for the transmission and reception of uhf ssb signals. The received signals are down-converted in the conventional manner into the high-frequency spectrum where they are detected by the station receiver. Similarly, a high-frequency signal generated by the station exciter is heterodyned up to uhf, then amplified and transmitted. Note the high degree of redundancy present in this system. Both the transmit and receive converters use a mixer and local-oscillator chain, the function of each being essentially identical to its counterpart.

Assuming the availability of a bilatera

*Some years ago, K6HCP and W6GDO ran successful 1296-MHz ssb schedules, each using a 2C39 as a simultaneous mixer and LO doubler. The resulting ssb output was easily copyable, if not exactly spectrally pure. Bandpass filters were used to attenuate the undesired products at the antenna. The equipment currently used by WA6UAM and K6UQH, described in this article, uses diode balanced mixers with injection at the ultimate LO frequency. This method of heterodyning produces clean 1296-MHz ssb without excessive intermodulation products

Editor

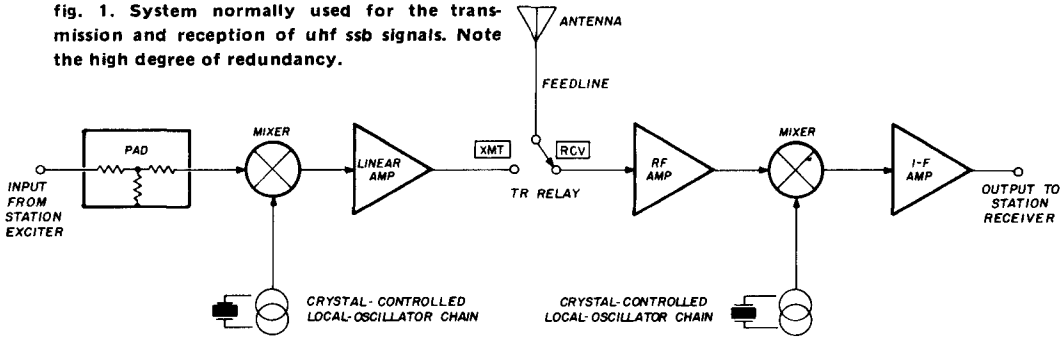
H. Paul Shuch, WA6UAM, 14908 Sandy Lane, San Jose, California 95124

mixer (one which operates equally well in both the *forward* and *backward* directions), the system can be simplified as indicated in **fig. 2**. Obviously, a passive mixer must be used in this application. Any active device designed to provide conversion gain in, say, the *up* direction,

of numerous stages of linear amplification *after* the transmit conversion.

It is evident from **fig. 2** that by eliminating redundant circuitry, the TR switching complexity has increased three-fold. Assuming that means could be found for eliminating the requirements

fig. 1. System normally used for the transmission and reception of uhf ssb signals. Note the high degree of redundancy.



cannot function as a *down* mixer as well. Fortunately, singly- and doubly-balanced diode mixers function effectively in either direction, with only a few dB of conversion loss.

The greatest drawback of the diode mixer, so far as transmit conversion is concerned, is its limited power-handling capability: This normally requires the use

for separate receive and transmit amplification, TR relays K1 and K2 could then be eliminated, too. Of course, such drastic simplification would jeopardize both the receive sensitivity and transmit power. However, depending upon the application, these tradeoffs might well be justified. Such was the case with the 1296-MHz station at WA6UAM.

The details for the Simple 1296-MHz Sideband System are shown in **fig. 3**. Equal emphasis was placed on simplifying the system to its minimum required content, and optimizing each sub-assembly to provide reliable communications over a reasonable range. Free-space loss and receiver noise calculations indicate that ssb communications between two such stations would be practical to distances of at least 100 miles (160 km).

Note the total elimination of TR relays and feedlines (and their resultant losses) in the microwave portion of this system. This is accomplished by mounting the mixer, filter and LO chain directly at the antenna (readily accomplished, as these modules are both lightweight and relatively small), and pumping only 28-MHz energy (plus 12 Vdc for the local oscillator) up and down the tower. The rf modules and antenna might even be

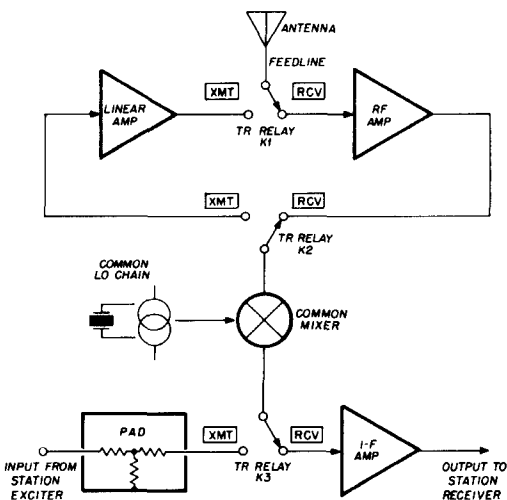


fig. 2. This uhf ssb system, which uses a common local-oscillator chain and balanced diode mixer, minimizes circuit redundancy but requires three TR relays.

combined into a single physical unit, as shown in fig. 4.

mixer

So far as design tradeoffs are concerned, the mixer is, by far, the most critical component of the Simple Sideband System. To obtain a reasonable receive noise figure, low conversion loss is of paramount importance. At the same time usable transmit rf levels dictate high power-handling capabilities. As will be shown in a minute, these two criteria tend to be mutually exclusive. With readily available Schottky-barrier (hot-carrier) diodes in a balanced mixer, the system seems to optimize at about 6-dB conversion loss, with 3 mW of usable output power. Don't scoff at these seemingly restrictive figures. Calculations (see page 21) will show that this type of performance is more than satisfactory for communications to the edge of the visual horizon, and perhaps beyond.

Several reproducible uhf balanced mixers have been published recently.^{1,2,3,4} The balanced mixer presented here is based upon a design developed by W6FZJ, and currently used by him on 2304 MHz. Versions for 1296 MHz have been built by both WA6UAM and WB6JNN, and provide a considerable improvement over the single-diode trough-line or interdigital designs frequently used by amateurs in uhf transmitting and receiving converters. An improved version of the W6FZJ mixer, which uses a commercially available balun to match the rf port of the mixer to the 50-ohm transmission line, will also be described.

Whatever mixer design is chosen, the diodes you select will determine its conversion loss and power-handling capability. One high-power, low-cost device is the Hewlett-Packard 5082-2817.*

*Hewlett-Packard 5082-2817 hot-carrier diodes are available in small quantities for \$1.50 each from any Hewlett-Packard sales office. Matched pairs (5082-2818, \$3.25), and matched quads (5082-2819, \$7.00) are also available. If you can't find a Hewlett-Packard sales office in the *Yellow Pages*, write to Hewlett-Packard, 1101 Embarcadero Road, Palo Alto, California 94303.

These diodes have a burnout rating of 4.5-watts peak, or 1-watt CW, and are capable of conversion efficiencies of better than -5 dB.

practical mixer circuit

The complete 1296-MHz mixer shown in fig. 5 uses hybrid construction (discrete components on etched microstripline), making duplication relatively straightforward for anyone with access to PC board fabrication facilities. Given sufficient time and patience, you can even "etch" your substrate with an Exacto knife and straightedge. At least four such manual efforts have been completed to date, and performance is equal in all respects to photochemically produced versions.

The equivalent circuit shown in fig. 6 will help to clarify the operation of the mixer. Rf energy injected into the delta (Δ) port is transformed by the balun so that there is a 180° phase difference between the signals applied to the two diodes. The diodes are effectively in series and of like polarity so that the applied rf simultaneously biases both diodes on and then off, for alternate half-cycles.

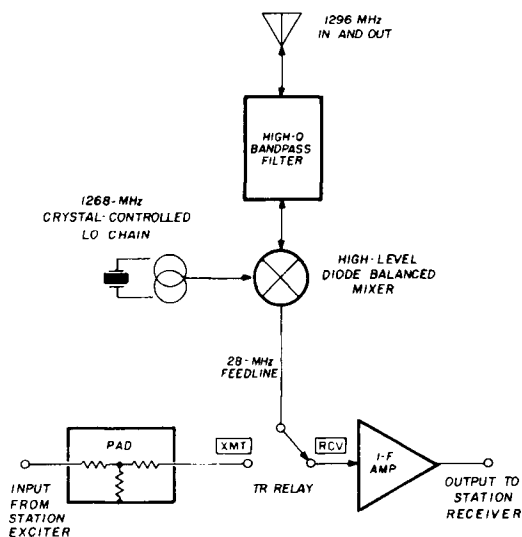


fig. 3. The Simple Sideband System, shown here, has been reduced to its ultimate simplicity but can still provide beyond-the-horizon communications when used with a high-gain antenna.

Rf energy applied to the sigma (Σ) input is transmitted down a quarter-wavelength, two-way power divider (which looks like a tuning fork) so that the signals it applies to the two diodes appear in phase. Since the diodes are in reverse polarity with respect to their bias return (common junction), this rf is applied to the two diodes out of phase. The simultaneous application of in- and out-of-phase rf signals to the diode pair results in a signal at their junction composed of the rf applied to the sigma (Σ) port, chopped at the rate of the rf applied to the delta (Δ) port. This complex repeating waveform can be shown by Fourier analysis to contain components of the sigma frequency, the delta frequency, their sum and their difference. Mixing, by the traditional definition, has occurred. The circuitry shown to the right of the diodes in **fig. 6** serves the purposes of signal conditioning (filtering out all but the difference-frequency component), dc bias return and a means of measuring diode bias current.

The most significant advantage of the balanced mixer over a single-ended design is that rf injected into the delta port is isolated from the sigma port, and vice-versa. To see how this is accomplished, consider a balanced signal applied to the two diodes through the delta port. In addition to feeding the diodes, this signal is shunted by the sigma port's power divider. Since this transmission line is a quarter-wavelength long at the delta frequency (assuming the delta and sigma signals are close in frequency), it transforms the short to an open, and the sigma port is effectively nonexistent so far as the delta signal is concerned.

Conversely, rf injected into the sigma port divides down the power divider, and appears to the diodes as two signals, equal in amplitude and phase. Looking toward delta, these two signals are cancelled in the balun and, thus, never reach the delta port.

It should be noted that single-balanced mixers provide no isolation whatever between the i-f port and either the delta or sigma port. Hence, filtering is required to remove the higher-frequency components from the i-f. Such filtering is accomplished in the hybrid balanced mixer by virtue of stubs at the i-f side of each diode, a quarter-wavelength long at 1296 MHz and open at the far end. These

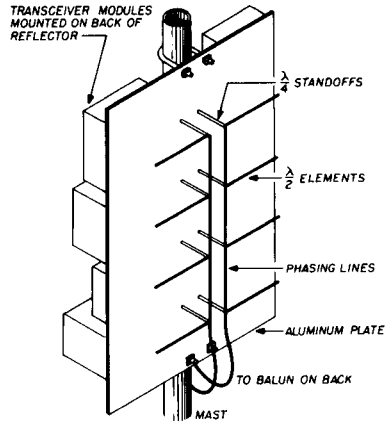
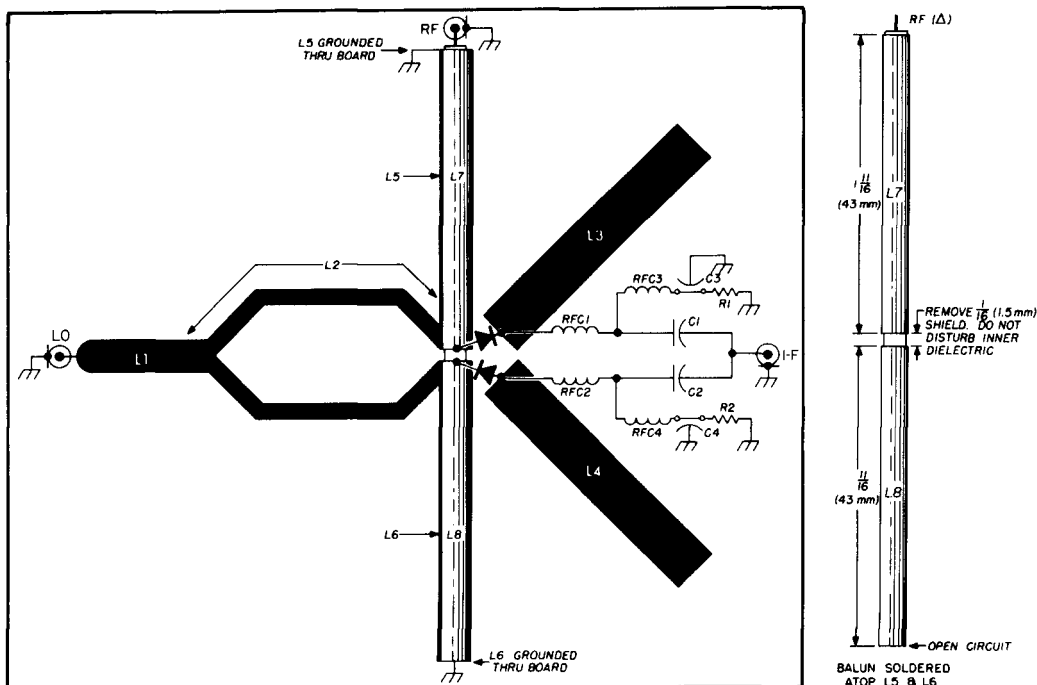


fig. 4. Antenna-mounted transceiver converter. With this arrangement, using the system of **fig. 3**, only 28-MHz energy must be run down the tower to the operating room.

quarter-wavelength sections ground out the i-f port to energy near 1296 MHz.

Derivation of the balun used in the hybrid balanced mixer is shown in **fig. 7**. **Fig. 7A** is a coaxial balun frequently used in antenna work. In **fig. 7B**, the same balun is straightened out to improve symmetry. Note that a common ground is still required between the far end of the stub and a point one quarter-wavelength back on the feedline. This ground is frequently accomplished by connecting to the walls of the half-wave-long box in which the balun is built. In the case of the hybrid balanced mixer, the return is to a ground plane, on the opposite side of a substrate to which the balun is attached.

Both bandwidth and balance may be improved by modifying the in-line balun



C1,C2	0.01 μ F disc ceramic	L5,L6	50-ohm micro-stripline, 0.168" (4.5 mm) wide, 1-19/32" (40.5 mm) long
C3,C4	1000-pF feedthrough	L7,L8	50-ohm UT-141 coaxitube, 0.141" (3.5 mm) diameter, 1-11/16" (43 mm) long
CR1,CR2	hot-carrier diodes (H-P 5082-2818)	R1,R2	10-ohm, 1/4-watt carbon composition resistors
L1	50-ohm micro-stripline, 0.168" (4.5 mm) wide, any length	RFC1,RFC2	2" (51 mm) no. 32 wire, close wound on 0.050" (1.5 mm) diameter form or ferrite beads on leads of C1 and C2
L2	75-ohm micro-stripline, 0.080" (2.0 mm) wide, 1-7/16" (36.5 mm) long, (along center)	RFC3,RFC4	22 μ H
L3,L4	38-ohm micro-stripline, 0.25" (6.5 mm) wide, 1-7/16" (36.5 mm) long		

fig. 5. This high-performance 1296-MHz balanced mixer uses etched 1/16" (1.5 mm) thick Teflon-fiberglass printed-circuit board and a coaxial balun. Full-size printed-circuit layout is shown in fig. 8. An equivalent circuit of this mixer, illustrating circuit operation, is given in fig. 6.

of fig. 7B as shown in fig. 7C. In this version the stub is a piece of coax identical to the original feedline. The center connector of the feeder is now connected to the center conductor, rather than to the shield of the stub. At the far end of the stub the center conductor is open. A quarter-wavelength toward the source (at the junction of the feeder and the stub) this open is transformed to a short, and rf sees the center conductor of the stub as being continuous with the shield. Therefore, the circuit at fig. 7C is

electrically identical to that of fig. 7B, but with improved physical symmetry. Balanced output is taken from the same point as before.

Note that at the far end of the stub the center conductor must be open, and the shield grounded. Again the balun may be constructed upon a substrate, with return through it to a groundplane.

The balun used in the 1296-MHz mixer is made from a single piece of UT-141 type semirigid coax (50-ohms, Teflon dielectric, 0.141-inch [3.5-mm]

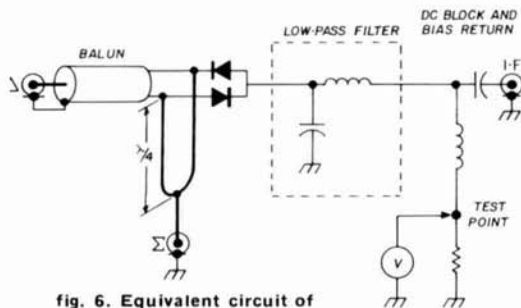


fig. 6. Equivalent circuit of the balanced mixer shown in fig. 5.

OD). Correcting for velocity factor, the quarter-wavelength sections are each 1-11/16-inches (43-mm) long. Judicious use of an Exacto knife and small tubing cutter will aid in the removal of 1/16-inch (1.5-mm) of the outer conductor at the junction of the feeder and the stub. Since no physical connection must be made to the center conductor at this junction, the Teflon dielectric should not be disturbed. Allow a short length of center conductor to extend beyond the quarter-wavelength section comprising the feeder coax. This will be attached to the center pin of the delta port's coax connector.

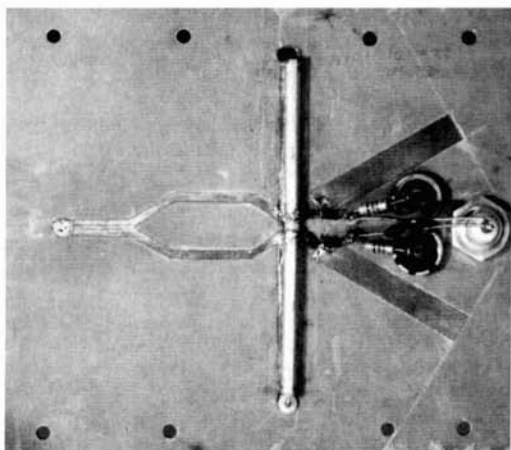
The mixer's substrate is etched on one side of a 1/16-inch (1.5-mm) thick, double-sided, 1 ounce, copper-clad, Teflon-fiberglass PC board. *Do not* use fiberglass-epoxy board, as its dielectric constant is not correct for the dimensions provided in fig. 5. The use of Teflon PC board is necessary in this design so that the velocity of propagation (and hence the electrical wavelength) of the striplines will approximate that of the coax balun. The full-sized PC layout is shown in fig. 8. All micro-striplines must be opposite a groundplane (the other unetched side of the double-sided board).

Although Teflon PC board makes an excellent substrate for micro-striplines at 1.3 GHz, it is quite expensive (and in

some areas, totally unobtainable). The use of fiberglass-epoxy board, though it would increase losses slightly, would bring this type of equipment within reach of many experimenters who might otherwise be deterred. Of course, a glass-epoxy substrate is incompatible with the UT-141 coax balun because of the widely different velocities of propagation of the two mediums. In order to develop a 1296-MHz balanced mixer on glass-epoxy board, a different method of unbalanced-to balanced transformation is required.

Anzac Electronics manufactures an appropriate balun of moderate cost, excellent electrical performance and small physical size which frees the mixer design from restrictions as to substrate material.* Mixers built on 1/16-inch (1.5-mm) G-10 double-clad PC board using the Anzac balun exhibited improved matching at the rf port, an effect which more than offsets any additional losses in the glass-epoxy dielectric.

A schematic of the improved 1.3-GHz balanced mixer using the commercial balun is shown in fig. 9. Note that pins 1, 3 and 5 of the balun must be grounded *through* the substrate to the groundplane. When mounting the balun, do not allow its case to short out the striplines of L2.



Construction of the doubly-balanced mixer of fig. 5, showing installation of the coaxial balun. Capacitors C1 and C2 can be seen between the two feedthrough capacitors.

*Anzac model TP-101, 500 kHz to 1.5 GHz, 50-ohms balanced to 50-ohms unbalanced transformer with midband insertion loss of 0.4 dB maximum and v_{swr} 1.6:1 maximum, \$15.50 in single quantities from Anzac Electronics, 39 Green Street, Waltham, Massachusetts 02154.

Full-size artwork for a mixer board on 1/16-inch (1.5-mm) G-10 PC board ($\epsilon = 4.8$) is provided in **fig. 10**. Either of these two balanced-mixer designs (**fig. 5** or **fig. 9**) will provide satisfactory performance in the Simple Sideband System for 1296 MHz.

output power - noise figure tradeoff

To avoid excessive intermodulation distortion in the transmit mode, it is desirable to inject into the i-f port a signal level at or below the mixer's 1-dB compression point. This is the level beyond which incremental increases in input power result in an ever-diminishing increase in output power. Such a situation typically occurs with i-f injection 5-dB below the local-oscillator signal level.

Due to the ready availability of any desired signal level at 28 MHz, the i-f injection level is not considered a limiting factor in system design. The following discussion assumes the use of the optimum i-f injection level in the transmit mode; that is, 5-dB below whatever LO insertion is applied.

In the transmit mode the usable output power is equal to the i-f injection level minus the mixer's conversion loss, L_c . For operation at the 1-dB compression point, this relationship can be expressed as

$$P_{out} = P_{LO(dBm)} - 5 \text{ dB} - L_c$$

This formula implies that the system power output continues to improve for increases in LO injection. This would be true were it not for the fact that conversion loss does not remain constant for all levels of LO injection. **Fig. 11** demonstrates the variation in conversion loss, as well as optimum power output, as a function of LO injection level for a typical microwave diode balanced mixer. Note that optimum conversion loss occurs at an LO injection level of around +8 dBm.

Beyond this point, though conversion efficiency degrades, output power con-

tinues to increase. Indeed, within the power restriction of the HP 5082-2817 diodes, it is possible to obtain about 16 mW of clean output power. However, recall that the Simple Sideband System uses the same mixer and local-oscillator chain for both transmit and receive. Any

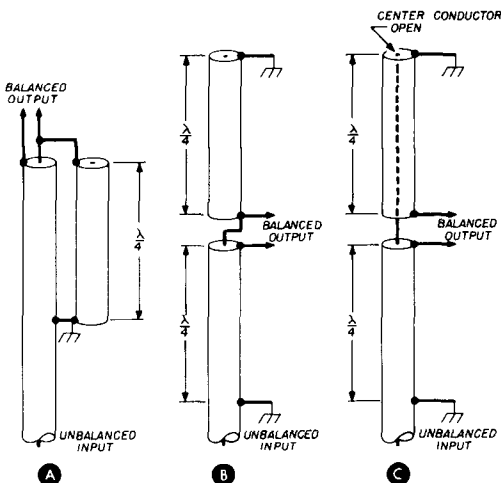


fig. 7. Derivation of the coaxial balun used in the balanced mixer of **fig. 5**. Conventional balun in (A) has been straightened out in (B) to improve symmetry. Balun in (C) is identical, electrically, to the circuit in (B) but symmetry has been further improved.

decrease in mixer conversion efficiency will degrade receive noise figure accordingly. Beyond +10 dBm of LO injection, transmitter power is gained only at the expense of receiver noise figure.

The break-even point occurs at an LO power of +16 dBm. Beyond this level, each dB of increase in transmitter output results in one dB of receiver degradation. Thus, the Simple Sideband System optimizes at 6-dB conversion loss, 40-mW of LO injection, 12.6-mW of i-f drive and 3-mW of output power. The tradeoff involved in determining this optimum performance point is illustrated by the $P_{out} + L_c$ curve of **fig. 11**. The sum of conversion loss and output power is used as a figure of merit for communications between two identical systems. This sum

represents the output power available at the i-f port of a receive mixer which is driven by an identical transmit mixer operating at the 1-dB compression point. Note that as local-oscillator power is increased, a knee is reached beyond which additional power will serve no

passband. The actual transmitter output power, after the filter, will thus be

$$+7.8\text{dBm} - 3.0\text{dB} - 0.5\text{dB} = 4.3\text{dBm} = 2.7\text{mW}$$

Note that the filter will also eliminate receiver image noise, as well as blocking those out-of-band signals which might

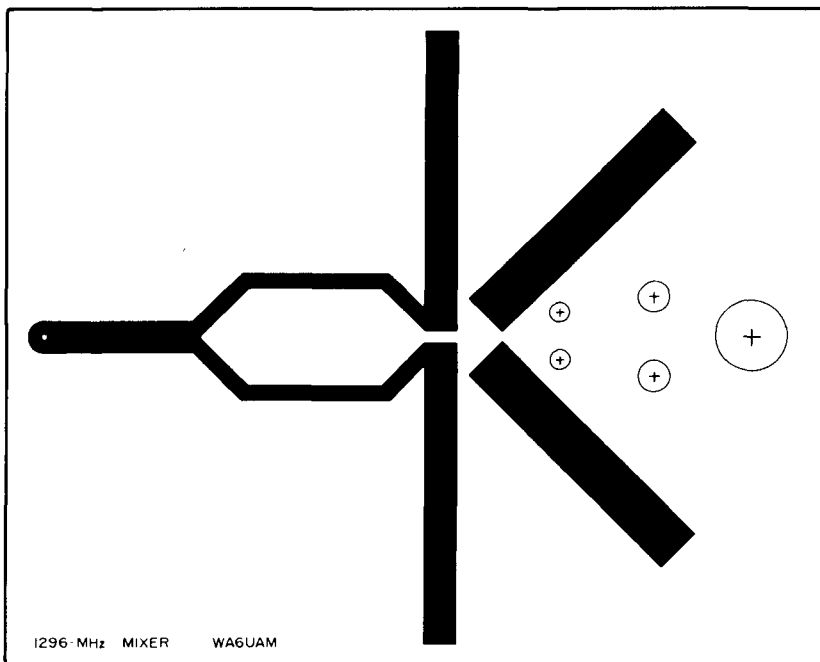


fig. 8. Full-size printed-circuit layout for the balanced mixer of fig. 5. Material is 1/16" (1.5 mm) thick, double-sided Teflon-fiberglass circuit board.

useful purpose. Thus it is desirable to operate the system at the knee of this curve, which I call the *transceive figure of merit* curve.

bandpass filter

With 40 mW of LO injection in the transmit mode, and using the balanced mixer described above, a mixer output power of 6 mW is indicated on a power meter. It must be remembered that this signal represents both the desired output signal (LO + i-f) and the image (LO - i-f). A bandpass filter with sufficient skirt selectivity to reject the image will also have about 0.5-dB insertion loss in the

otherwise enter the mixer and cause cross-modulation distortion and interference. Of course, filter insertion loss must be added to mixer conversion loss and i-f noise figure when determining receive converter performance.

Physically, the bandpass filter can be a half- or quarter-wavelength coaxial resonator, or a trough-line cavity such as has been used in previous 1296-MHz receiving converters. Coupling in and out can be accomplished by means of links, loops, taps, capacitors or even the coaxial matching scheme used by K6UQH in his latest converters.⁵ In the interest of avoiding multiple responses, a similar

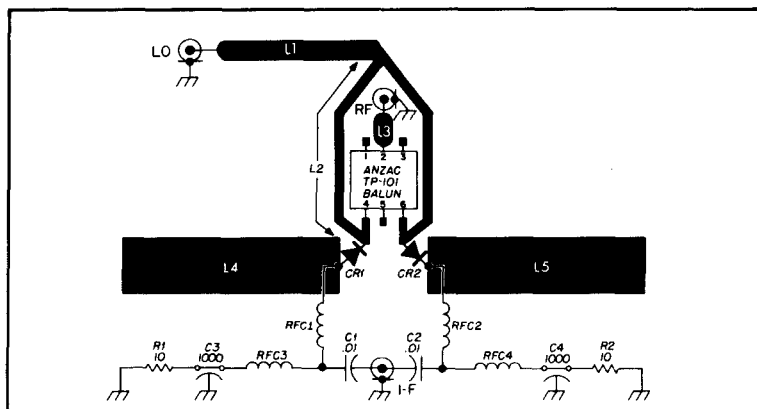
filter at the output of the LO chain may prove desirable.

local-oscillator chain

The key criteria here are stability and spectral purity. For maximum stability it is advisable to invest in the best possible low-temperature coefficient crystal you can afford.* An additional ten dollars invested in a quality crystal can do much

provide minimum crystal feedback consistent with ready starting, and should of course be buffered.

Spectral considerations dictate very careful selection of the multiplication scheme used to reach the desired injection frequency. High-order multiplication in a single stage is out, as the resultant harmonic comb requires extensive filtering. W6FZJ, whose success on both



- | | | | |
|----------|---|------------|--|
| C1,C2 | 0.01 μ F disc ceramic | L4,L5 | 25-ohm micro-stripline, 0.30" (7.5 mm) wide, 1.14" (29 mm) long |
| C3,C4 | 1000-pF feedthrough | R1,R2 | 10-ohm, 1/4-watt carbon composition resistor |
| CR1, CR2 | hot-carrier diodes (H-P 5082-2818) | RFC1, RFC2 | 2" (51 mm) no. 32 wire, close wound on 0.050" (1.5 mm) form or ferrite beads on leads of C1 and C2 |
| L1,L3 | 50-ohm micro-stripline, 0.10" (2.5 mm) wide, any length | RFC3, RFC4 | 22 μ H |
| L2 | 75-ohm micro-stripline, 0.045" (1.0 mm) wide, 1.24" (31.5 mm) long (along center) | | |

fig. 3. Improved 1296-MHz balanced mixer uses commercial balun and double-clad epoxy circuit board. Full-size printed-circuit layout is provided in fig. 10.

to alleviate slight frequency drift which (when multiplied into the microwave region) can make ssb transmission and reception a running battle between your right hand and the tuning dial. The oscillator circuit should be designed to

*The Croven C180DBX-00 5th-overtone crystal is highly recommended. This series-resonant, HC-18/U crystal has a calibration tolerance of ± 10 ppm and temperature tolerance of ± 5 ppm from 15° to 35° C. \$12.00 in single quantities, or \$8.00 each for two or more crystals of the same frequency. Write to Croven Ltd., 500 Beech Street, Whitby, Ontario, Canada.

432-MHz EME and 2304-MHz tropo-scatter speaks well for his expertise in such matters, recommends doubling in every stage of any LO multiplier. If the starting frequency (the crystal-oscillator stage) is in the 70- to 125-MHz region, any spurious responses present after repeated doubling will be sufficiently separated in frequency to be easily filtered.

The balanced mixer used at WA6UAM receives 40-mW of LO injection. Obtaining this power level at 1200 MHz is relatively simple with today's low-cost

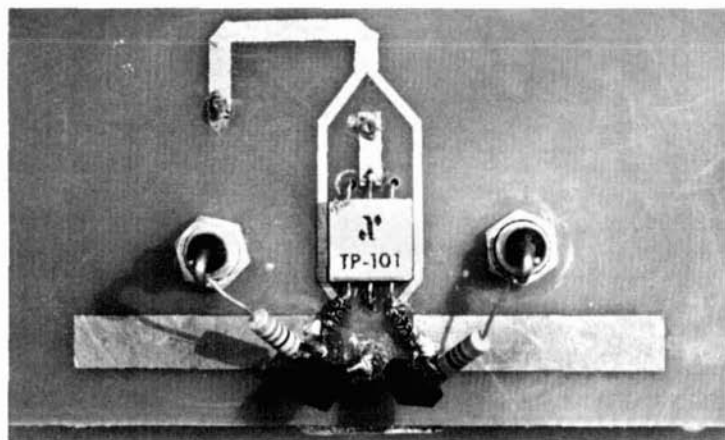
uhf transistors. Stability will be enhanced by designing the second stage of the LO chain (buffer) for 100-mW output, and running succeeding doublers at or close to unity gain. Resistive 3-dB pads between stages will alleviate excessive drive and provide impedance matching.

When designing active frequency doublers, recall that second-harmonic generation is enhanced by a collector

the Simple Sideband System could be duplicated without the use of specialized test equipment. In the case of the LO chain, alignment can be accomplished and injection measured by merely monitoring the diode current of the balanced mixer.

local-oscillator circuits

The primary advantage of the modular system which I use is the ease with which



Construction of the doubly-balanced mixer using the Anzac TP-101 balun.

conduction angle of 180° . This condition is easily met by grounded-base, zero-bias operation. Fortunately, this is also probably the simplest frequency-multiplier circuit to drive and adjust. Incidentally, it was stated earlier that the components of

substitutions can be made, and performance of various circuits compared. The Simple Sideband System has already worn three different LO chains; no doubt others will be attempted in the future. The block diagram of fig. 12 shows what

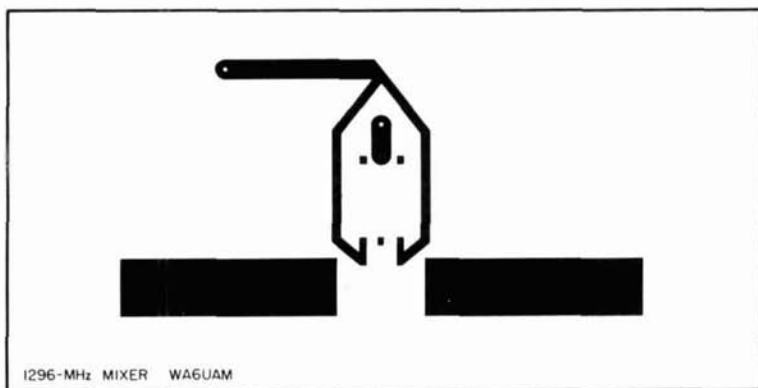


fig. 10. Full-size printed-circuit layout for the improved 1296-MHz mixer. Board is 1/16" (1.5 mm) thick, double-clad 1-ounce copper G-10 fiberglass-epoxy circuit board.

has thus far proved the most workable compromise between stability and spectral purity on the one hand, and low cost, simplicity and ease of alignment on the other.

However, this LO chain violates a number of the *ideal* design principles outlined above. For example, the purist will want the last multiplier to double rather than triple, and would probably use an active device rather than a diode. The decision to go with a diode multiplier was based primarily on the cost of 1.3 GHz transistors at the required power level. Tripling was used here because of the greater ease of generating a high level of power at 422 MHz, as compared to 630 MHz. The common-base configuration, although simple, was abandoned in the lower-level stages in deference to the greater gains available from common-emitter circuits.

The active multipliers are all operated at a low power level as a concession to stability, with the two 422-MHz power amplifiers providing plenty of drive to the tripler. Considering the low conversion efficiency of the diode tripler circuit, a high drive level is a must.

The low-level stages shown in **fig. 13** were designed by W6FZJ for use in a 432-MHz receiving converter, and published in his *432 Newsletter*. Except for the crystal frequency and the number of turns on two inductors, his original circuit is unchanged when used in the 1296-MHz LO chain. Copies of the original circuit have been successfully built by a number of San Francisco area 432-MHz enthusiasts, and spectrum analyzer tests prove the W6FZJ design to be superior to any of my own attempts to date.

Since the tripler which raises the injection frequency to 1267 MHz exhibits about 10-dB conversion loss,* a half-watt of drive is necessary at 422 MHz to achieve the desired 40-mW of LO injection.

*Greater tripler efficiency is possible through the use of an idler circuit, a technique avoided by the author in the interest of simplicity.

This is accomplished by applying the 10-mW output of the low-level LO module to two stages of power amplification, operating at 10- and 7-dB of gain, respectively. The 2N3866s were selected because of their low cost and ready

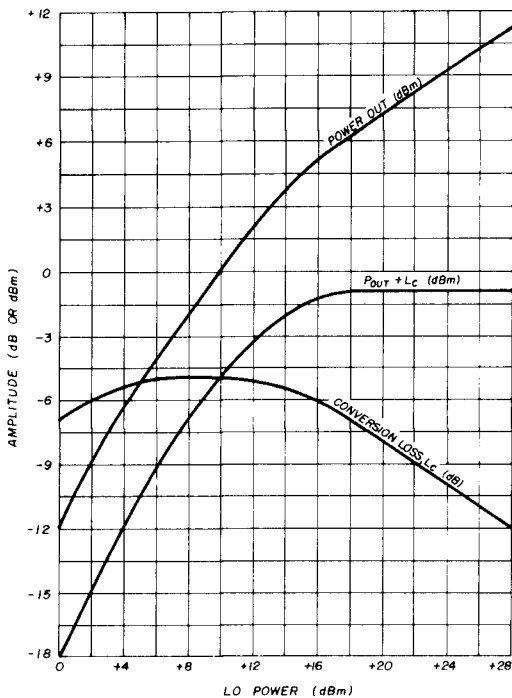


fig. 11. Balanced mixer conversion loss, output power at the 1-dB compression point and their sum (transceive figure of merit) for a typical microwave balanced mixer, all as a function of local-oscillator injection level. The transceive figure of merit represents the i-f output power available from a receive mixer driven directly by the output of an identical transmit mixer.

availability from a number of mail-order surplus component dealers.

The power amplifier circuits are shown in **fig. 14**. Care should be taken to closely duplicate the input and output tank circuits unless a spectrum analyzer is available, as adequate spectral purity occurs when these particular circuits are tuned for maximum indicated output.

The slab inductors in the collector

circuits provide high output Q, and the pi-network filter (C8, L3, C9) feeding the second stage tends to suppress any harmonics generated by the first. The first 2N3866 is biased to class AB for increased gain; the second stage is run in class C

tributed constants. Design of the poles was accomplished as follows: It was desired that the filter resonate with the tuning capacitors (C2, C3) at midrange, or 1.5 pF. Assuming an additional 0.5 pF of stray and coupling capacitance, the

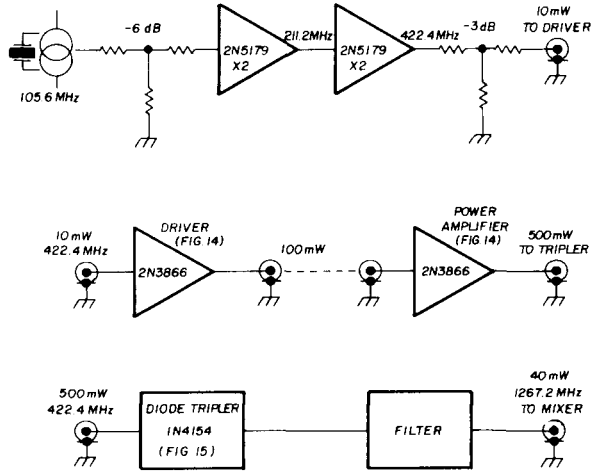


fig. 12. Block diagram of the local-oscillator chain used with the Simple Sideband System for 1296 MHz. Each of the individual sections is built into a small module; these are connected together with miniature 50-ohm coaxial cable.

for improved collector efficiency. If the stages are built separately, each can be tuned for maximum power into a 50-ohm load.

The diode tripler and filter assembly was first built in the popular trough-line configuration. Later, an interdigital filter was attempted. In both cases performance was satisfactory. However, the construction process required extensive metalworking. As many amateurs avoid projects which involve bending sheet metal or cutting brass tubing, I decided to reduce the tripler/filter to a PC board. The result is shown schematically in fig. 15.

Rf energy from the 422-MHz power amplifier, fig. 15, is applied to CR1, a GE 1N4154 high-speed switching diode through an L-network (L1, C1) similar to that used by K6UQH in his trough-line multiplier/mixers. The harmonic comb developed at the output of the diode is applied to a two-pole resonator (L2, C2, L3, C3) which blocks all but the 1267-MHz component.

The filter combines lumped and dis-

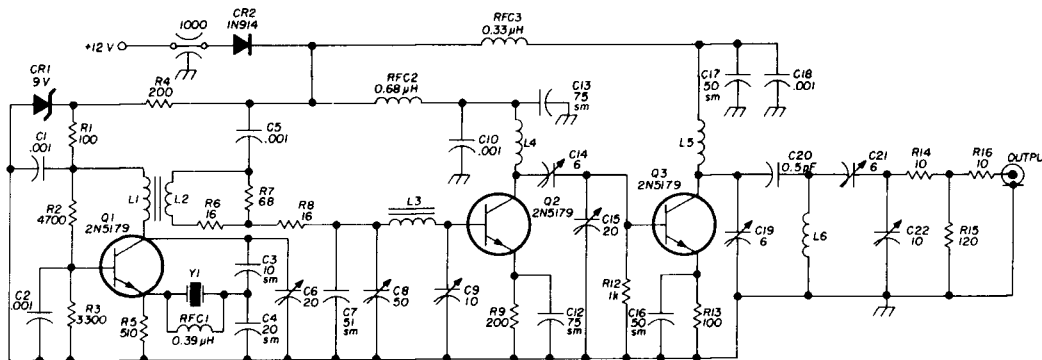
tributed constants. Design of the poles was accomplished as follows: It was desired that the filter resonate with the tuning capacitors (C2, C3) at midrange, or 1.5 pF. Assuming an additional 0.5 pF of stray and coupling capacitance, the

$$\theta = \arctan \frac{X}{Z_0}$$

where θ represents wavelength of the stripline in *degrees*. To convert to fractions of a wavelength, divide θ by 360° . Thus, for 62.8-ohm inductive reactance with an arbitrarily selected stripline characteristic impedance of 25 ohms,

$$\theta \arctan \frac{62.8}{25} = 68.3^\circ = 0.19 \text{ wavelength}$$

A 25-ohm micro-stripline on 1/16-inch (1.5-mm) G10 PC board is 0.3-inch (7.5-mm) wide. The 0.19 wavelength at 1267 MHz (correcting both for velocity factor and width-to-height ratio) is 0.865 inch (22 mm).



- | | | | |
|-----------|--|--------|---|
| C6, C15 | 20-pF trimmer (JFD DJV 300) | L3 | 12 turns no. 28 on Micrometals T-25-13 toroid core |
| C8 | 50-pF trimmer (JFD DJV 305) | L4 | 6 turns no. 24, close wound on 0.1" (2.5 mm) diameter form |
| C9, C22 | 10-pF trimmer (JFD DJV 302) | L5, L6 | 1½ turn no. 22, 1/8" (3 mm) diameter, 1/4" (6 mm) long |
| C14, C19, | 6-pF trimmer (JFD DJV 301) | RFC1 | 0.39 μH miniature inductor (Nytronics Deci-Ductor) |
| C21 | | Y1 | 5th overtone crystal, series resonant, HC-18/U holder, 105.600 MHz for 28.8-MHz i-f |
| C20 | 0.5-pF ceramic (two 1-pF capacitors in series) | | |
| L1 | 10 turns no. 28 on Micrometals T-25-13 toroid core | | |
| L2 | 4 turns no. 28 on cold end of L1 | | |

fig. 13. Crystal-controlled local oscillator circuit, based on a design by Joe Reisert, W6FZJ.

Matching the resonators to the relatively low impedances of the diode and the output transmission line can be accomplished by tapping up on the micro-striplines the required distance above ground. Although formulas exist for approximating the required tap position, matching in the circuit shown was determined empirically.

An important (and often neglected) consideration in diode multipliers is bias current. Resistor R1 in fig. 15 enables the diode current to be varied over a wide range. Remember that diode current will affect conduction angle, which should be 120° to maximize third-harmonic generation.

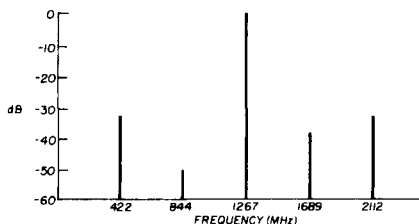
transmit i-f attenuator

Proper operation of balanced mixers requires that each port be terminated in its characteristic impedance (usually 50 ohms). Most methods used to sample a low-level ssb signal from a high-frequency transmitter would result in a horrendous impedance mismatch at the mixer's i-f port. As 12.6-mW of sideband injection is

desired, one recommended method of assuring i-f impedance matching is to run about one watt of ssb into a 20-dB resistive pi- or T-pad at the mixer's i-f port. Since the attenuation pad will provide the proper termination to the mixer, the method of coupling out of the station transmitter has no effect on the mixer's operation.

i-f amplifier

The noise figure of a receiving converter without pre-conversion gain is the



Spectrum output of the 1267.2-MHz local-oscillator chain when tuned for maximum mixer diode current. The 422- and 2112-MHz spurs are down 32 dB, the 1689-MHz spur is down 38 dB and the 844-MHz spur is down 50 dB.

level of man-made and atmospheric noise exceeds that of receiver noise by several orders of magnitude, so noise figure, per se, is not usually a significant consideration in high-frequency receiver design. Of course, such is not the case in the microwave region. To achieve a reasonable noise figure in any uhf converter, a low-noise i-f amplifier must be used to mask the following receiver noise.

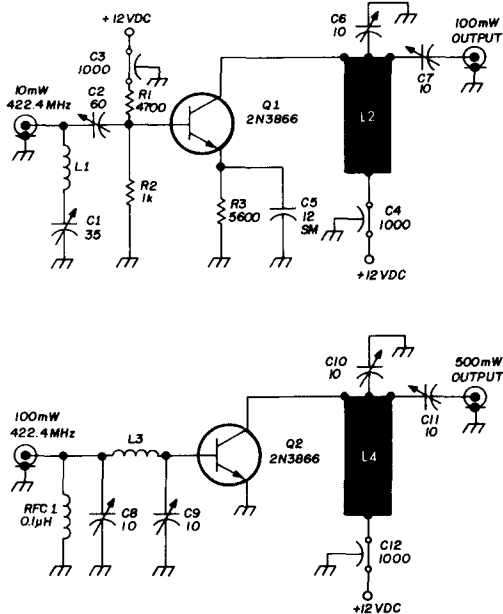
Numerous circuits have been described in the past which will yield reasonable gain at 28 MHz with a noise figure under 1 dB. WB6NMT, known for his pioneering efforts in 220-MHz EME, uses neutralized fets, while W6FZJ favors a dual-gate mosfet following the mixer. An appealing circuit by W9PRZ uses a dual jfet in a cascode configuration and is described in a Siliconix applications note.⁶

system performance calculations

It remains to be shown that the simple microwave ssb system described here lends itself to satisfactory communications over reasonable distances (my experience shows the following calculations to be somewhat on the conservative side). The overall noise figure of the receive system is the sum of filter loss (0.5 dB), mixer conversion loss (6 dB) and i-f noise figure (1 dB). Thus, a receive noise figure of 7.5 dB is assumed. With the 2.1-kHz i-f bandpass of a good side-band receiver, the graph of fig. 16 indicates the receive sensitivity to be about -133 dBm.

Good intelligibility on single sideband requires a 6-dB signal-to-noise ratio. Allowing a 10-dB signal-to-noise ratio for good measure, the receiver requires a -123 dB signal. At +4.3 dBm of transmitter power, given 10-dB of antenna gain at each end, and allowing 5-dB of additional loss for antenna aiming errors, the permissible path attenuation between transmit and receive stations is 142.3 dB. The free-space loss formula is⁷

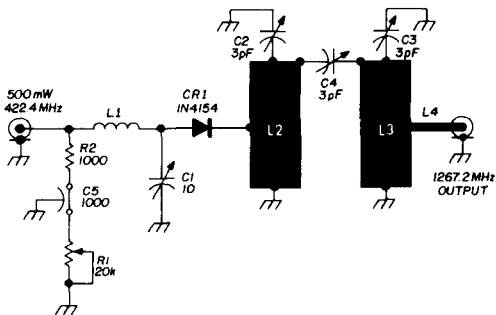
$$L_{FS} = 36.6 + 20 \log_{10} f_{MHz} + 20 \log_{10} d_{miles}$$



- C1 3-35 pF trimmer
- C2 8-60 pF trimmer
- C6-C11 10-pF concentric piston trimmers
- L1 2 turns no. 18, wound on 1/4" (6 mm) mandrel, 1/8" (3 mm) long
- L2,L4 brass strip, 0.5" (12.5 mm) wide, 1.5" (38 mm) long, mounted 1/8" (3 mm) above ground plane
- L3 2 turns 1/8" (3 mm) wide brass strip, 0.1" (2.5 mm) diameter, 0.5" (12.5 mm) long

fig. 14. The two 422-MHz power amplifiers provide one-half watt output. The first stage, Q1, provides 10-dB gain, while the second stage, Q2, provides 7-dB gain.

sum of the feedline and TR relay losses (if any), input filter insertion loss, mixer conversion loss and i-f amplifier noise figure. For the system presented here the noise contribution of these stages prior to the i-f amplifier is less than 6.5 dB. Feeding the output of the mixer into a high-frequency ssb receiver would, however, result in a system noise figure approaching 20 dB. Many amateurs are surprised to learn that the noise figure of even a high quality commercial communications receiver is seldom below 10 or 15 dB. In the high-frequency spectrum the



- C1 1-10 pF concentric piston trimmer
- C2,C3 0.3-3 pF concentric piston trimmer
- C4
- CR1 1N4154 high-speed switching diode
- L1 2 turns no. 20, 0.1" (2.5 mm) diameter, 0.25" (6 mm) long
- L2 micro-stripline, 0.3" (7.5 mm) wide, 0.865" (22 mm) long, grounded at bottom, tapped 0.20" (5 mm) from ground end
- L3 Same as L2 but tapped 0.25" (6 mm) from ground end
- L4 50-ohm micro-stripline, 0.1" (2.5 mm) wide, any length
- R1 20k, 10-turn trimpot

fig. 15. The 422- to 1267-MHz diode tripler is built on 1/16" (1.5 mm) double-clad, glass epoxy circuit board.

which can be rewritten to solve for distance at 1296 MHz

$$\log_{10} d_{\text{miles}} = (L_{FS} - 98.85)/20$$

Given 142.3 dB of permissible free-space loss, an HP-35 calculator yields

$$d(\text{maximum}) = 161 \text{ miles (259 km)}$$

Amateurs who have operated simple equipment in the 23-cm band find it difficult to believe that a 161-mile path is possible with only 3-mW of output power. After all, they reason, that's greater than the APX-6's range, and those have 3-watts output. It should be remembered, however, that directly-modulated oscillators tend to be extremely unstable, and that reception of their emissions requires a wideband receiver. The APX-6 i-f strip is about 5-MHz wide and bandwidth has a serious

impact on receiver sensitivity. Fig. 16 indicates a deterioration in receiver sensitivity of 10 dBm for each tenfold increase in i-f bandwidth. This more than offsets any path increase afforded by the greater power of the APX-6 or similar equipment.

direct conversion

If simplicity is the goal, there is practically no limit to the evolutionary process. This last step occurred almost by accident, while developing test equipment for 1296 MHz. A weak-signal source was built for 1296.00 MHz to permit calibration and receiver testing. Since a few milliwatts of stable power was desired, I used the same techniques as I used for building the converter local oscillator. Later a key was added, and the signal source used for on-the-air CW contacts over a limited range.

Eventually, a means for monitoring transmit quality from the ssb converter was desired. An antenna and tuned cavity feeding a diode detector and audio amplifier produced the characteristic ssb "Donald Duck" squawk in a speaker. However, for high-quality signal monitoring a ssb converter was required. By using the 1296.0-MHz signal source developed earlier, driving a balanced mixer with its i-f port feeding an audio amplifier, a direct-conversion receiver was built. If the

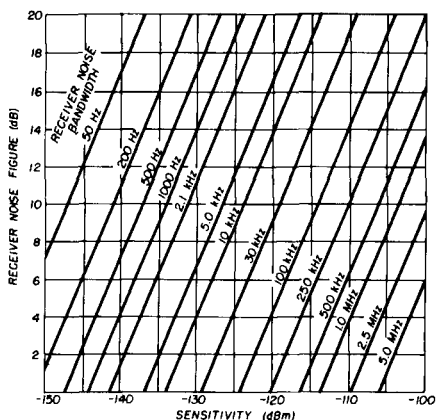


fig. 16. Receiver noise figure vs sensitivity for various receiver bandwidths.

transmitter (suppressed) carrier frequency and the receiver LO frequency are the same, the difference frequency at the i-f port of the mixer will be audio sidebands. No input filter is required because the image is merely the other sideband — and at 1296 MHz QRM is hardly a problem yet.

If a direct-conversion double-sideband receiver will work, there's no reason to expect otherwise for direct double-sideband generation. Indeed, when audio was applied at the i-f of the balanced mixer, sidebands around 1296.0 MHz appeared at the rf port. Though extremely low power, the signals could be copied in a sensitive receiver at a range of about a mile.

The resulting direct-conversion double-sideband transceiver is shown in **fig. 17**. Though primarily a lab accessory and demonstration rig, it provides reliable communications over moderate distances. It is simple in the extreme, and suggests the possibility of microwave double-sideband walkie-talkies. The concept may even work at greater power levels than the few microwatts attempted to date. Certainly there's no more basic a way to produce a microwave sideband station.

conclusion

The primary advantage of ssb in the microwave spectrum, as anywhere else, is in the significant increase in receiver sensitivity resulting from the narrow bandwidth which is required. The only limiting factor is stability, a criterion which can be readily achieved by judicious application of good engineering practice to the design and construction of local-oscillator chains. The design trade-offs presented here make microwave ssb feasible over considerable distances, while requiring a minimum of specialized skills, equipment or technique.

acknowledgements

I wish to express my deep appreciation to Don Farwell, WA6GYD, for giving me my first contact on 1296 MHz and kindling the fire, to Frank Pacier,

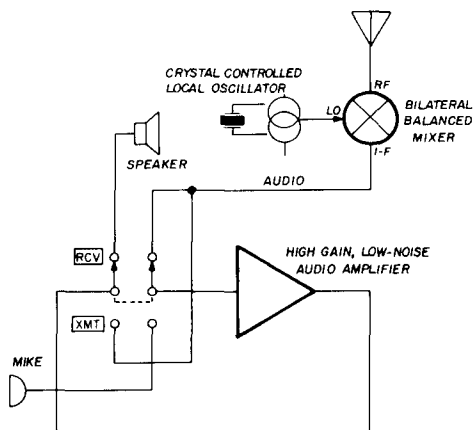


fig. 17. Simple direct-conversion double-sideband transceiver for 1296 MHz.

W6VMY, for the countless hours we spent together working on APX-6s in the early days, to Bill Troetschel, K6UQH, who shamed me into giving up modulated oscillators by his snide remarks at uhf conferences, to Bob Ney, WB6LLD, who gave me my first microwave transistors, and to Joe Reisert, W6FZJ, who taught me how to use them. And most important, a word of thanks to my wife, Suk, who for the past three years has shown more understanding of the hours spent on the 1296 project than I had any right to expect.

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ham radio



miniaturized communications receiver

Full construction details
for the Minicom —
a complete
communications receiver
that can be used
on the 40- and
80-meter bands

This article has to do with the art of homebrewing your own communications gear — the specific application is a miniature communications receiver. It was inspired by the huge packet of mail I received following publication of my article extolling the virtues of the LM373 IC manufactured by National Semiconductor.¹ Most of the letters contained requests for additional construction details, parts information and printed-

circuit artwork. Unfortunately, the original receiver contained some odd-ball components, and the board layout went the way of all trash during the year that passed between submission and publication, so I had to play the heavy and turn down most requests. As time went on and similar letters arrived, even a year later, I decided to do it all over again as a real construction article.

the homebrew art

If you are planning to skip this part, do so at your own risk because I may throw in a few clinkers during the construction phase that will cause untold agony for those who skip ahead.

Obtaining needed parts is probably the most annoying problem plaguing the do-it-yourself fan. Having an up-to-date library of standard and surplus catalogs does not even guarantee success. Even a calm, logical, well-ordered person can be reduced to a shattered, babbling hulk as a result of unsuccessful forays into the electronics marketplace. That's probably why kits have become so popular. For the intrepid craftsman, however, this may not be a practical answer since the manufacturers don't always kit what you want to build. To overcome these roadblocks, ingenuity and improvisation become the key factors in maintaining mental health

Ray Megirian, K4DHC, Box 580, Deerfield Beach, Florida 33441

and ensuring completion of a cherished project.

Aside from improvising in the parts department, miniaturization is generally best implemented by using printed-circuit construction. It is in this area that thoughtful layout is all important. Without carrying the shrinking process too far, a nicely balanced design has been achieved in this receiver without overcrowding or requiring fussy assembly techniques. The principal factor that limits size in this project is panel space. There is no sense in shrinking the receiver to postage stamp size if you need ten times that much space for the essential front-panel controls.

Integrated circuits are now a way of life and often provide the only means by which ten pounds of circuitry can be squeezed into a five-pound bag. This advantage can be lost, however, if an IC chosen for a particular function requires more external components than the same circuit would use in discreet form.

On top of this, you become a prime candidate for the funny farm by virtue of spending three days trying to lay out the artwork for this nightmare. By using a little discretion, ICs can be selected which will provide all the performance you expect while requiring a minimum amount of valuable printed-circuit real estate.

printed circuits

The above comments are of little use if your etchings are a lost cause. Of course, not all do-it-yourselfers use PC assemblies, but these techniques do make a project more professional in appearance and simplify duplication. Though most of the methods suitable for home fabrication of PC boards have been thoroughly covered in previous articles, I'd like to throw in a few comments on my method since I find it simpler, faster and superior to any of the others.

First, the circuit is laid out in pencil to exact scale on one-tenth (25 mm) grid paper. You'll have to develop your own skill in this phase of the operation but be prepared for a few frustrations until you

get the hang of it. I try to avoid the need for jumpers but this is not always possible.

The next step is to lay out the positive of the printed circuit with sticky-back circuit trace tape and pads commonly used for this purpose. If there are no copper areas other than the lines and circles, a piece of clear film may be placed over the drawing and the tape and donut-shaped pads applied to the transparent film. If copper areas, such as ground planes, are present in the design, as they are in this receiver, a piece of Rubylith[†] is more appropriate. This material consists of a clear polyester base on one surface of which is a thin red film. Sections of this film may be stripped away after first scoring the perimeter with a sharp knife. The remaining circuitry is applied with tape and pads as before.

When the positive artwork has been completed, a negative is prepared by contact-printing the artwork on a piece of 3M reversing film. A 30-second exposure in bright sunlight followed by a few seconds for developing result in a negative replica of the original artwork. This negative is then used to contact-print the circuit on a piece of sensitized copper-clad board. Here again a 30-second shot of sunlight will do it. The circuit board is then developed and etched in the normal manner.

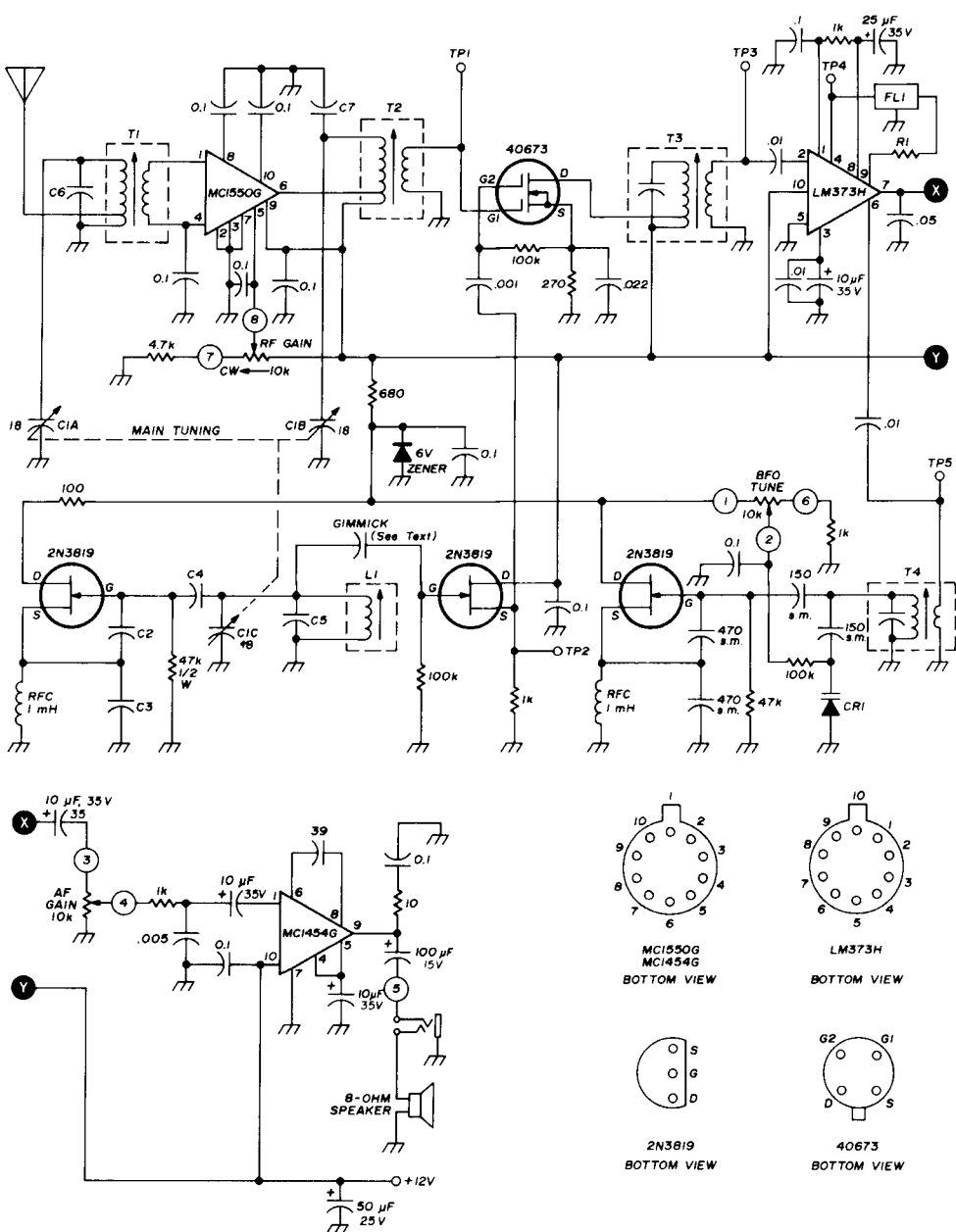
The 3M reversing film is a member of the Scotchcal* family which also includes sensitized aluminum sheet stock suitable for making panels, name plates, dials, etc.

The time required for preparing the original artwork may vary from a matter of minutes to several days, but once complete, this method will produce a finished circuit board in a matter of minutes, even if you include the time spent in coating the board with photoresist. No camera work or darkroom is required and the results are as good as the original layout.

Incidentally, a simple method for

[†]Rubylith is a registered trademark of Ulano.

*Registered trademark of the 3M Company.



- | | | | |
|-------|---|----------|--|
| C1 | 3-section variable, 18-pF per section (J.W. Miller 1460 or similar) | FL1 | Ceramic filter (Murata SFD455D or CFS455J, see text) (a 56-pF coupling capacitor is used with the SFD455D and is not shown in the schematic) |
| C2,C3 | 220-pF for 80, 470 pF for 40 (silver mica) | L1 | see fig. 2 |
| C4 | 39 pF for 80, 100 pF for 40 (silver mica) | R1 | 3000 ohms for SFD455D filter, 2000 ohms for CFS455J filter |
| C5 | 15 pF for 80, 70 pF for 40 (silver mica) | T1,T2,T4 | see fig. 2 |
| C6,C7 | 20 pF for 80, 130 pF for 40 (silver mica) | T3 | miniature 455-kHz if i-f transformer |

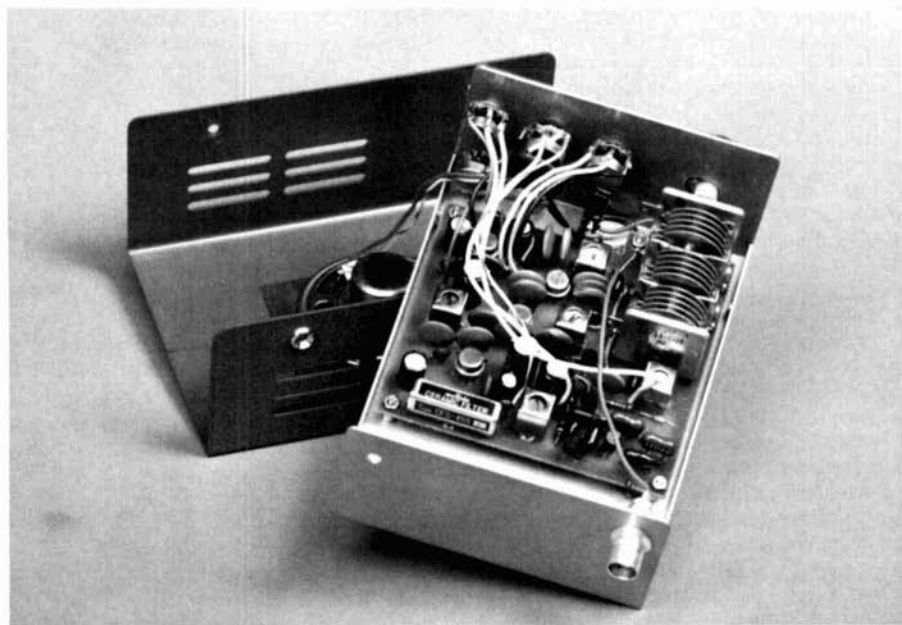
fig. 1. Schematic for the complete minicom receiver. Circled numbers correspond to the numbers on the printed-circuit layout (fig. 3).

achieving a rapid etch in ferric chloride is to brush the copper surface constantly with a soft paint brush while the board is immersed in the solution. One-ounce copper in fresh solution will etch in four or five minutes using this method while simple agitation may take four or five times as long.

druggist. For those of you who want to buy everything in small quantities from one place, Kepro packages the above materials and sells through several of the large mail-order houses.

minicom receiver

The miniature communications re-



Inside the cabinet of an earlier version of the receiver which used an IC mixer. This copy also sports the more selective ladder filter seen along the left rear edge of the board.

Another point worth mentioning is that when coating your copper stock with photoresist, a thin layer is always good insurance against problems during the developing process. This is especially true if trichloroethylene is used as the developer. I paint the resist on with a cotton swab and avoid spray cans like the plague.

I buy my Rubylith, reversing film and photoresist from a photo supply house. Trichloroethylene can sometimes be found in drug or hardware stores but I find it less expensive to buy a gallon (3.8 liters) from a local chemical supply agency. Developer for the reversing film is that ever-popular number, isopropyl alcohol, which is available from your local

ceiver described here is similar to the one I mentioned earlier. The only significant change is that an IC is used in place of an fet in the rf amplifier (see fig. 1). The original rf stage had a tendency to oscillate and the MC1550G IC completely eliminates this problem. An rf gain control was also added since this is easily accomplished with the IC.

In some versions of the receiver I experimented with, I used an IC balanced mixer. The MC1496 was considered but was abandoned because of the relatively large number of external components it required. Instead, an SG3402T by Silicon General was used since it only requires a couple of bypass capacitors as external components. This design worked fine and

one of the receivers pictured here has the IC mixer.

The other receiver has a dual-gate mosfet mixer — this is the version which is described in detail. The decision to go with the mosfet mixer was purely philanthropic. Searching for an SG3402T IC might result in considerable mental an-

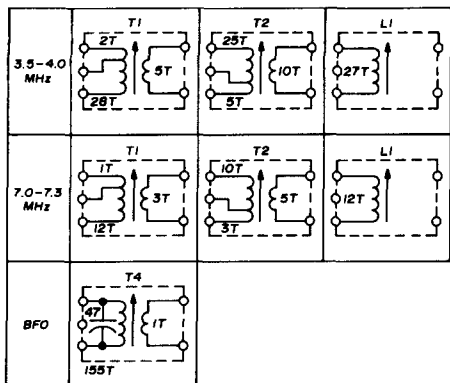


fig. 2. Construction of transformers and inductors used in the minicom receiver (see text).

guish which can be easily avoided by using the mosfet.

The mixer output feeds the LM373H IC which performs the functions of i-f amplifier, agc system and product detector. The main selectivity-determining device is part of the LM373H circuitry and consists of a 455-kHz ceramic filter. Actually, you have a choice between a simple 2-section filter (Murata SFD455D) which results in a 3-dB bandwidth of around 4.5 kHz or a more costly ladder filter (Murata CFS455J) with a 3-kHz bandwidth at 6 dB. The circuit board is designed to accommodate either filter and the choice depends primarily on the size of your wallet. Since a receiver of this type would normally not be used in contest work or for any serious fixed-station operation, I feel the simple 2-section filter is quite adequate. Also, it costs about one tenth the price of the ladder filter.

I decided from the beginning to forget about a-m reception and to make this receiver a strictly ssb/CW affair. The

receiver described in the previous article used a multigang switch to select either a-m or ssb/CW; it may be referred to if you are interested in making the required modifications. You may also wish to read that article for more details regarding the LM373H IC.

The final stage in the minicom receiver uses the MC1454G audio power amplifier IC. Here again I prefer this particular IC since it does a good job with very few external components and comes in a metal package. It will adequately drive a small speaker such as the built-in unit shown in the photograph. A larger speaker can be plugged into the phone jack.

inductors and transformers

All the coils and transformers used in the construction of the receiver are fabricated from miniature 3/8-inch (95 mm) square by 1/2-inch (127 mm) high transistor i-f transformers. With a little patience and a small soldering iron, they can be stripped and rewound for so many applications that it pays to keep a drawer-full around the shack. If you've reached the bifocal stage like me, a magnifying glass is helpful.

Both 455-kHz and 10.7-MHz transformers are used for this improvisation, so stock up on both kinds. The 455-kHz transformers have a winding of about 150 turns which is resonated with a 180-pF capacitor. The 10.7-MHz fm units contain a 47-pF capacitor across about a dozen turns. The entire assembly consists of a molded plastic base, an iron core, a threaded cup core, a plastic retainer for the cup core and the metal shield can.

Most types have two small dimples alongside either solder tab on the shield can which lock everything together. Forcing a thin knife blade down the inside of the shield can and prying the dimples slightly outward will improve your chances of separating everything without damage. Gently pull on the base pins until the base assembly pulls out of the shield can. Normally the cup core and its retainer will remain inside the can and may be left there. Occasionally I've run into transformers in which the cup-core

retainer is part of the base assembly and remains attached when the base is removed. In this case, just remove the cup core and set it aside until you are ready to reassembly everything.

First unsolder all the leads running to the five pins. Also unsolder the leads from the tuning capacitor. The only



Shield Can



Cup Core



Core Retainer



Iron Bobbin



Base



Tuning Capacitor

Exploded view of a typical i-f transformer of the type used in the minicom receiver.

transformers not having tuning capacitors are the oscillator transformers with red cores. Save these capacitors for possible use in special transformers since they are the only ones that will fit into the space provided.

When the wires have been unsoldered the iron coil bobbin may be pulled out of its socket. This piece is generally held in place by contact cement that is easily removed. The wire used in these coils has solderable insulation and is very easy to use, so salvage as much as you can. Clamp

a miniature alligator clip onto one end of the iron coil bobbin so you can hold it while the new winding is applied. If the winding has a tap, just bring out a loop at the proper turn.

If you require some center-tapped transformers, bifilar wind these using two separate wires. Put the large winding on first and squeeze some coil wax on the winding to hold it in place. Remount the bobbin and solder the leads to their proper pins. I generally don't use any cement on the bobbin, but you can if you want. The small secondary winding can now be added by soldering one end of the lead to its proper pin and feeding the wire around the bobbin for the required number of turns before soldering the remaining end.

A few well-placed chunks of coil wax are melted with a soldering iron until the wax flows in and around the coil to hold everything firmly in place when it hardens. Make sure all leads are dressed down the side of the coil and against the plastic base so there will be no interference with vertical travel of the cup core. Push the base assembly back inside the shield can and the transformer is ready to install.

Both 80- and 40-meter versions of this receiver were built around the same circuit board. The coil table in fig. 2 gives winding data and pin connections (bottom view) for all the coils. The 80-meter receiver uses 455-kHz stock while the 40-meter coils were wound on 10.7-MHz forms. A 47-pF capacitor from one of the latter is used to tune the bfo transformer. Don't forget to install this item when fabricating the bfo coil. Salvaged wire may be used for all coils except the bfo. Since you won't have a single piece of salvaged wire long enough for a 155-turn winding, use some fresh number-40 magnet wire.

construction

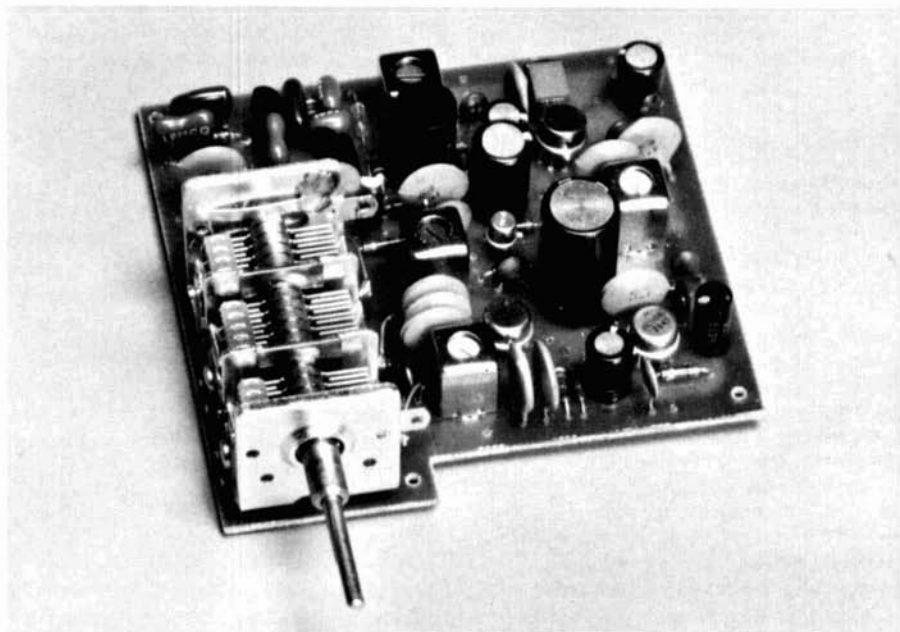
The PC board is 3.7-inches (9.4 cm) square and mounts all parts except the front panel controls (fig. 3). To prevent interference with panel-mounted controls, enough blank space has been left on

the filter are next, then the ceramic, mica and small electrolytic capacitors. The coils, transformers and large electrolytics are next while the tuning capacitor is saved for last.

Before mounting this last item, cut the three solder lugs down to a length of

amount of coupling should be adequate but may be adjusted later if required.

Leads of regular insulated hook-up wire may be installed next for the points going to front-panel controls, antenna, the speaker or closed-circuit jack and the power supply.



The printed-circuit assembly of the minicom receiver. The mosfet mixer is almost in the center of the board. The small ceramic filter may be seen at the right rear edge of the board.

1/8-inch (32-mm). Use a flat washer between the board and capacitor frame at each mounting screw to avoid interference with the trimmer assemblies on the two forward gangs. Toothed washers under each screw head should be used to ensure good contact with the copper and prevent loosening. Connect each gang of the tuning capacitor to its appropriate point on the board with solid bus wire.

Coupling between the hfo tank and the source-follower is accomplished with a gimmick capacitor. Solder a 1/2-inch (127-mm) length of bus wire and a 3/4-inch (190-mm) long piece of insulated hook-up wire in the holes provided for the gimmick. Wrap the insulated lead loosely once around the bus wire. This

If you wish to test the receiver before installing it in a cabinet, go ahead and wire up the controls. There are two holes along the front and one along the rear edge for grounds. These are for convenience and may be used as you see fit. The use of metal spacers for mounting the board will ground the common on the board to the metal cabinet.

test and alignment

There are five test points provided on the circuit board. Each is noted in **fig. 1**. The padding capacitor values called out are those used in the prototype receivers, but some alteration may be necessary if tracking is poor or the frequency range is greater or less than nominal. The 80-

meter version should tune from 3.5 to 4.0 MHz and the 40-meter receiver from 7.0 to 7.3 MHz.

Power up the receiver with a 12-volt supply (fig. 4) and observe that the current with no signal is around 35 mA, indicating that you managed to avoid any

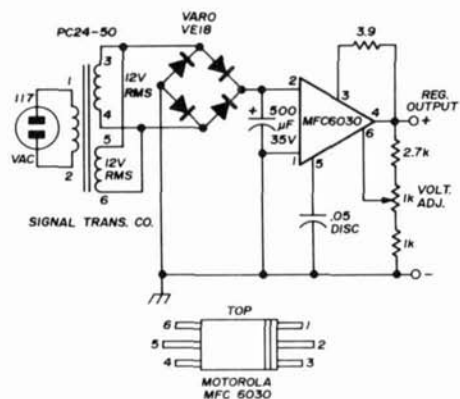
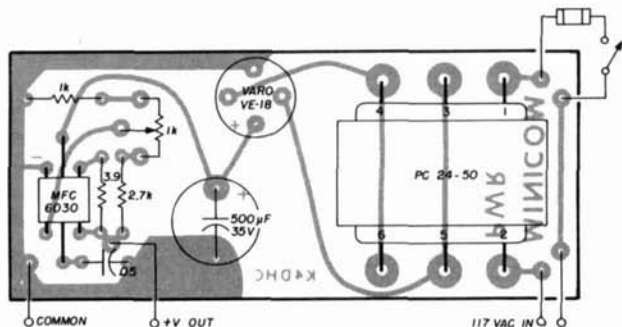


fig. 4. A 12-volt power supply suitable for use with the receiver. A printed-circuit layout for this ac power supply is shown in fig. 5.

short circuits. If smoke is absent, warm up your signal generator and start aligning. The following procedure is abbreviated, but should start you off in the right direction.

The two trimmers should be run up snug but not tight, the two gain controls turned up full and the bfo set to mid-range. Adjust the core in the bfo transformer until you hear some noise, indicating the frequency is close to 455 kHz. Connect the generator to the antenna terminal and run the output up and down until you pick up a signal and know the receiver is working. Set the tuning capacitor to full mesh and the generator to the low end

fig. 5. Full-size component layout for the ac power supply.



of the band. Adjust the core in the hfo coil until the signal is picked up.

Run the tuning capacitor all the way open and check for a signal at the high end of the band. If all is well, center up the tuning range by means of the core in the oscillator coil. Adjust the cores in transformers T1 and T2 for maximum gain at the low end of the band and the capacitive trimmers for maximum gain at the high end. Peak the i-f transformer for greatest noise. The bfo can then be adjusted so zero beat occurs about mid-position of the tuning control.

closing comments

If you don't have any capacitor diodes suitable for use in the bfo tuning circuit, glass silicon diode rectifiers generally work. That is what I used in the final version. The dipped silver-mica capacitors used in the tuned circuits should be the smallest sizes available or you may run into mounting problems. The lead spacing and outside diameter of the electrolytics should be taken into account when buying these items. Most of the ones I used were obtained from Radio Shack. Even then, it was found that capacitors marked with the same values and voltages often varied in case size. These conspiracies are all around, so be wary.

The cabinet shown in the photograph is a Radio Shack 270-252 and costs \$2.59. Dimensions are 4 x 2-3/8 x 6 inches (4.8 x 6.0 x 15.2 cm) which makes a fairly compact package. Since panel space is at a premium, the speaker and its perforated metal grill were epoxied to the top of the cabinet. There is plenty of

room left inside for a 12-volt pack of penlight cells or for a small power supply. The circuit for a power supply I built is shown in fig. 4. It will deliver about 11 volts of regulated power. The receiver will work on any voltage from about 9 to 12 volts with very little difference in performance.

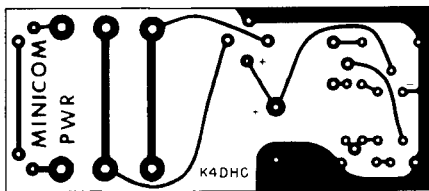
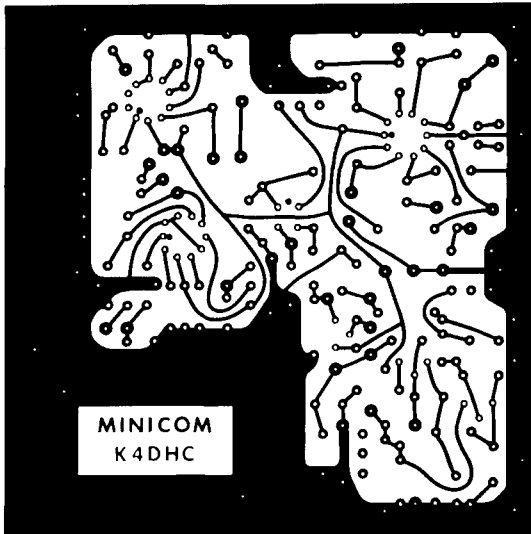


fig. 6. Printed-circuit layout for the minicom receiver and power supply (not full size).

Naturally, other variations of this receiver are possible. A two-band version which covered both 80 and 40 meters without bandswitching was breadboarded. The oscillator covered the range from 5.25 to 5.75 MHz, resulting in an i-f of 1750 kHz for both bands. The output from a crystal oscillator operating at 2.205 MHz was then mixed with the 1750 kHz signal to produce a second i-f at 455 kHz. A separate, high-capacitance two-gang tuning capacitor was used to tune the rf stage. This arrangement hit 80

meters at one end and 40 meters at the other end of the tuning range, eliminating any need for bandswitching.

Experiments with these techniques at 20 meters left a lot to be desired, however, and I found that a converter worked best for multiband operation on the higher frequencies. Odd-ball i-f transformers are a cinch, though, and many specials have been fabricated for successful use in all kinds of circuitry. The 1750-kHz i-f transformer consisted of 36 turns tuned with the original 180-pF tuning capacitor. A tap at 2 turns for the MC1550G and a secondary of 10 turns to feed the mosfet mixer completed the unit.

The stock 455-kHz oscillator transformers (red core) have no built-in tuning capacitor. With a 180-pF capacitor, these transformers will tune to around 1.0 MHz. The 10.7-MHz transformers with a 180-pF capacitor will resonate at around 5.8 MHz. The regular 455-kHz i-f transformers with a 47-pF capacitor tune to about 700 kHz. Double-tuned transformer assemblies, and center-tapped transformers to couple from the output of an MC1496 mixer to the LM373H were also made.

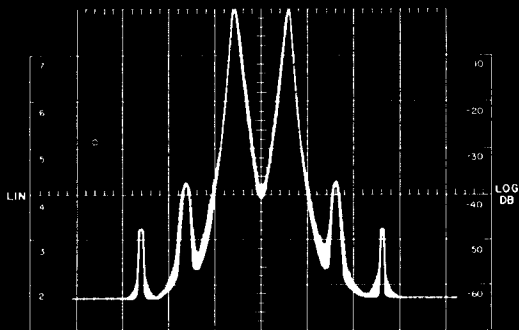
At the time this receiver was being developed, I was corresponding with Al Bernard, WA2JTN, who happened to have some very small knobs which he provided for this project. They are only 5/16-inch (79 mm) in diameter. They are ideal for this application but, unfortunately, they are in woefully short supply, so you'll have to settle for the smallest you can find.

As for the rest of the parts, I know you can't buy the Murata ceramic filters any place so I'll keep some on hand. For a complete list of parts I can supply, please send along a self-addressed, stamped envelope with your inquiry.

reference

1. Ray Megirian, K4DHC, "Using The LM373," *73 Magazine*, April, 1972, page 37.

ham radio



intermodulation-distortion

measurements on ssb transmitters

A comparison of
IMD measurements
of amateur
ssb equipment
shows that
industry standards
should be set
by the EIA

Specifications for the suppression of odd-order distortion products in amateur ssb transmitting equipment generally appear to be vague, inadequately defined and relegated to the sole domain of the equipment manufacturers. One observation might be that some amateur ssb specifications seem to be generated in sales departments rather than in engineer-

ing departments. Rarely, if ever, are the manufacturers' transmitter intermodulation distortion products clearly stated in easily understood terms or on any uniform basis. For example, the third-order IMD specifications I have reviewed are stated merely as -30 dB, an apparently good number, if valid, by the present state-of-the-amateur art. However, an IMD specification stated in this way is ambiguous because it does not give the basis, the power level at which the measurement was made, nor other pertinent data such as frequency, worst or best case measurement, etc.

It is significant to note that all intermodulation distortion power is valueless and only causes interference to adjacent channels of operation. The purpose of this article is to explore some of the foregoing with respect to the Collins S-Line and some other contemporary equipment using measurement data taken by relatively sophisticated laboratory test equipment which, operating under a quality system, has certified calibration accuracy traceable to the National Bureau of Standards.

I used the Hewlett-Packard Model 141S Spectrum Analyzer Display Section with the 8553L rf and 8552A i-f heads for making the measurements. This instrument is a recognized standard in the electronics industry with a specified calibration accuracy of a 0.5 dB. It covers

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the range of 1 kHz to 110 MHz, with interchangeable i-f and rf heads and has variable selectivity. My tests were conducted at 100-Hz bandwidth which is necessary for accuracy and ease of measurement. The instrument's spurious responses, with a -40 dBm signal to the input mixer, are better than 70 dB down. All analyzers have spurious responses since they are all sensitive to overload, so it is especially important to observe this critical parameter—otherwise it will be evidenced by false, spurious presentations.

IMD measurements

The methods of making IMD measurements, together with considerable discussion have been covered in several excellent, pertinent publications.^{1,2,3,4} These references reveal that IMD measurements may be taken on one of two bases. In the conservative method which I used, the spurious level is referenced to *either* tone of a two-tone test. The other method is also acceptable, but is a less conservative method; it compares one distortion product to the sum of two tones, or the PEP. This yields a more impressive number, resulting in a -6 dB *apparent* improvement. This is because of

the fact that the PEP value, or the sum of the two tones, is twice the voltage, providing a 6-dB greater reference level. Therefore, with that power level as the reference, the distortion products would *appear* to be 6-dB further down. A third method that is widely used in military work is the Intercept Point method⁵ which resolves most of the ambiguities. However, I will not go into that here.

Most vacuum-tube manufacturers, and military and commercial suppliers tend to specify the distortion products of their equipment using the conservative method. Quite naturally, equipment manufacturers may indulge in some "specsmanship" by publishing performance specifications which tend to favor themselves. During the preparation of this article I contacted the National Bureau of Standards, the IEEE and the EIA to ascertain whether any standards had been published on the subject of ssb transmitter IMD measurement. They indicated that none were published. A proposed EIA specification was prepared but, unfortunately, it has never been published; it was to be based on the liberal basis; i.e., the PEP reference. I have therefore concluded that the amateur equipment manufacturers in the United States, with the one notable exception of Collins, have chosen to use the liberal interpretation while the rest of the industry and the military appear to adhere to the conservative method. The point is that amateurs should be aware of the differences and the implications of both.

For purposes of clarity in this article, I will refer to the two bases as the conservative and liberal methods and, unless stated, all references of mine will be on the conservative basis. In other words, you should add -6 dB to all my data to make it consistent with most of the published specifications and test data on amateur ssb equipment. For example, take the RCA tube specification sheets for the very popular 6146B type tubes. The manufacturer states that these tubes exhibit -24 dB CCS and -26 dB ICAS for their third-order products at PEP power output levels of 49 and 61

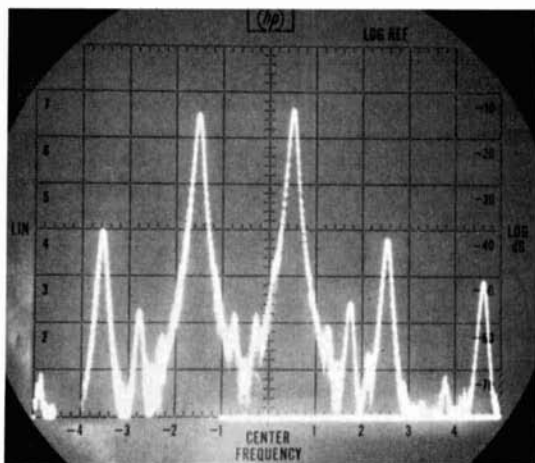


fig. 1. Spectrum analyzer display of intermodulation distortion test on a Signal One CX7A. Two-tone test, 800- and 1800-Hz tones. Horizontal scale is 500 Hz per division. Third-order products are 25-dB down (see text).

watts, respectively, "referenced to either of the two tones and without the use of feedback to enhance linearity," i.e., the conservative method.

Eimac makes the more explicit statement: "The intermodulation distortion products will be as specified or better for

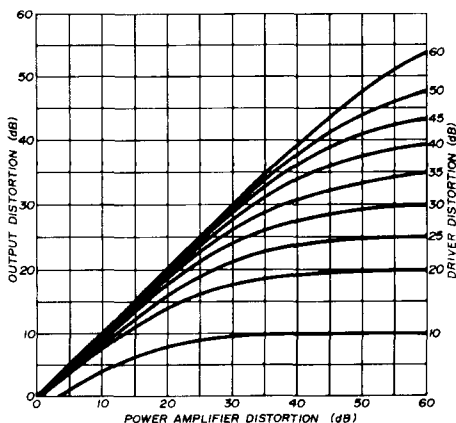


fig. 2. How IMD levels of the driver and output stage combine to determine overall IMD performance (courtesy Collins Radio Company).

all levels from zero-signal to maximum output power and are referenced against one tone of a two-equal-tone signal." That statement is extremely significant, as we shall see. Allowing for tube variations in performance, matching, aging and power supply regulation, combined with other miscellaneous factors such as neutralization, drive regulation, bias, etc., it is impossible to achieve a conservative -30 dB third-order IMD at the 100-watt level from the 6146 family of tubes without the use of negative rf feedback. Bill Orr showed that sweep tubes generally exhibit less than this performance when operated near or at full power, e.g., in the -18 to -22 dB region for the third-order products.¹

Looking at the data sheets for the 8072, the output tube used in the Signal/One CX7A, RCA specifies, on the conservative basis, -30 dB on the third-order products at 80 watts PEP power output. Signal/One specified their equip-

ment as a "nominal 300-watt PEP input and 160-watt PEP output." They further specified that their third-order IMD was "greater than 30 dB below each of two equal tones at full rated output." This specification is on the conservative basis and, extrapolating from the tube data sheets, it is an obvious impossibility because of the tube manufacturer's 80-watt PEP output specification versus the equipment manufacturer's 160-watt PEP output specification, but it surely makes the meters dance. For my IM test results of -25 dB at full power out on a CX7A which had just been overhauled by the factory, see fig. 1. The exciter did, however, meet its -30 dB IMD specification at 100 watts PEP output.

tube operating conditions

During the course of my measurements, a friend brought in his Yaesu FTDX560 for a quick check. The third-order products, at full power out, predictably were -22 dB. At 40 mA of quiescent plate current, 10 mA less than that specified, the third-order products measured -20 dB. It was interesting to observe that the fifth-order products were measured at -50 dB at 60 mA of quiescent plate current and were only -35 dB at 40 mA. Throughout my measurements, this type of result was common. Since the third-order products are generally the

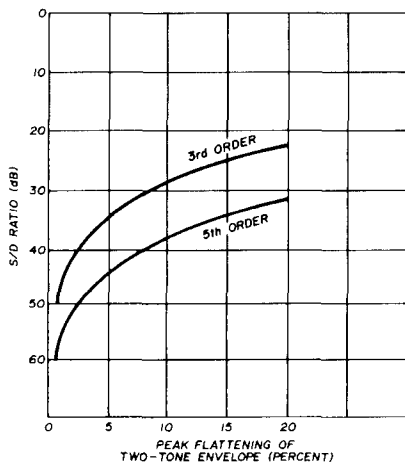


fig. 3. Relationship of two-frequency envelope peak flattening to signal-to-distortion ratio.

worst offenders, I have not commented on the fifths. However, in a local or short skip situation, *all* products play an important role.

One significant fact I found was that the third-order products could be improved 6 dB by merely resetting the quiescent plate current up to 60 mA from

amplifier is significantly higher for less linear operation. This means that the lower power stages may be operated inefficiently at class-A bias to provide very low IMD levels while the output stage is usually biased for higher efficiency and increased IMD levels. If output stage efficiency is a driving factor, the

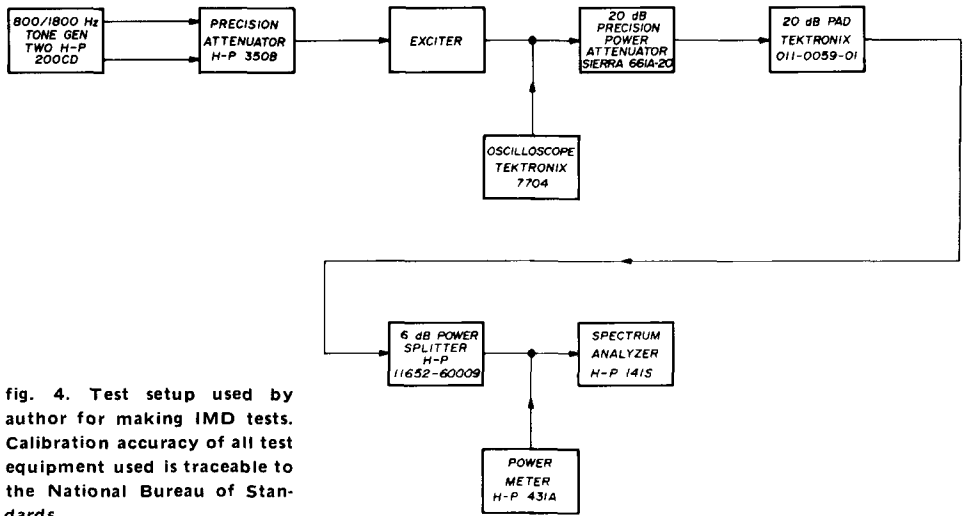


fig. 4. Test setup used by author for making IMD tests. Calibration accuracy of all test equipment used is traceable to the National Bureau of Standards.

the specified 50-mA level. A note of caution is in order here, since this probably would affect tube life under full-bore operation because of the additional heat, and TV sweep tubes are very dissipation limited. It is important to note that most amateur equipment is operated at or near the full capability of the output tubes.

Looking at the practical situation, with some signal degradation from linear amplifiers, most amateur stations are probably transmitting signals with third-order IMD products in the -20 to -24 dB region. By way of contrast, commercial and military equipment is generally specified in the -30 to -35 dB range. State-of-the-art military equipment is specified in the -40 dB range with -50 dB attainable. It is clear that IMD is less in linear stages than in non-linear stages and becomes progressively worse as the linearity of a stage is compromised from class A to B1 and B2 operation. On the other hand, the efficiency of a power

output stage IMD performance will limit the overall performance of the equipment. The way in which the IMD levels of the driver and the output stage combine to determine the overall performance is illustrated in fig. 2.*

In a period of time when we are concerned with already crowded amateur bands, IMD specifications are worthy of consideration. I do not presume to recommend military specs for amateur equipment, but I do urge amateurs to strongly consider the credibility of the published specs, look at the tube data sheets, and operate their equipment in a reasonable manner. By this I mean something less than maximum power, using an

*Distortion measured in dB below one tone of a two-tone signal. Products are assumed to add in phase. Fig. 2 is derived from a plot of the relation

$$x = 20 \log 10^{y/20} + 1$$

where x is driver distortion minus amplifier distortion, and y is driver distortion minus output distortion.

adequate monitoring and control system combined with all the other facets of the overall problem. Now you may understand why some rigs sound and look better than others.⁶

I wrote letters to each of the five major U.S. amateur ssb equipment manufacturers requesting data on their IMD specifications and measurements. Three of the four who replied stated that they use the PEP reference as I indicated earlier. The two largest Japanese manufacturers were not queried, as they do not specify IMD. Since they use sweep tubes or 6146s at full power without rf feedback, their third-order IMD products can readily be predicted to be between -18 and -26 dB; with sweep tubes, the -18 to -22 dB region.

Collins S-line

Let's take a look at the IMD performance of Collins' equipment which was designed over fifteen years ago, but which probably exceeds the IMD suppression performance of all current production amateur communications equipment. Two features make this possible. One is an excellent two-stage alc system combined with the use of rf negative feedback. The advantage of this is simply that a rig with 10-dB of rf negative feedback will be essentially 10-dB cleaner than a rig without it. To this date, no other production amateur equipment in the world is known to use rf negative feedback. As I previously pointed out, RCA specifies the 6146As and 6146Bs at -26 dB, to which -10 dB of feedback at 14 MHz is added, so Collins' -30 dB spec can be easily met or exceeded, allowing for all variations.

It is significant to note that every piece of amateur ssb equipment, both linears and exciters, manufactured by Collins employs rf negative feedback! Collins advises that every S-Line, KWM-2, and linear amplifier goes through an IMD measurement test in their production acceptance test procedure. That unique type of quality control for amateur equipment is to be commended. Collins also states that tubes are the major reason for rejection for IMD products so this

would indicate that the tubes should be given much more consideration than is normally the case.

For example, in my Collins 32S-1 exciter I always match the 6146s for equal quiescent plate current. It is quite revealing to note the wide variation of this single parameter from the same

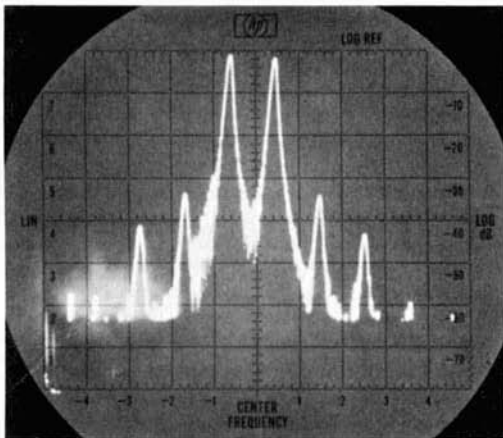


fig. 5. IMD distortion of Collins 32S-1 exciter at the 100-watt PEP level. Third-order products are about 35-dB down; fifth order products are more than 40-dB down.

manufacturer. In the course of making my measurements, it was noted that the very smallest amounts of indicated grid current on the 6146s resulted in a substantial increase in the distortion levels. This indicates that any departure from class AB1 is totally unwarranted and should serve as a warning to those who would defeat an alc system in any fashion. Pappenfus discusses the resulting flattopping in two chapters of his book (see fig. 3).

Now let's look at some measurements taken on my 32S-1 exciter, which is more than thirteen years old. Third-order product measurements were made in an engineering calibration laboratory using the block diagram shown in fig. 4. The result at the 100-watt PEP power output level is shown in fig. 5. Sutherland and Orr have shown that the third-order products are generated on a kinked curve

due to distortion cancellation,² so my power level tests were considered appropriate to preclude errors. Also, it was desirable to see if tube balance by plate idling current is significant and if there was any real difference between 6146As versus 6146Bs. RCA states there is none. My test data tends to confirm this, but my sample size was very small. Further, the effects of varying the various operating parameters of the 6146s are shown in fig. 6.

During the course of taking this data, despite using two husky fans, it was noted that heat dissipation is a major constraint. Repeatability of the test data was heavily dependent upon proper cooling and reasonable operating periods to minimize the thermal impact. Therefore, serious consideration should be given to this parameter during normal operating, and especially under contest conditions. One first thought is to open the cabinet cover. Next, of course, would be a small, quiet fan mounted off the chassis to preclude microphonics. It must be recognized that the two-tone test is a very strenuous exercise of the equipment since the average power is substantially higher than with speech.

I thought it would be valuable to ascertain the IMD level of the 6CL6 driver stage in the 32S-1 to determine if it could be improved, thereby improving the 6146B output stage IMD. It measured a startling -22 to -29 dB on the third-order products, depending on the power level, a figure that at first was of very serious concern. Later it was determined that, with the feedback loop closed, what I was reading was the net IMD after subtracting the counter distortion being used to linearize the output tubes. Without any doubt, the driver, which is essentially operating class A, is producing IMD in the -40 dB region. No measurable improvement in the driver IMD was attained, as read directly or indirectly in the power-amplifier linearity, with any change in its operating biases.

I would like to describe some of the modifications which were installed in my 32S-1 exciter to increase its linearity.

Capacitor C61, a 10-pF ceramic which forms the basic feedback network in the S-Line, has been placed in parallel with a Corning glass 5.6-pF capacitor. This provides a measured third-order improvement of 3 dB at 14 MHz at full power output. Another simple mod, although not affecting the IMD, provided a de-

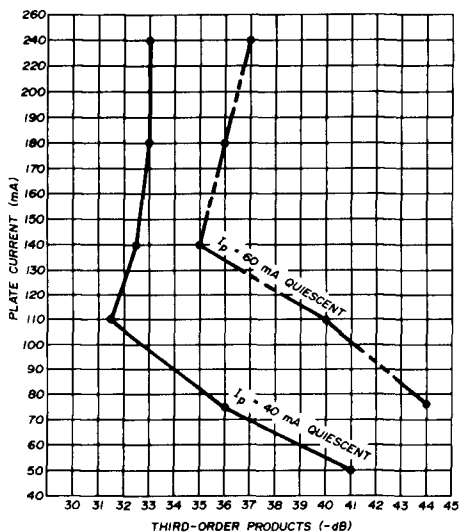


fig. 6. Effect of varying Collins 32S-1 quiescent (idling) plate current on third-order distortion products. The 40-mA level is normally used but 60 mA quiescent plate current improves IMD. During these tests plate voltage was 820 volts and screen voltage was 275 volts.

crease in the audio harmonic distortion—this is the addition of a 250k resistor between the plates of V1A and V1B, the audio amplifiers.⁷ This results in an audible improvement in the speech quality. I note that the same principle is applied in the Yaesu FTDX560.

To make up for the loss of gain due to the inverse feedback, the vox amplifier, V15A, will require a 10- μ F bypass from the cathode (pin 3) to ground. Otherwise the vox will probably cease to operate as there is about 15-dB loss of audio signal, the amount of the feedback, through the system. Further, I set the 6146B quiescent plate current at 60 versus the 40 mA which is specified by Collins. This yields an additional 4-dB improvement in the

third-order distortion products. Of course, this might cause a heating problem and therefore affect tube life in some equipment, but this is not so in my case as I require only 40 watts of PEP drive for my class AB1 linear amplifier.

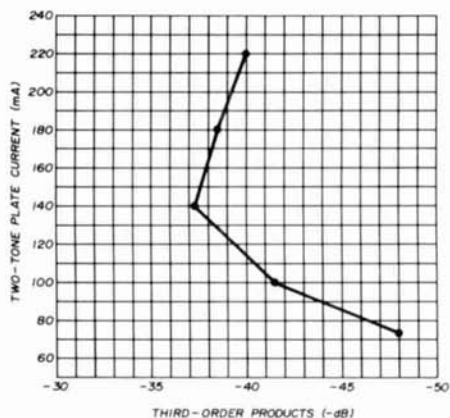


fig. 7. Third-order IMD performance of Collins 325-1 exciter modified by the author (see text). Test conducted at 14.25 MHz; plate voltage, 780 Vdc; screen voltage, 240 Vdc; quiescent (idling) plate current, 60 mA.

Also, I run the 6146B screens from the basic low-voltage supply rather than the bleeder arrangement in the original design.⁸ This improved screen voltage regulation will increase the power output and also should slightly improve the IMD, although no comparative measurement was made.

Tests were also made to determine the effects on IMD which would result from rf clipping. Only 1-dB of degradation was measured, at about 15-dB of clipping. Some of this is probably due to the fact that the alc system is being partially deceived through the loss of the high peaks by the clipping, as well as the natural result of the higher average power level. The combination of these modifications allowed a reduction of IMD at the 100-watt output level from -32 to -39 dB, as shown earlier. Fig. 7 shows the results produced by reducing the plate and screen voltages in an effort to find an optimum operating condition. The power output was down to 60 watts PEP but the

desired IMD reduction was attained.

On the subject of tubes, there are stories circulating that 6146As are cleaner than 6146Bs, etc. I wanted to determine just what advantages, if any, there might be between the two types. A series of tests was conducted using matched pairs for quiescent plate current, unmatched tubes, and mixed 6146As and 6146Bs. The results were relatively inconclusive with up to 3-dB variations measured. My sample size was too small to develop any significant trends, so I would stick to the published literature, i.e., use well-matched tubes that are in good condition and run them cool at less than maximum power, neutralize carefully, load properly, etc.

While the test setup was available, I decided to measure the harmonic suppression of my S-Line. It measured -47 dB on the second harmonic and greater than -60 dB on the fourth while operating at 14.25 MHz into a matched 50-ohm load.

other equipment

My basic data are concerned with the Collins S-Line, but other measurements on a limited basis are also presented to

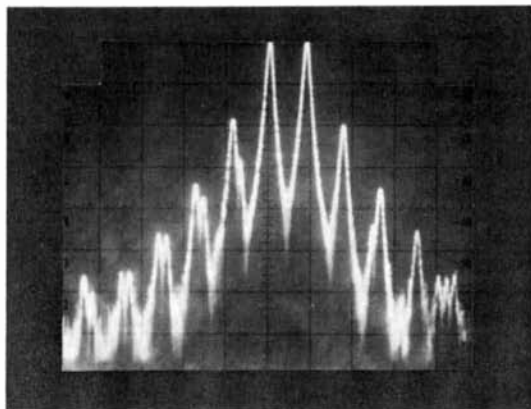


fig. 8. Spectrum analyzer display of two-tone test on Kenwood T599 ssb transmitter, referenced to one of two equal tones. Maximum two-tone PEP output without limiting was 72 watts as observed on Tektronix 585A oscilloscope in conjunction with a Hewlett-Packard 431B power meter. This display shows third-order products down -19 dB, fifth-order products down -34 dB.

support some of my earlier statements. From these it may be seen that, with the exception of Collins, the conservative, -30 dB IMD specifications are not attainable at full power levels, regardless of the specifications published by the manufac-

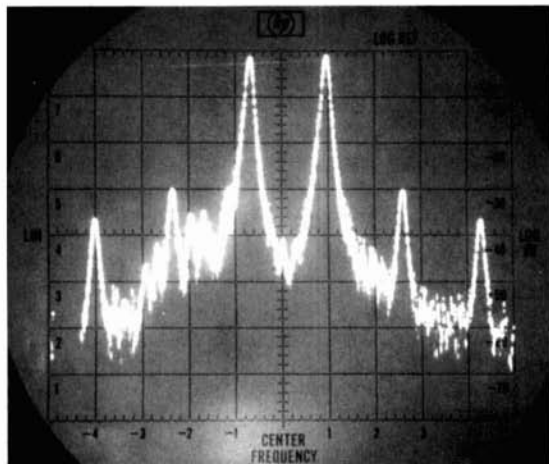


fig. 9. Spectrum analyzer display of two-tone test on Collins KWM-2A ssb transmitter, referenced to one of two equal tones. Maximum two-tone PEP output without limiting was 100 watts. This display shows third-order IMD products down -30 dB, fifth-order products down -37 dB.

turer. In one case, the Kenwood T599, the IMD specs are not published by the manufacturer. My measurements at 72 watts PEP output of -19 dB on the third-order products differ with those published⁹ by 8 dB as shown in fig. 8. Two other amateurs, using the same measurement equipment, confirm my data.

Fig. 9 shows the measured -30 dB results taken on an old Collins KWM-2 at the 100-watt PEP output level. It was sorely in need of total refurbishment, but it still meets the published specifications.

conclusion

If you are a concerned amateur, and we all should be, let me say, *caveat emptor!* The IMD performance may be more or less readily determined to within a couple of dB by examining the output tubes, considering their specified input power, and reading the literature. What I

have found has been clearly supported in all the text books. If we want to radiate cleaner signals, there are not any magic formulas to accomplish that. I would, however, lobby for one published standard method of IMD measurement so that everyone understands the related specification and measurements. Only one manufacturer of amateur equipment, Collins, specifies their IMD suppression on the conservative basis, although even they do not make it clear in their literature. All other amateur manufacturers adhere to the liberal basis which provides them with a relative 6-dB advantage. It is a valid measurement, though somewhat misleading, and is often misunderstood and certainly misquoted. It now becomes obvious that in order to compare the proverbial oranges, all manufacturers should use one specification standard.

I would like to express my sincere appreciation to Bob Bruemmer, WB6CGG, who spent many hours setting up the measurement equipment used for taking the data presented and verifying its calibration.

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ham radio

modern rf amplifiers for communications receivers

A discussion of
the performance
characteristics of
modern rf
amplifier stages,
and how to choose
the circuit
best suited
for your own
application

Since James Lamb first described the modern communications receiver in 1932 amateurs have expected a good receiver to have one or two rf amplifiers. There was good reason for this in the 1930s as mixers were noisy and even the relatively noisy rf amplifiers which were available were an improvement. The rf amplifiers were also necessary to compensate for the losses in the tuned circuits required to attain a decent image ratio with single conversion to an i-f around 455 kHz.

The pentode tube was used almost exclusively in rf amplifiers for thirty years. Many amateurs will remember the succession of tube types—58, 6D6, 6K7, 6SK7, 6AK5, 6BA6, 6DC6, 6BZ6 and 6EH7. Bipolar transistors were used briefly during the 1960s, not because they made better rf amplifiers, but to satisfy the demand for all solid-state receivers. The junction fet (jfet) and dual-gate mosfet soon appeared and replaced the bipolar devices in new designs.

An rf amplifier does several things for a receiver. First of all, it provides gain to make up for any losses in the rf tuned circuits. Secondly, it provides low-noise gain to override mixer noise. It can also provide an extra gain-controlled stage and can be used to perform impedance-matching functions.

However, the rf amplifier also has disadvantages which must be weighed against the advantages in any particular application. Most important, since it places an additional unprotected stage ahead of the selective filters, it can aggravate mixer nonlinearity by amplifying close-by, unwanted signals.

antenna noise figure

The receiving system is a chain consisting of the antenna noise figure, the input stage, the second stage and so on. If the chain is properly designed the overall system noise figure is determined by the first link in the chain, the antenna noise figure.

The ultimate factor in deciding what weak signals you can hear is the signal-to-noise ratio between the signal and the atmospheric, galactic and manmade noise impinging on your antenna. If the signal is equal to the noise level you can at least detect it and possibly carry on marginal communications. Therefore, the receiver

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should be quiet enough for you to hear the ambient noise level. Anything much quieter than that is superfluous.

The atmospheric noise level has been measured and is available in terms of antenna noise figure.¹ Fig. 1 shows the antenna noise figure for the northeastern United States between 0800-1200 local time in the winter. The noise falls within the shaded area 80% of the time, above it 10% of the time, and below it 10%. In addition, there is galactic noise striking the earth's atmosphere at all times. The galactic noise level is shown by the dashed curve for all frequencies but it can only penetrate to your antenna at frequencies above the critical frequency.

A third curve extending up to 10 MHz gives the average level of manmade noise at a quiet receiving location. It is often the limiting factor at frequencies below 10 MHz.

What is the lowest antenna noise figure you can expect in the high-frequency range? The figure of 18 dB is often quoted as the limit and fig. 1 shows that this is the galactic noise level at 30 MHz. The critical frequency seldom reaches 21 MHz so galactic noise is still the determining factor on that band.

On 20 meters the critical frequency may sometimes be high enough to shut out galactic noise but the atmospheric noise is above 28 dB 90% of the time. On 40 and 80 meters manmade noise puts a floor under the minimum antenna noise

figure. Therefore, the assumption that the lowest antenna noise figure encountered on hf is 18 dB is theoretically valid.

There is reason to believe, however, that on some few occasions the noise level on 10, 15 and even 20 meters drops below the predicted values, perhaps down to 10 dB or less.^{2,3} Little information is

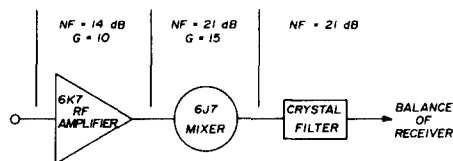


fig. 2. Noise characteristics of a typical communications receiver of the 1930s.

available to explain these occasional quiet periods. Perhaps they are due partly to unusual absorption of galactic noise as it passes through the atmosphere. As you go *higher* in frequency, of course, the galactic noise decreases so that the antenna noise figure is 13 dB at 50 MHz and 6 dB at 100 MHz.

The overall noise factor of a system composed of a receiver and an antenna is

$$F_{sys} = F_a - 1 + F_r \quad (1)$$

where

F_{sys} = overall system noise factor (ratio)

F_a = antenna noise factor (ratio)

F_r = receiver noise factor (ratio)

Assume you are operating a receiver with a 10-dB noise figure (noise factor = 10) on 10 meters where the antenna noise figure is 18 dB (noise factor = 63). How much does the receiver degrade the overall noise figure?

$$F_{sys} = 63 - 1 + 10 = 72 \text{ or } 18.6 \text{ dB}$$

For a perfect receiver (zero-dB noise figure) the calculation is

$$F_{sys} = 63 - 1 + 1 = 63 \text{ or } 18 \text{ dB}$$

Thus, the receiver degrades the noise figure of the system by only 0.6 dB.

The story is different at vhf. Suppose

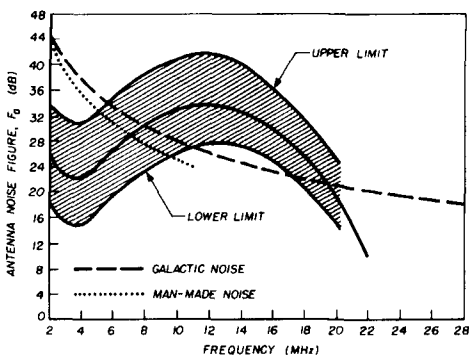


fig. 1. Atmospheric noise levels expressed as antenna noise figure for 0800 to 1200 local time on a typical winter day in the northeastern United States.

you are operating at 100 MHz with the same receiver. Here the antenna noise figure is only 6 dB (noise factor = 4).

$$F_{sys} = 4 - 1 + 10 = 13 \text{ or } 11.1 \text{ dB}$$

In this case the NF is degraded by 5.1 dB over that of a perfect receiver.

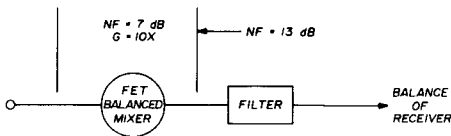


fig. 3. Noise characteristics of a modern fet balanced mixer feeding an i-f strip.

receiver noise figure

One rule-of-thumb says that the first stage of a well designed receiver should contribute all except one dB of the overall receiver noise factor. The overall noise factor of a receiver can be found from

$$F_r = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} \quad (2)$$

where F_r = overall receiver noise factor (ratio)
 F_1, F_2, F_3 = noise factors (ratio) of first, second and third stages
 G_1, G_2 = power gain (ratio) of first and second stages

Apply this formula to the receiver shown in fig. 2 which is typical of receivers used in the late 1930s.

$$\begin{aligned} F_r &= 25 + \frac{126 - 1}{10} + \frac{126 - 1}{10 \times 15} \\ &= 25 + 12.5 + .83 \\ &= 38.3 \text{ or } 15.8 \text{ dB} \end{aligned}$$

Notice how little the second and succeeding stages contribute to the overall noise factor.

Let's look at another example. Fig. 3 shows a modern fet balanced mixer working from the antenna into an i-f strip with a NF of 13 dB (noise factor = 20). The

mixer, including its input circuits, has a NF of 7 dB (noise factor = 5) and a gain of 10 dB.

$$F_r = 5 + \frac{20 - 1}{10} = 6.9 \text{ or } 8.4 \text{ dB}$$

Substitute a modern diode balanced mixer with a 6-dB NF (noise factor = 4) and 0.4 gain for the fet mixer in fig. 3 and you obtain

$$F_r = 4 + \frac{20 - 1}{0.4} = 51 \text{ or } 17.1 \text{ dB}$$

This receiver obviously needs an rf amplifier to reach an acceptable operating noise factor.

rf amplifier noise figure

A simplified schematic and equivalent circuit of an rf amplifier is shown in fig. 4. The noise factor of such a stage below 20 MHz is approximated by

$$F = 1 + \frac{R_{A'}}{R_D} + \frac{R_{eq}}{R_A} \left(1 + \frac{R_{A'}}{R_D} \right)^2 \quad (3)$$

where F = amplifier noise factor (ratio)
 $R_{A'}$ = transformed antenna resistance = $n^2 R_A$
 R_D = dynamic resistance of tuned circuit = QX_L
 R_{eq} = equivalent noise resistance of amplifying device (fet or tube)

The first two terms, $1 + R_{A'}/R_D$, give the noise contribution of the input tuned circuit. When the antenna is exactly matched to the receiver $R_{A'} = R_D$ and the noise factor of the input tuned circuit is 2, or 3 dB.

The third term, $(R_{eq}/R_{A'}) (1 + R_{A'}/R_D)^2$, is the noise contribution of the fet or tube and reduces to $4R_{eq}/R_{A'}$ when the antenna is matched to the receiver. Above about 20 MHz the input impedance of both tubes and fets falls off, shunting the dynamic resistance, R_D , adding additional factors to the calculations.

When the antenna is matched to the receiver the NF of the input circuit is 3 dB. This NF can be made to approach zero dB by reducing the transformed

antenna resistance, R_A' . Overcoupling by increasing the primary turns, which *reduces* the ratio n^2 , will decrease R_A' . This technique is sometimes useful at vhf when the noise factor of the matched amplifier is less than 6 or 8 dB. However, this is done at the sacrifice of rf selectivity since R_A' effectively shunts R_D , lowering the Q of the tuned circuit. The optimum value of R_A' which gives the lowest possible NF is

$$R_{A'} \text{ (optimum)} = R_D \sqrt{\frac{R_{eq}}{R_D + R_{eq}}} \quad (4)$$

input tuned circuits

The input tuned circuit(s) of an rf amplifier has two functions. It matches the antenna to the active device and it provides rf selectivity. Fig. 5 shows various ways the single tuned circuit may be used as an input circuit.

The most common input circuit is the untuned primary to resonant tank circuit shown in fig. 5A. The size and coupling of the primary is determined by the characteristics of the antenna. Most modern receivers are designed for 50- or 75-ohm transmission lines and the primary is adjusted so that the reflected impedance, combined with the impedance of the primary itself, is the proper value. The match is rarely exact and will vary from one end of a band to the other.

Receivers with low-impedance inputs are sensitive to the characteristics of the antenna and line to which they are connected because there is a large step-up ratio from primary to secondary. Older receivers used 200- to 400-ohm primaries to match the open transmission lines of the day and were more tolerant of the type of antenna used.

The tapped coil method of coupling the antenna is often used at vhf (fig. 5B) because it allows convenient adjustment of the coupling to produce optimum r_A' for minimum NF. Using a noise generator to determine NF, a fine wire is successively soldered up from the bottom of the coil until the best NF is found. The

output impedance of the coil can also be varied by tapping down, as shown.

The classic R390 military receiver has a versatile input circuit that will handle random-length wires, balanced or unbalanced lines (fig. 5C). A random-length wire or whip is connected to the top of

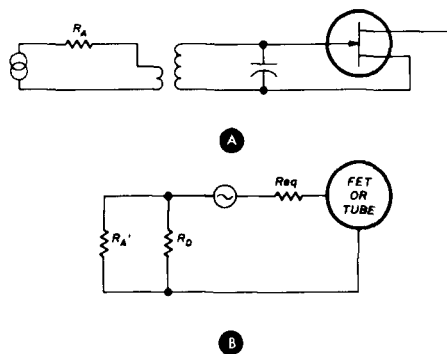


fig. 4. Noise sources in the antenna input stage of a communications receiver. Simplified circuit is shown in (A). Equivalent circuit is shown in (B).

the tuned circuit through C1 (input 1). The value of C1 varies from 5pF on the 16- to 32-MHz range to 120 pF on the 0.5- to 1-MHz band. Balanced lines are connected to the outside terminals of input 2 and are electrostatically balanced to ground by the capacitive divider. Unbalanced transmission lines are connected to one side of input 2.

One method of obtaining a precise impedance match at a particular frequency is shown in fig. 5D. This circuit became prominent when it was used in the famous R9'er impedance-matching preamplifier in the late 1940s.^{4,5} The coil and variable capacitor are adjusted successively for maximum output until no further improvement is obtained. The circuit was said to match resistance from 58 to 3120 ohms when the coils were loaded with a 7k swamping resistor and the variable capacitors had a range of 5 to 100 pF.

The pi network allows precise adjustment of both the input and output impedances (fig. 5E). It is sometimes used

at vhf to adjust the coupling for minimum noise factor.

filters

The trend today is toward more complex circuitry between the antenna and the rf amplifying device. The ultimate rf selectivity is provided by crystal lattice filters. Conklin has described practical filters for 20 meters with stop bands

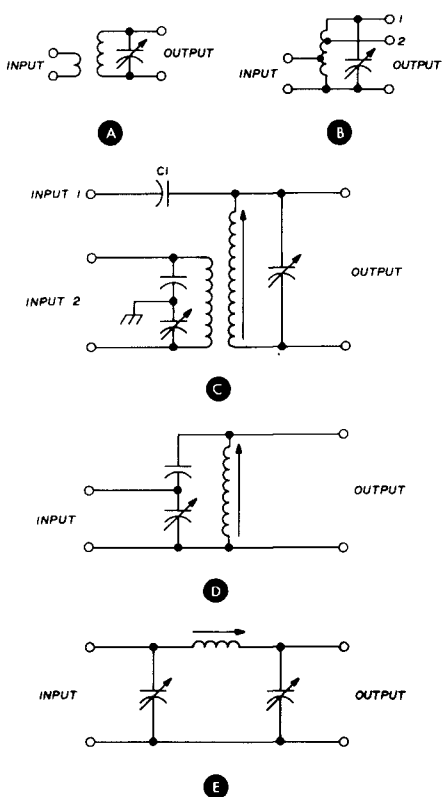


fig. 5. Antenna input circuits used in communications receivers.

100-dB down and 6/60 dB shape factors better than 1.8:1.⁶ He used a switch selected set of eleven filters, each 33-kHz wide, to cover the entire 20 meter band (fig. 6A).

Helical resonators are capable of Q s of 700 at the high frequencies and more than 1000 at vhf and several of them can be cascaded. A recent article⁷ described practical helical resonators for 15, 20 and

40 meters (fig. 6B). Their disadvantages include size and their requirement for fixed tuning. A three-section, 15-meter filter measured 10½-inches (26.7-cm) long, 5¼-inches (13.3-cm) high and 3½-inches (8.9-cm) deep.

Multiple conventional tuned circuits can be mutual-inductance coupled, common-inductance or -capacitance coupled or top-capacitance coupled. The common-inductance coupled circuit in fig. 6C was used in a recent home-built 75-meter DX receiver.⁸ The value of the coupling coil for that band was given as $0.3 \mu\text{H}$.

A similar circuit using top-capacitance coupling is shown in fig. 6D. In one recent high-frequency receiver design C_c was a 0.2- to 3-pF ceramic capacitor.⁹ The coupling was optimized by successively reducing C_c from maximum capacity in small steps and then returning the main tuning capacitors until there was a slight loss in gain as indicated by the S-meter.

Old TRF receivers sometimes lumped their tuned circuits at the front of the receiver. One such preselector circuit used four tuned circuits with both mutual-inductance coupling and common-inductance coupling (fig. 6E).

Cohn has shown how to maximize stop-band attenuation while minimizing insertion loss for multicircuit rf filters.¹⁰ One filter designed from his work is shown in fig. 6F.

selection of device and operating conditions

The rf amplifier designer has three devices from which to choose: vacuum tubes, bipolar transistors and fets. The vacuum tube can be eliminated because it is not compatible with the modern solid-state receiver in terms of heat generation, size, reliability and power supply requirements. The bipolar transistor is deficient in signal-handling ability. This leaves the fet as the almost universal choice for high-frequency rf amplifier applications.

When selecting an rf amplifier device the designer must consider such char-

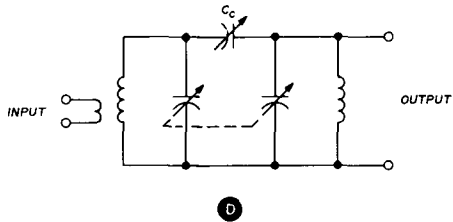
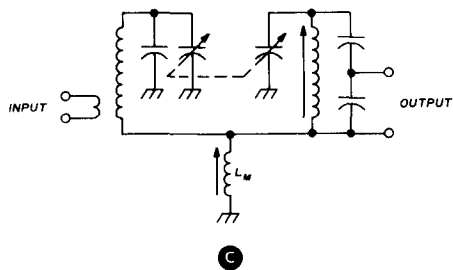
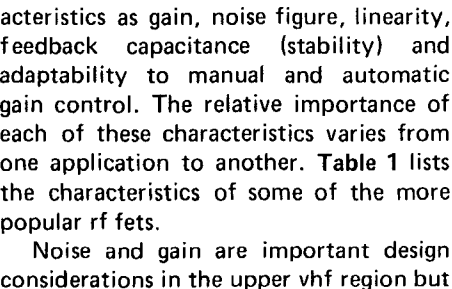
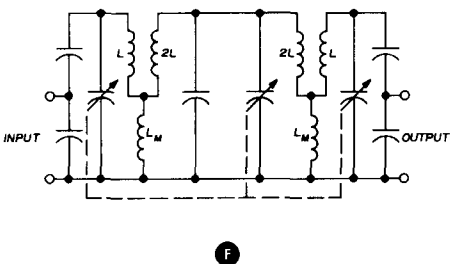
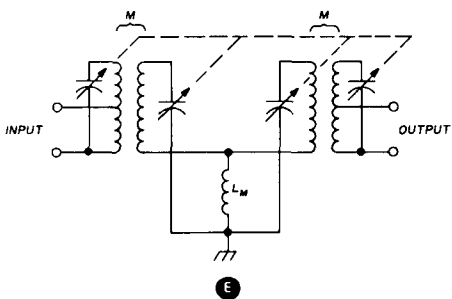
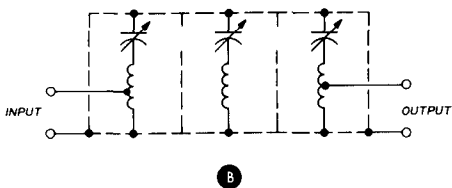
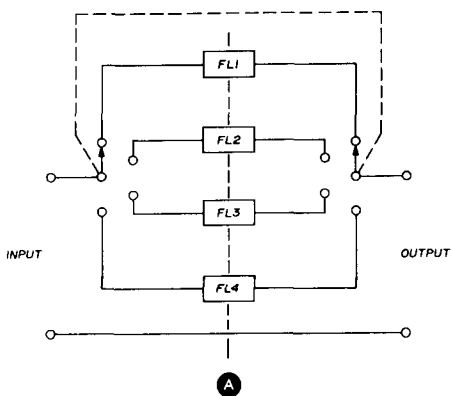


fig. 6. Multi-element rf input filters used in communications receivers. Use of each is described in the text.

are secondary to linearity at the high frequencies. An idea of the noise performance of fet's is given by the equivalent noise resistance formulas.

$$R_{eq}(jfet) = \frac{1}{G_m} \quad (5)$$

$$R_{eq}(mosfet) = \frac{0.67}{G_m} \quad (6)$$

$$R_{eq}(triode) = \frac{2.5}{G_m} \quad (7)$$

$$R_{eq}(pentode) = \frac{I_b}{I_b + I_{c2}} \left(\frac{2.5}{G_m} + \frac{20 I_{c2}}{G_m^2} \right) \quad (8)$$

The operating transconductance, G_m , should be used in the formulas. In the case of jfets the G_m is specified at zero bias although the device is actually operated at a negative bias where the G_m is considerably less.

The gain of the rf amplifier should be just enough to overcome the losses of the tuned circuits and to override mixer noise. The rf passband may be anywhere from 60 to 150 kHz wide at 14 MHz,

even with multiple tuned circuits, and all signals within the passband will be fully amplified. An rf amplifier with a gain of 10 dB will reduce the effective dynamic range of the mixer by 10 dB for signals within the rf passband.

Select devices with high pinch-off

handle less signal than the mixer, thereby degrading the performance of the receiver. Gain is preferably controlled by a manual or automatic attenuator between the antenna and the amplifying device.

Stability of the rf amplifier is a func-

table 1. Characteristics of selected rf amplifier fets. A 6BA6 vacuum tube is included for comparison purposes.

type	min G_m	device	max R_{eq}	mA I_{DSS}	max C_{gs}	max C_{rss}	min BV	V_p	ref freq	max NF
CP650	100,000	jfet	10	0.3-1.2A	25	25	25	2-10	50	2.5
40673	12,000	mosfet	55	5-35	6	.03	20*	-4	200	6
3N140	6,000	mosfet	94	5-30	7	.03	20*	-4	200	4.5
2N5397	6,000	jfet	167	10-30	5	1.2	25	1-6	450	3.5
2N4416A	4,500	jfet	222	5-15	4	0.8	35	2.5-6	100	2
E300	4,500	jfet	222	6-30	5.5	1.7	25	1-6	100	2
HEP802	2,000	jfet	500	2-20	-	-	25	-	-	-
6BA6	4,400	pentode	3550	-	5.5	.0035	-	-	-	-

* = BV_{DGO} , others BV_{GSS}

voltage, V_p for best linearity. Even within a given type it pays to select. The pinch-off voltage of the standard 2N4416A, for example, is specified at 2.5 to 6 volts. For best linearity jfets should be biased at approximately $V_p/2$. Dual-gate mosfets are run closer to zero bias, occasionally with slight positive bias.

Maximum linearity also demands that the operating point of the device be fixed and not varied for gain control purposes. The cross-modulation versus gain reduction characteristics of the 3N140 mosfet are shown in fig. 7.¹¹ In this case gain is reduced by varying the bias on gate 2. When operated at its normal conditions the device will handle a 130-mV signal before cross-modulation occurs. Changing gate-2 bias to reduce the gain by 5 dB results in dropping the signal-handling ability to 75 mV. Reducing the gain still further, to -15 dB, increases the signal-handling ability to 300 mV.

All devices, tubes, bipolars and fets, have linearity-vs-gain reduction curves similar to the 3N140. The exact location of the peaks and valleys varies from type to type and even within the same type. If you apply manual or automatic gain control to an rf amplifier it is possible to bias the device to a point where it will

tion of the feedback or reverse transfer characteristics of the device. This is composed almost entirely of capacitance, C_{rss} or C_{gd} in a fet. In the triode jfet C_{rss} runs from 1 to 3 pF, too high to use the device in an unneutralized common-source circuit. The dual-gate mosfet may be used in common-source circuits because its C_{rss} is only 0.03 pF. This is comparable to that of many pentodes although it is still considerably greater than the 0.0035 pF of the old reliable 6BA6.

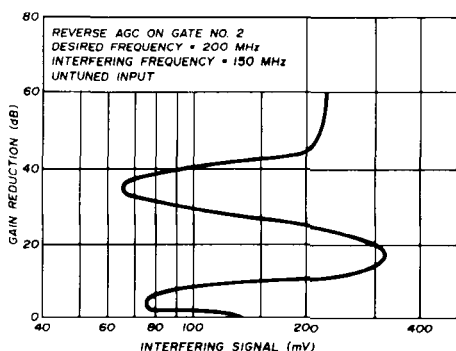


fig. 7. Level of interfering signal required to produce cross-modulation in a 3N140 dual-gate mosfet as gain is varied by changing the bias on gate 2.

circuits

Pentodes were long the workhorse of rf amplifier circuits so it is fitting to look at the pentode circuit before going on to newer devices. The 6AK5 came out of World War II research into better tubes for vhf. In 1946 it was used in the famous R9'er, a broadband, impedance-matching rf preamplifier (fig. 8).

The biasing and supply circuitry of the R9'er, a broadband, impedance-matching rf preamplifier (fig. 8).

rather than by a cathode potentiometer. The input and output tuned circuits are broad-banded by loading them down to a Q of 50 with resistors. Capacitive dividers permit adjustment of input and output impedance matches. The R9'er provided a dramatic improvement in noise factor

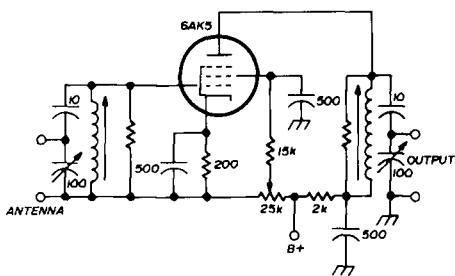


fig. 8. A pentode is used in the famous R9'er impedance-matching preamplifier popular in the late 1940s.

when connected ahead of some of the prewar receivers which typically had a NF of 14 dB or worse. The NF of the R9'er was 6 dB.

The modern day rf amplifier workhorses are the dual-gate mosfets such as the 3N140 and the 40673. The NF of the mosfet in the circuit of fig. 9 with input matching optimized for noise, is 2 dB at 28 MHz and the gain is 26 dB.¹² Since both of these figures are better than required for high-frequency work, the excess gain and NF could well be traded for better signal-handling characteristics.

In this circuit resistors R3 and R4 form a voltage divider to provide 4 volts bias to gate 2 of the mosfet. Unlike tubes

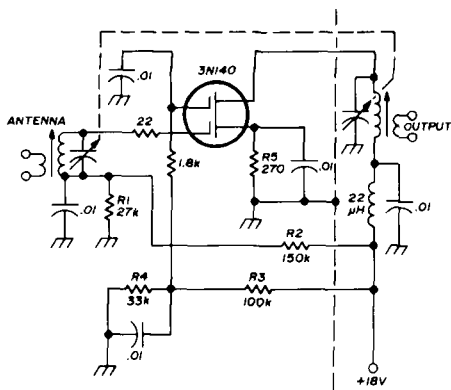


fig. 9. A modern rf amplifier stage using a dual-gate mosfet. Gain of this stage is 26 dB at 28 MHz; NF is 2 dB.

and jfets, the mosfet can be run at zero or positive bias and the transconductance is maximum near zero bias. Resistors R1 and R2 form another voltage divider to develop sufficient positive bias to overcome the negative bias of R5 and bias gate 1 near the zero bias point.

The jfet has such large feedback capacitance that, without neutralization, it is unstable in the common-source circuit. One remedy is to run the device in grounded gate. Fig. 10 shows the circuit of a broadband preamplifier covering 0.5 to 50 MHz using a grounded-gate jfet.^{13,14} The amplifier has a NF of less than 2.5 dB and a dynamic range — the range between the weakest usable signal and the signal which causes a 1-dB compression of the output — of 140 dB! The performance of this preamplifier is due

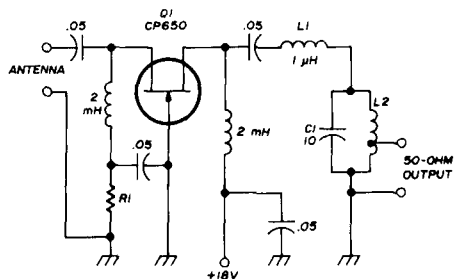


fig. 10. Wideband (500 kHz to 40 MHz) preamplifier using a power fet provides wide dynamic range.

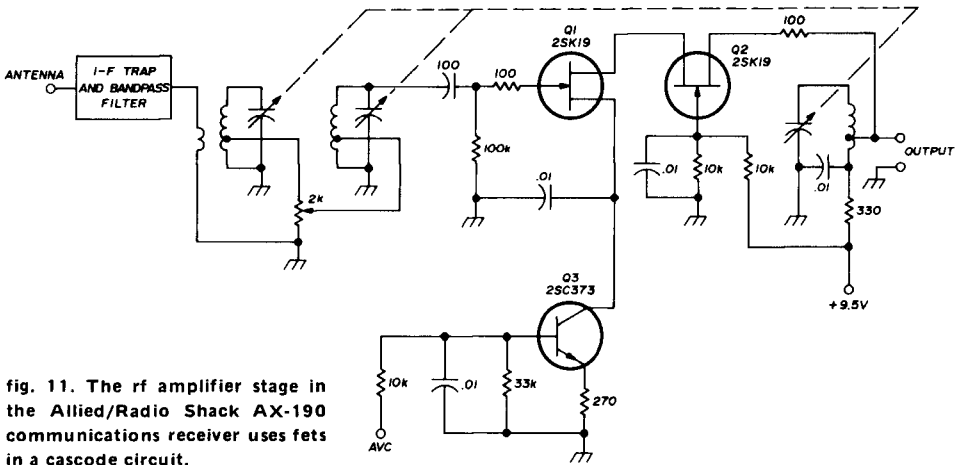


fig. 11. The rf amplifier stage in the Allied/Radio Shack AX-190 communications receiver uses fets in a cascode circuit.

power fet of the Crystallonics CP650 family. It consists of 15 fets in parallel on a single chip and provides a minimum G_m of 100,000 μhos .

In fig. 10 resistor R1 is selected to set the drain current of Q1 at 30 to 40 mA at which point the G_m will be about 55,000 μhos . The input impedance of a grounded-gate device is equal to approximately $1/G_m$ (18 ohms for this circuit). The input circuit results in a mismatch to a 50-ohm line but results in only about 1-dB loss in gain and improves the NF over the matched condition by approximately 0.5 dB.

The output circuitry is a lowpass filter, L1/C1, which provides a constant 200-ohm load to the fet over the entire

frequency range. L2 is a 200- to 50-ohm matching transformer.

Jfets can also be used in the cascode circuit without neutralization. This circuit was chosen by the designers of the Allied/Radio Shack AX-190 receiver (fig. 11). The cascode circuit is stable because the input cannot "see" the output through the very small drain-to-source capacitance of the second device which uses the grounded-gate configuration.

Two tuned circuits are used in front of the amplifier, coupled through an attenuator pot. The drain of Q2 is tapped down on the output tank to preserve its Q. The 100-ohm resistors are parasitic suppressors. Transistor Q3 acts as a variable source resistor which is actuated by

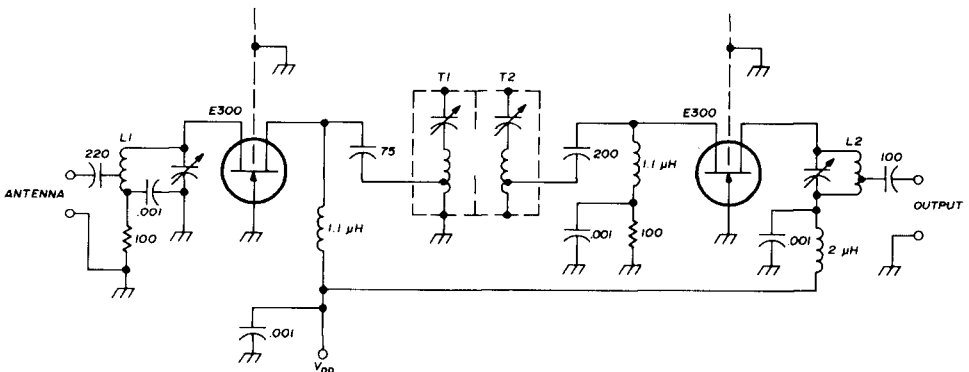


fig. 12. A selective rf amplifier using two grounded-gate fet stages. Selectivity is provided by the helical resonators T1 and T2. For high-frequency operation it would be better to tap the fets down on L1 and L2 to obtain more selectivity.

the avc system. This is one method of overcoming the incompatible avc requirements of fets and bipolar transistors.

Another interesting rf amplifier circuit which uses grounded-gate fets as buffer and impedance-matching devices for a pair of helical resonators is shown in fig. 12.¹⁵ Designed for color tv reception on channel 10 while rejecting channels 9 and 11, it is claimed to provide 15-dB gain and a 4-dB NF at 193 MHz. The input and output circuits provide little selectivity because of the heavy loading of the fets. At high frequencies it would be better to tap the fets down on the tuned circuits so they could contribute to the overall selectivity of the receiver.

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design data for pipe masts

One of the best
materials for
antenna masts
is steel pipe —
here is how
to design
your own

One of the best materials available for building self-supporting antenna masts is steel pipe. It is widely available, uniform in quality and reasonable in price. A well designed mast is adequately strong, neat and attractive, and relatively light weight. And, using steel pipe, it is not too difficult to design a fold-over mast which allows all antenna work to be done at ground level. Even maintenance on the mast itself does not require work at any great height.

However, attaining all of these advantages does require some design work. This is particularly important for safety. The purpose of this article is to present a set of design curves which will give a safe and satisfactory design while using the minimum of material.

construction

The general construction of a typical fold-over pipe mast is shown in fig. 1. At the top is the antenna and rotator, carried by the smallest size pipe. This is inserted into the upper end of the next size pipe for a short distance, and fastened by through-bolts or welding. The second section is inserted into the next larger, and so on. The bottom section is hinged to a fixed upright pipe, which gives the fold-over feature. It, in turn, nests into a larger section of pipe set into the ground. A yoke is provided to fasten the mast to the upright after erection. Fig. 1 shows a block and tackle for pulling the mast to the vertical position but a winch, fastened to the upright, may be used instead.

Most mast designs use the widely available standard-weight pipe, each size of which nests neatly into the next larger size, over the range from 1½ to 4 inches (38 to 100 mm). Larger sizes still nest,

Standard and *Extra Strong* (ASTM nomenclature) are the two pipe weights commonly encountered. The American Petroleum Institute has a separate designation for well casing, but this is called tubing rather than pipe, although some sizes are identical to pipe sizes. The critical dimension for *Standard* weight pipe are:

size	OD	wall thickness
4-inch (102-mm)	4.5" (114 mm)	0.237" (6.0 mm)
3½-inch (89-mm)	4.0" (102 mm)	0.226" (5.5 mm)
3-inch (76-mm)	3.5" (89 mm)	0.216" (5.5 mm)
2½-inch (64-mm)	2.875" (73 mm)	0.203" (5.0 mm)
2-inch (51-mm)	2.375" (60 mm)	0.154" (4.0 mm)

The ASTM recommended fiber stress values for *Standard* weight pipe is 20,000 psi (bending). The design procedure presented here uses a 10% reduction from this stress figure, based on good used pipe. Editor

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but there is a gap between the walls. Very high masts, or those with unusually heavy top loads, can be built with extra-strong or double-extra-strong pipe, but such designs are not considered here as the data are calculated for standard-weight pipe.

design criteria

The critical or design load on a section may be caused by wind load when the mast is vertical, or by erection load as the mast is being raised. Both loads should be calculated and the design chosen for the worst of the two.

For wind load, two design winds are commonly used. For most of the country, it is assumed that the worst wind to be encountered is 85 mph (137 Kph), a value to be expected once in 50 years or so. For Florida, the Gulf Coast and locations such as Cape Hatteras, a maximum wind of 125 mph (201 Kph) is also used. Your county engineer can provide the recommended value for your location (see reference 1).

During erection there is some deflection, or bending, of the mast. The greatest load occurs as each section is horizon-

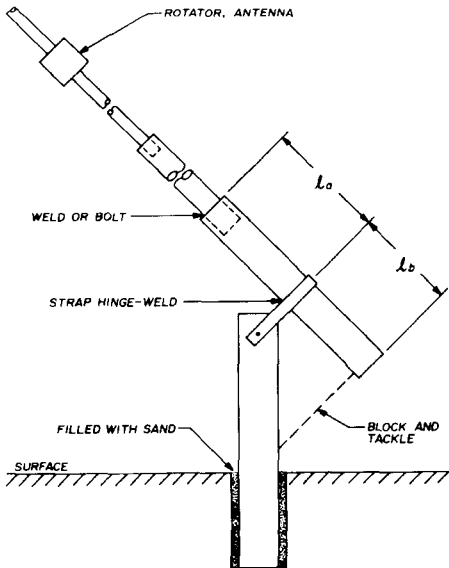


fig. 1. General layout of the fold-over pipe mast (not to scale).

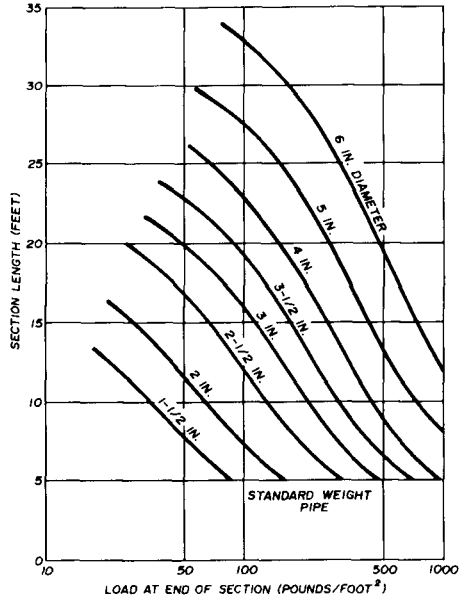


fig. 2. Allowable section length at erection for standard weight pipe, fiber stress = 18 kips.*

tal and this is the loading which must be designed for.

The wind and erection impose two different types of load on the section. One is the concentrated load at the topmost end of a section due to the forces on the section above. The second is the distributed load acting along the length of the section. As the concentrated load becomes larger there is less strength left for the distributed load, so the section length must become smaller. Accordingly, the problem of design is to determine the allowable section length.

The concentrated load during erection is the weight of the antenna, rotator and sections above the one being considered. The concentrated wind load includes the sum of all wind loads above the section being considered. The usual load is calculated on the basis of projected area. This is the area covered by the shadow of the

*The units of force are pounds, tons, kilograms, etc. In engineering practice the word *kip* is frequently used; it merely means a thousand pounds. Thus 18 kips can also be written 18,000 pounds. Editor

object. If the object is not symmetrical, as a Yagi beam, the largest projected area is used. The loading depends on whether the object is flat or round, as follows:

	wind loading	
	pounds per square foot (kg per square meter)	
	85 mph (173 kph) wind	125 mph (201 kph) wind
Flat objects	30.3 (147.9)	65.9 (321.8)
Round objects	18.1 (88.4)	39.0 (190.4)

The projected area is often given in the instructions for commercially made antennas and rotators. It is easily calculated from the dimensions of the element.¹

Given this concentrated load on the topmost section, design of the most proper involves solving section load equations for allowable section length. To simplify this process the equations have been reduced to a series of graphs, **fig. 2** and **3** for load during erection, and **figs. 4** and **5** for wind loads. Use of these curves will be explained through an example.

example

Assume that the design is for an all tubing six-meter antenna, having two square feet (0.186 square meter) projected area and weighing 15 pounds (6.8 kg). A small TV rotator is available, having one-half square foot (0.046 square meter) of mostly flat plate area, and weighing 8 pounds (3.6 kg). This area is not subjected to unusual winds. Mast height is forty feet (12.2 meters).

The concentrated load on the top section is 15 plus 8 or 23 pounds (10.4 kg). Entering **fig. 2** at the bottom with this weight and moving upwards, it is seen that the top section could consist of 12-feet (3.7-meters) of 1½-inch (38-mm) pipe, or 16-feet (4.9-meters) of 2-inch (51-mm) pipe or 20-feet (6.1-meters) of 2½-inch (64-mm) pipe. In keeping with the scale of the antenna, suppose the 1½-inch diameter (38-mm) pipe is used.

The concentrated wind loading is due to 2 square feet (0.186 square meter) of antenna and one-half square foot (0.046 square meter) of rotator. From the table above, the loading is 2 x 18.1 plus 0.5 x 30.3, or 51 pounds per square foot (249

kg per square meter). Reading upward from this load on **fig. 4**, it is seen that the maximum allowable length for 1½-inch (38-mm) pipe is 8 feet (2.4 meters). Since

this is the critical value, it becomes the length of the topmost section.

Assume that the sections are to be fastened by welding, with 6-inch (15.2-cm) insertion into the next section. From **fig. 3**, the weight of the 8½-foot (2.6-meter) total of the top section is 23 pounds (10.4 kg). The wind loading on the exposed 8 feet (2.4 meters), from **fig. 5**, is 25 pounds per square foot (122.1 kg per square meter). Thus, the weight load at the top of the second section is 23 + 23 or 46 pounds (20.9 kg) and the wind loading is 51 + 25 or 76 pounds per square foot (371.1 kg per square meter).

Using **fig. 2** again, the maximum allowable length of the next section using the nesting 2-inch (51-mm) pipe is 11½ feet (3.5 meters) for erection loads. From **fig. 4**, the allowable length for wind loads is 9 feet, which becomes the section length. Proceeding as before, the loads on the next section are 46 plus 35 or 81 pounds (36.7 kg) during erection, and 76 plus 35 or 111 pounds per square foot (541.9 kg per square meter) for wind.

Again, using **fig. 2** and **4**, the allowable length of 2½-inch (64-mm) pipe is 13 feet

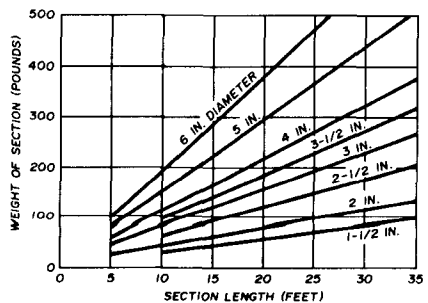


fig. 3. Weight of standard pipe.

(4 meters) for erection load, and 12½ feet (3.8 meters) for wind load. The 12½ feet (3.8 meters) is the length l_a in fig. 1. The load on the section l_b in fig. 1 is the same in magnitude, so this part could also be 12½-feet (3.8-meters) long. However, a stock length for pipe is 21 feet (6.4 meters). Assume that this is all that is available. Then the third section will need to end one-foot (30-cm) above ground to reach the desired 40-feet (12.2-meters) total height. This is not unreasonable.

10½ feet (3.2 meters) of the lower section plus some amount on the upright. Assume that the upright is fully exposed, a safe assumption. The wind load to the top of the upright is 111 plus 55 or 166 pounds per square foot (810.5 kg per square meter) maximum, the exact value depending on the final choice of upright length. From fig. 4, the upright can be only 6-feet (1.8-meter) long if it is 2½-inch (64-mm) diameter, or 13-feet (4-meters) long if it is 3-inch (76-mm)

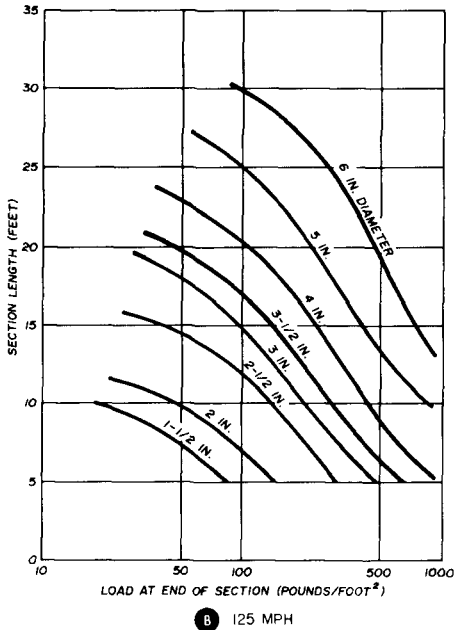
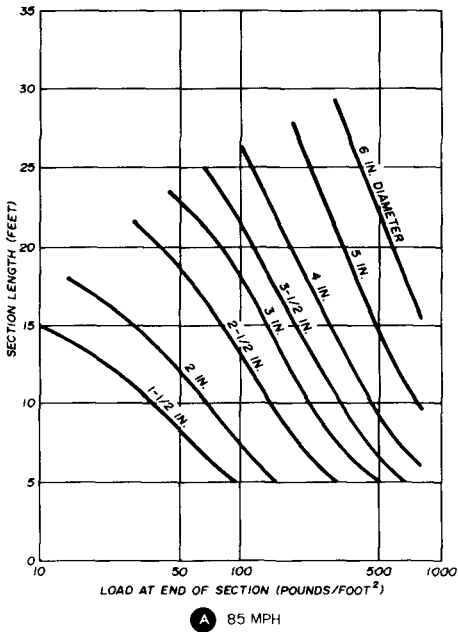


fig. 4. Maximum allowable section length for standard weight pipe with winds of 85 and 125 mph (fiber stress = 18 kips).

If a counterweight is added to the lower part of the third section to just balance the top weight, the erection loads on the fixed upright pipe are essentially zero. Even if no counterweight is used, the balancing effect of the part l_b of fig. 1 reduces the load on the upright to less than the load on section l_a of fig. 1. Thus, if the upright is no smaller than the lowest mast section, it will have adequate strength for erection.

The wind load on the upright is that of the upper sections plus that on the top

diameter. Since 12½ feet (3.8 meters) is needed as a minimum, this is just about right (half of the 21-foot [6.4-meter] length of the 2½-inch [64 mm] section, plus one-foot [30-cm] ground clearance).

Factors affecting the length of pipe buried in the ground are discussed below. For this example, assume that this is ten percent of mast height, or 4 feet (1.2 meter). Total upright length is thus 13½ plus 4 or 17½ feet (5.3 meters). The jacket section buried in the ground needs to have one-inch (25-mm) clearance, so

it needs to be a four-foot (1.2-meter) length of 5-inch (127-mm) diameter pipe.

The results of this design example are:

Top section: 1½-inch (38-mm) diameter top section, total length 8½ feet (2.6 meters), exposed 8 feet (2.4 meters).

Second section: 2-inch (51-mm) diameter second section, total length 9½ feet (2.9 meters), exposed 9 feet (2.7 meters).

Lower section: 2½-inch (64-mm) diameter lower section, total length 21 feet (6.4 meters), hinge at 12½ feet (3.8

all-purpose design curves for these. The best way of proceeding is to work with your county engineer, and use the practices developed for your particular area. The local power or telephone company should also be able to supply the necessary data.

For reasonably good soils, such as firm loams or clays, a good starting point is to assume that the foundation depth is equal to ten percent of the height, with the jacket set in concrete of sufficient size to keep the soil load to a safe value. A maximum load of 4000 pounds per

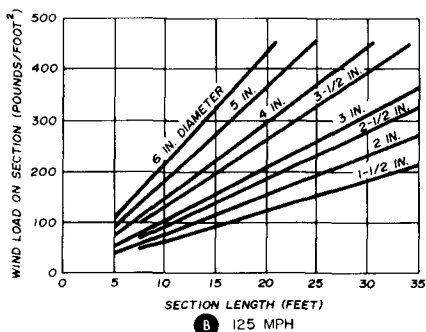
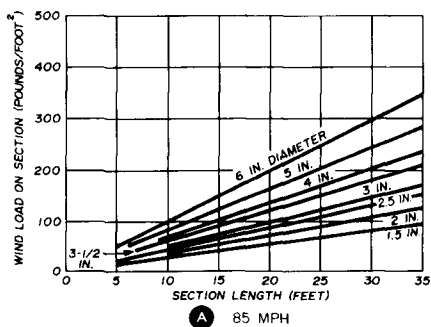


fig. 5. Wind loading for standard weight pipe, 85- and 125-mph winds.

meters), 1-foot (30-cm) ground clearance at bottom.

Upright: 3-inch (76-mm) diameter upright, total length 17½ feet (5.3 meters), exposed 13½ feet (4.1 meters), buried 4 feet (1.2 meters).

Jacket: 5-inch (127-mm) diameter jacket, total length 4 feet (1.2 meters), all buried.

If necessary, this design could be carried higher, using larger pipe sizes.

It is often necessary to try several initial assumptions as to length and diameter of the top section. With a little practice, this can be done in a few minutes.

foundations

Because of the great variability of soils, it is not possible to provide a set of

square foot (19530 kg per square meter) is often used, with the design being adjusted to give 100% safety factor above the design load. If you haven't done this work before, the county engineer can show you the steps.

safety

Any antenna mast can become a hazard if good safety practices are not followed. Remember that a quarter- or half-ton of steel thirty- to seventy-feet (9- to 21- meters) in the air is no toy. If you lack experience or don't have the proper facilities, get qualified help. Always remember, *safety is no accident.*

reference

1. John J. Nagle, K4KJ, "How to Calculate Wind Loading on Towers and Antenna Structures," *ham radio*, August, 1974, page 16.

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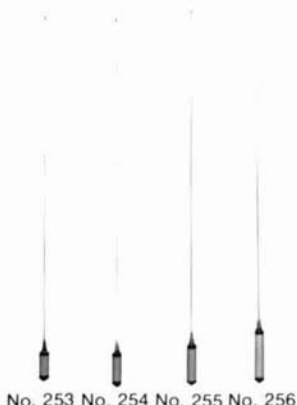
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a refinement
of previous
reciprocating-detector
circuits appearing
in *ham radio*

Stirling Olberg, W1SNN, 19 Loretta Road, Waltham, Massachusetts 02154

In my last article on the reciprocating detector¹ the final paragraph contained the statement, "... It is hoped that other amateurs will try it and perhaps find some of the features we missed; or perhaps shoot down those reported." In the months following publication of the article, I have received considerable mail explaining what I missed, or telling me I was copying some one else's idea, which had been invented using tube circuits in 1907. For the most part, the questions or descriptions were useful in answering all who posed other questions. But most of all, demonstration of several shortcomings were made obvious. Acknowledgements usually follow the last paragraph in an article; but mine must come first, and I thank all who wrote. This article is presented to answer most of the queries received and to set the record straight on what the reciprocating detector (RD) is, and what it is not.

typical queries

Many requests were for circuitry that could be used to incorporate the RD in receivers with i-f amplifiers at frequencies well above the limits of the practical reciprocating detector. The method of obtaining the RD reference is through feedback, which is partly carrier-level controlled and which would require

shielding of the adjacent circuits and the use of semiconductors well out of the price range of the average amateur. Other requests desiring to use the RD with transceivers required extensive investigation into the operation of these sets. In most cases I recommended that the amount of work would not justify the results.

older sets

Many amateurs installed the RD in older sets that had single filters, or none at all, with the hope that ssb, as well as the other features described would result in a receiver that could compete in the melee on bandedge pileups, or that could put these receivers in the same class with a modern receiver. This is not possible, and it was not my intention to mislead anyone into thinking it was.

The problem here is perhaps best resolved by careful consideration of the facts on how the receiver operates; for some because of the avc characteristics or the lack of them.

The set could never be used successfully on ssb. Why? Let's take the case of a receiver with single-filter selectivity. Suppose the receiver has one filter 3.1-kHz wide with a 455-kHz i-f. A reciprocating detector with a 455-kHz reference frequency will require the user to offset-tune the front end. He will receive some of the sideband he is looking for and will have all the pertinent features of noise impulse suppression of the RD, but part of the sideband will be clipped and will sound hard.

If there is no filter at all, and the bandwidth is very wide (which is usually the case), then either sideband will get through easily, along with the adjacent channel. Obviously filters are a *must* and dual filters are the best in my opinion.

The attack characteristics of the avc in older sets are such that these systems cannot be used with the reciprocating detector. The RD can't stand overloads,

and in many cases the rf signal presented by the i-f amplifier of older sets to the RD is in excess of 3 volts, which will certainly saturate it. I don't have a cure for this problem in the design presented here. Unless you can redesign your old receiver to accommodate today's signal amplitudes, I can't recommend an RD to replace your existing detector unless you wish to use it for some of the other modes of operation.

Before describing the RD converter, I'll describe the operation of the RD and define some terms.

circuit description

Let's start by looking at the circuits of fig. 1. The description deals first with the circuit of fig. 1A, a bit different from most detector circuits. A dsb signal will be used to actuate the RD switch. The rf input is fed into a battery and resistor combination, which provides bias to keep transistor Q3 just below, but not quite at, cutoff. Transistor Q3 therefore serves as a half-wave rectifier for the incoming signal and as a current source for the emitters of Q1, Q2. This current source is the reference for the base of Q2, enabling it to conduct on the positive reference peaks. Therefore, since Q1 and Q2 emitters are driven from a common-current source, Q1 is enabled and conducts when Q2 is off, but only on negative reference peaks. Neither Q1 nor Q2 can conduct unless Q3 is also enabled, which occurs only on positive rf signal peaks. Therefore Q2 conducts when the rf signal is in phase with the reference signal, and Q1 conducts only on the 180-degree difference with respect to the reference.

Now, since the audio and rf outputs are obtained differentially from those two switching transistors, a transfer of the conduction of Q1 to Q2, or vice versa, causes a polarity flip. It is this flipping action that is required to convert the waveform to a sine wave.

In the paragraphs above I have

continually used the word "reference," and in doing so may have confused the issue. By reference, I mean the beat signal that is synthesized from the rf input signal. Through feedback, routing the signal through the filter, FL, we have

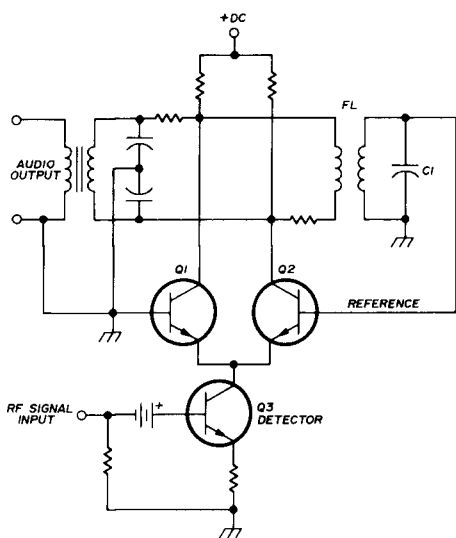
automatically provided a beat frequency oscillator, which is dependent upon the signal. More about this later.

synchronous mode

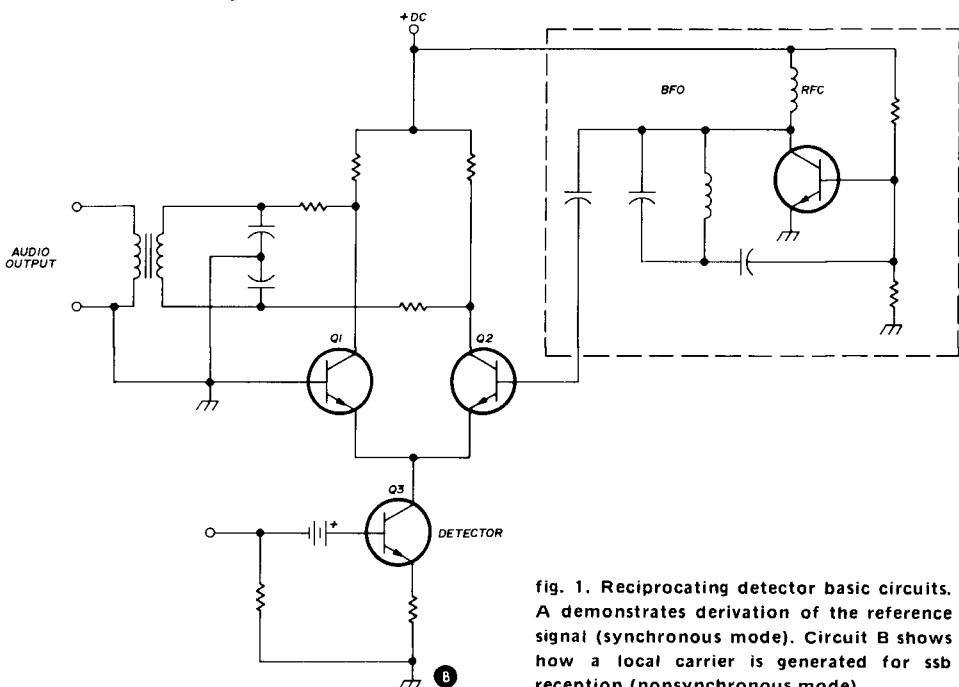
So far I've talked about a system that is self-controlled through the use of the carrier-synthesized reference. Now comes another term we must use: the synchronous mode. The reference signal is synchronous with the carrier because it is *generated* by the filter. The feedback through the filter, FL, establishes this action. The signal is recovered from the switch through an audio transformer (acting as a low-pass filter in the demonstration circuit).

nonsynchronous mode

Since it has been demonstrated how the reference signal is derived from the received (carrier) signal, and you now know what is meant by the synchronous mode, I'll try to answer the question most amateurs get around to asking: "How do you get a reference when you have a single sideband signal with no



A



B

fig. 1. Reciprocating detector basic circuits. A demonstrates derivation of the reference signal (synchronous mode). Circuit B shows how a local carrier is generated for ssb reception (nonsynchronous mode).

carrier?" A third definition now rears its head: nonsynchronous mode—because there is *no* carrier-generated bfo signal if the carrier is properly suppressed.

It will be easier to understand what's going on with the aid of **fig. 1B**. It's the same circuit as in **fig. 1A** but without the feedback loop. It uses a separate oscillator in the same fashion as a product detector. It is, in fact, exactly like a product detector.

Let's rearrange some of the circuits and voltages and see what happens. First we replace the input signal to transistor Q3 with a small dc voltage. This voltage is converted to a fixed current in the collector of Q3. Now we replace the bfo with the filter circuit. Transistors Q1 and Q2 are now part of a differential ampli-

and filter bandwidth, which many readers want to decrease because of the noise-elimination effects. Let's go back to dsb. The synchronous bandwidth of the signal is about one-third of the filter passband, or about 150 Hz. This is the case where phase correlation, previously discussed, is used. With an ssb input signal, the reference point follows the signal. Now, if the sides of the filter are too steep, phase synchronism will not be consistent and the reference signal will hop around trying to follow the input signal.

The peak deviation of a virtually unfiltered RD reference signal can't swing more than 30 degrees. This is not too obvious. Remember that the 180-degree phase change in the incoming signal is completely wiped out by the flipping

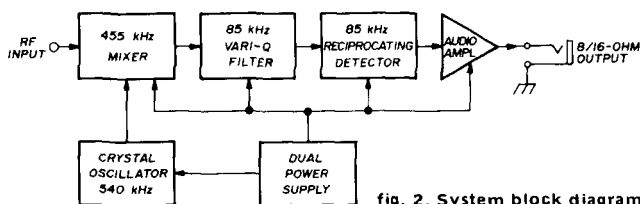


fig. 2. System block diagram.

fier. Through regenerative feedback Q1 and Q2 form a simple oscillator operating at the filter center frequency.

The dc voltage impressed on the base of Q3 is the average value of the half-wave rectified signal. The flipping action previously described for the synchronous mode still occurs. However, it's difficult to follow. This is because of the intermediate phase changes, which result from the frequency difference between the input signal and the self-generated reference signal. In this mode, the reference level is no longer completely amplitude controlled by the input signal, but it does have signal-induced phase fluctuations. This signal is now pure rf since it is the filtered version of the signal envelope. So now the question should really have been, "How do you detect a reference for ssb signals?"

bandwidth and noise reduction

We will now discuss the lock-in range

action of the reciprocating switch. So a filter with a bandwidth of 500 Hz or so will yield little or no jitter, even if the input is random noise. As for amplitude variations, this same filtering reduces these changes in the reference signal to a degree that most amplitude variations that approach zero are not evident. The fluctuation rate of these variations could be in the vicinity of 250 Hz. It should now be obvious why the circuit can and does reject impulse noise of short duration and reduces the intensity of long static crashes. It should also be obvious why a filter with sides too steep or too narrow will not help, except, perhaps, on noise. If, however, the filter is too narrow and only improves noise rejection, the phase jitter will ruin the effectiveness of the reciprocating detector for its other purposes.

455-kHz i-f receivers

It took a lot of looking to find a way

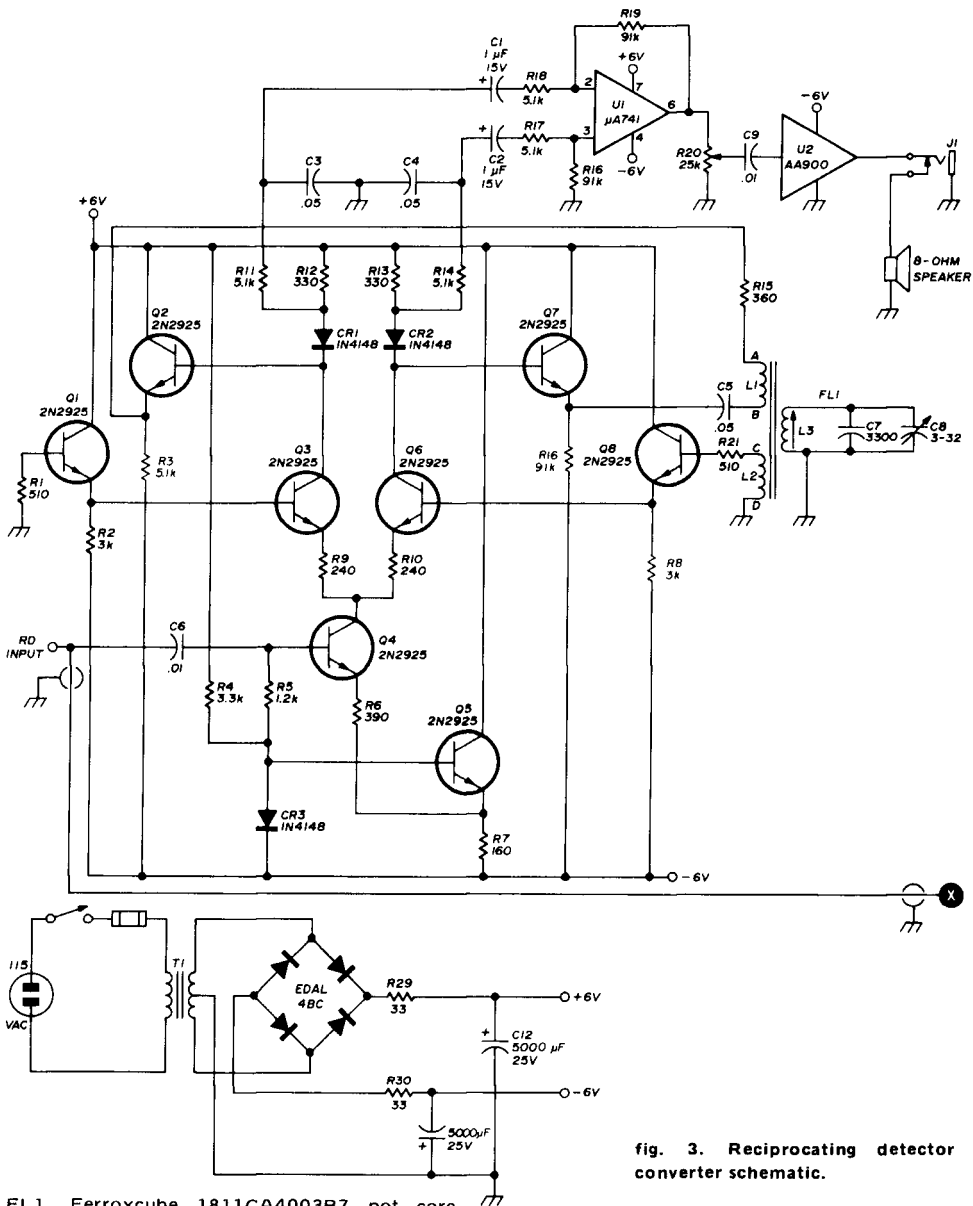
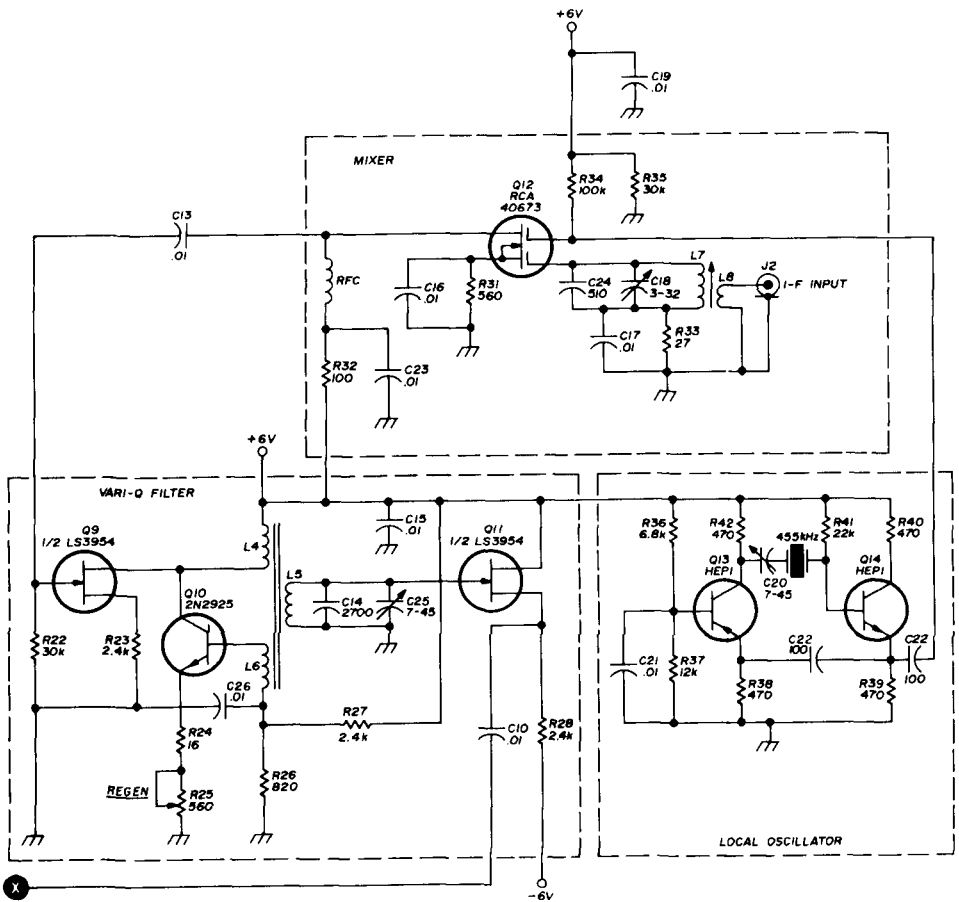


fig. 3. Reciprocating detector converter schematic.

- FL1 Ferroxcube 1811CA4003B7 pot core with 1811 bobbin. L1 is 5 turns no. 30 enamelled; L2 is 36 turns no. 30 enamelled; L3 is 30 turns no. 36 enamelled
- L4, Vari-Q filter wound on Ferroxcube 1811-CA250CB7 pot core with 1811 bobbin.
- L5, L6 L4 is 15 turns no. 30 enamelled; L5 is 130 turns no. 36 enamelled; L6 is 26 turns no. 30 enamelled
- L7, Mixer coil, 455 kHz. L7 is 130 turns no. 36 on Amidon Associates T44-15 toroid core. L8 is 8 turns no. 36 wound on same toroid

that would allow the RD to be used with almost any receiver (see fig. 2). A mixer is modulated by a crystal-controlled oscillator. The mixer input has a tuned circuit adjusted to match a 455-kHz i-f output. It can easily be coupled to the last i-f stage through a coaxial cable and a small capacitor. The input circuit can be adjusted to accept a wide range of frequencies simply by changing the input transformer



to one for the desired frequency. The crystal must also be changed.

The vari-Q filter is excellent for reducing interference. Its passband may be set by a variable capacitor and adjusted by a potentiometer (C15 and R25, respectively, fig. 3). Adjustment is variable over a 15-kHz range.

construction

The circuit (fig. 3) is conventional. The reference filter includes a variable capacitor operated from the front panel. This control allows the reference signal to be offset for receiving ssb signals. The control can be marked to indicate upper or lower sideband.

*PC board available from the author. Write for details. Please include a self-addressed stamped envelope.

The circuit is constructed on a PC board* except for the af amplifier and power supply. My unit is contained in a 4x4x8-inch (10x10x20-cm) cabinet finished to match other equipment on the operating desk.

Point-to-point wiring is used. Components in the parts list and schematic are not sacred except for the pot cores. Semiconductors should be silicon. Almost any general-purpose npn transistors may be used. The mixer transistor is an RCA 40673, although substitutes are available that will work just as well.

references

1. Stirling Olberg, W1SNN, "Reciprocating Detector," *ham radio*, March, 1972, page 32.
2. Stirling Olberg, W1SNN, "Vari-Q Filter," *ham radio*, September, 1973, page 62.

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miniature filament transformers

When miniature
filament transformers
are used in
low-voltage
power supplies
the output voltage
may be higher
than expected

In the old days when you bought a filament transformer you hardly ever bothered to measure the secondary voltage. You knew that, at no load, it would be roughly 10% or so higher than at full load. This allowed for a reduction when loaded and also allowed for some voltage drop in the connecting wires to the tube sockets. Also, filament transformers were used primarily in those days to heat

filaments or heaters and these voltage requirements weren't very critical.

Now things have changed. With miniaturization and the lower power-supply voltages required for semiconductor circuits using transistors, ICs and LEDs in analog and digital equipment, filament transformers are often selected by the experimenter as convenient power-supply transformers. Sometimes this is disastrous because, unless the transformer is fully loaded to its rated current capacity, the secondary voltage may be much higher than expected.

power supply

Consider an experience I had. I needed a 15-volt dc power supply to furnish 20 mA to a transistor circuit. Good regulation was not a requirement but this transistor circuit absolutely could not tolerate a supply voltage greater than 20 volts. Anything over 20 volts could zap the works.

For the power supply I decided to use a 12-volt filament transformer and a full-wave bridge rectifier feeding a capacitive filter. My initial rough calculations indicated that the output couldn't possibly be more than 20 volts even at no load after allowing for a 110% no-load secondary voltage (plus an increase of 7% because my line voltage is a steady 125 volts ac rather than 117 volts). This worked out to 20-volts dc maximum at no load.

John T. Bailey, 86 Great Hills Road, Short Hills, New Jersey 07078

Since the load current of 20 mA was quite modest and since I wanted to hold the size of the power supply down, I looked around for a miniature 12-volt filament transformer with a lower current rating than the generally available 600-mA units. At Radio Shack I found a 12-volt, 300-mA transformer with a core that measured only $1\frac{3}{8} \times 1\frac{1}{8} \times \frac{3}{8}$ inches ($35 \times 29 \times 10$ mm). I hooked it up, connected my voltage-sensitive load, turned on the juice and promptly zapped the transistor. What went wrong? Transients? Not this time. I measured the no-load dc output of my power supply (belatedly) and found it to be 27.5 volts!

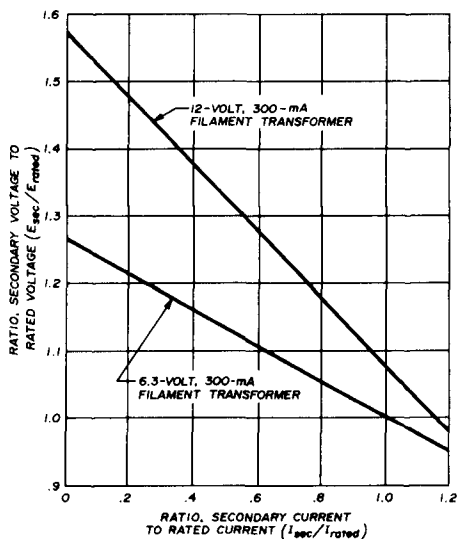


fig. 1. Chart shows how the secondary voltage increases as the secondary current is decreased in two miniature filament transformers.

The no-load secondary voltage to the bridge rectifier measured 20 volts ac instead of 14 volts as originally estimated.

miniature transformers

This sad experience aroused my curiosity about miniature filament transformers so I made some measurements and tests. I pass the results along for the benefit of others. I went back to Radio Shack and picked up one of their 6.3-volt, 300-mA filament transformers. This one had the

same core size as the 12-volt, 300-mA unit even though the VA ratings have a 2 to 1 ratio. Now I had a 6.3-volt and a 12-volt transformer to test and compare. Each transformer was connected in turn to a Variac to energize the primary at the rated 117-volts ac. An adjustable resistive load was connected to the secondary and varied to draw from rated full-load to no-load secondary current.

The results are shown in fig. 1. From this graph it is evident why my equipment was zapped. The no-load or light-load secondary voltage is considerably higher than the voltage at full-rated current. This revelation isn't meant to be a condemnation of the Radio Shack transformers. Actually they are well-made, American-produced products which put out their specified voltages at their full-rated currents.

Sometimes when electronic components are miniaturized there are trade-offs involved. With transformers the core losses go up and the copper losses are greater due to the higher resistance of the small wire used. Would you believe that the primary current at no-load can be greater than when the secondary is fully loaded? I measured these primary currents on the 6.3-volt, 300-mA transformer. Using a thermocouple-type milliammeter to get an rms measurement, I read 49 mA at no-load and 42 mA at full load. Using a scope revealed a more distorted primary current waveform at no-load which confirms that core losses are high with miniature transformers.

Next I measured the resistances of the windings. The 12-volt unit had a primary resistance of 270 ohms and a secondary resistance of 8 ohms. The 6.3-volt unit had 420- and 3-ohm windings. These readings are many times higher than the corresponding resistance for physically larger transformers of higher current ratings and partially account for the low regulation factor. In conclusion, when using miniature filament transformers you must expect higher-than-normal voltages when less-than-rated secondary currents are being drawn.

ham radio

versatile squelch-audio amplifier for fm receivers

A simple
squelch system
with sharply
defined threshold
that may be added
to any fm receiver

Next to attaining the impossible is building a squelch-audio circuit that really works. Even more unlikely is locating a squelch circuit which will function well in a variety of different fm receivers. The circuit described here achieves the next to impossible with readily available components.

circuit

The audio amplifier is a conventional, run-of-the-mill IC amplifier. Others may work just as well. Audio from the fm detector output is connected to the audio gain control through shielded audio line, properly filtered and amplified to drive a loudspeaker. A second, similar arrangement connects the detector output to the squelch sensitivity control — the signal is then filtered by a simple RC circuit, amplified by Q1 and rectified. Only noise above the audio portion of the signal spectrum is affected by this processing. Under no-signal conditions negative bias is maximum and Q2 is turned off at a threshold level determined by the sensitivity control setting. Transistor Q2 then begins a logic toggling action through U1, a 7400 IC. A low on pin 8 of U1 clamps off a portion of U2, thus quieting the speaker. A signal carrier reverses this process, passing audio uninhibited

Robert C. Harris, WB4WSU, Box 487, Leesburg, Virginia 22075

through U2 to the speaker. The toggle effect caused by the SN7400 IC provides an extremely sharply defined threshold.

The only limiting factor with this squelch-audio amplifier is the no-signal, noise output voltage from the fm detector which should be at least 0.75 volt ac as read on a sensitive voltmeter. Eliminating no-signal noise is one of the requirements of a good squelch system;

replacing the SN7400 with a conventional Darlington transistor pair makes much lower clamping currents possible.

results

This squelch system compares favorably to the best of commercial circuits, and is readily adaptable to a multitude of fm receivers, unlike many commercial circuits. The circuit has served flawlessly

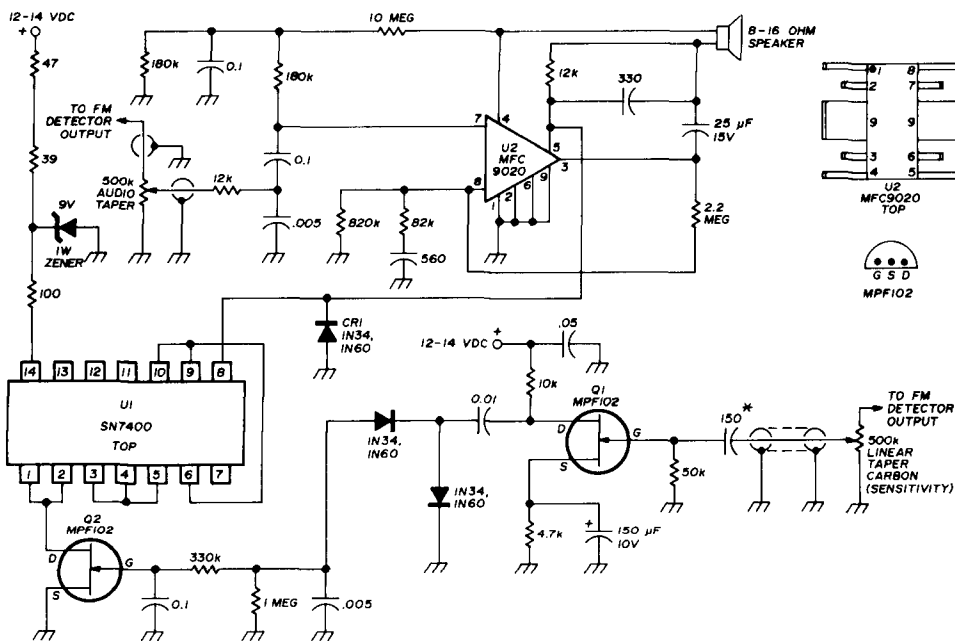


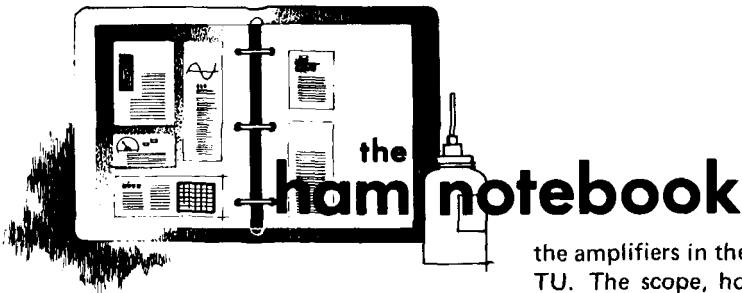
fig. 1. Schematic diagram for the versatile squelch-audio amplifier system. Diode CR1 may be eliminated if the B+ line is not keyed between transmit and receive. The 150-pF capacitor marked with an asterisk may be replaced with a smaller value, if necessary, for increased voice rejection.

the other is making it possible for very weak signals to pass. This circuit responds to the weakest of signals.

This squelch circuit performs well with supply voltages from 12- to about 14-volts dc. Squelch sensitivity is affected slightly by the varying power supply voltages inherent with mobile operation, but is well within acceptable limits. Current drain is on the order of 35 mA although lower values are possible through experimentation. For instance,

for two years as the replacement for an entire T-33 Motorola Dispatcher audio squelch system at a considerable reduction in current drain. Plenty of audio output is available and two hours of perforated-board construction is about all it takes to assemble the circuitry. The original was built on a 3x3-inch (76x76-mm) board and mounted inside the receiver. Nominal cost of the unit is about \$5.00

ham radio



the Heathkit HO-10 and SB-610 as an RTTY monitor scope

Any RTTY enthusiast who has tried to use either the HO-10 or SB-610 with the ST-series of terminal units has been quite disappointed. Both of these scopes offer too little gain for a good display with the one-megohm isolation resistors in the TU discriminator. These resistors prevent external cables (and scope) from loading the discriminator and also provide some filtering to clean up the display.

One solution that has been used is to build a pair of amplifiers into the TU. This is a good solution and is relatively simple. However, I have three TUs and only one scope devoted to RTTY monitoring. The obvious answer is to include

the amplifiers in the scope rather than the TU. The scope, however, does not have the voltages necessary for a solid-state amplifier nor the room for an additional tube. There is a tube in the unit (both HO-10 and SB-610) which is never used at this station and is probably seldom used elsewhere. The two-tone generator uses a 6J11, dual pentode, to generate the tones. It is possible to use this oscillator stage as an amplifier with a minimum of additional parts and expense. The display is nearly as good as that provided by my lab scope.

One of the objectives of this modification was to minimize the changes to the unit. Wherever possible the original components have been retained. The plate networks were removed as were all components wired to the grid and cathode of each of the two tube sections. The potentiometers which were used to set the tone levels are used to set the cathode bias. The only components added were four resistors (grid) and four capacitors (cathode bypass and plate coupling). The original wiring of the tone oscillator switch remains as a method of disabling the RTTY display when observing the transmitter. The single-tone position with horizontal sweep turned on gives somewhat of a time display at no additional cost.

Fig. 1 shows the circuit as it would appear in the HO-10. Numbered components are original components. Component numbering and values will differ somewhat in the SB-610, but the circuits are similar. Save the few parts removed and it will be possible to return the unit to its original condition with a few minutes of your time and no expense.

Robert Clark, K9HVV

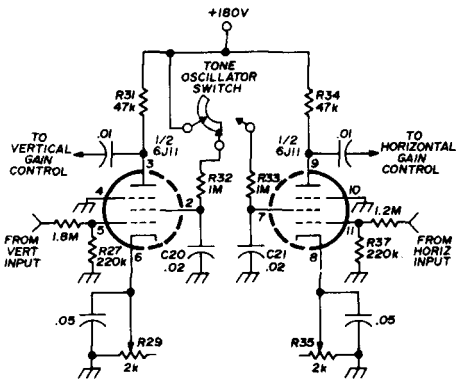


fig. 1. Amplifier for RTTY display uses components included in two-tone test oscillator. All numbered components are original Heath designations. Tube is a 6J11 dual pentode.

adding carriage return to the automatic line-feed generator

The automatic line-feed generator featured in the January, 1973, issue of *ham radio* can be modified to provide the

requirement that the printer be modified with a non-overline kit. It has the advantage that it can be used with model 15s, 19s, Mites, Kleinschmidts and other printers provided that a suitable mechanical mounting can be devised for the micro-switch and that the interfacing of the

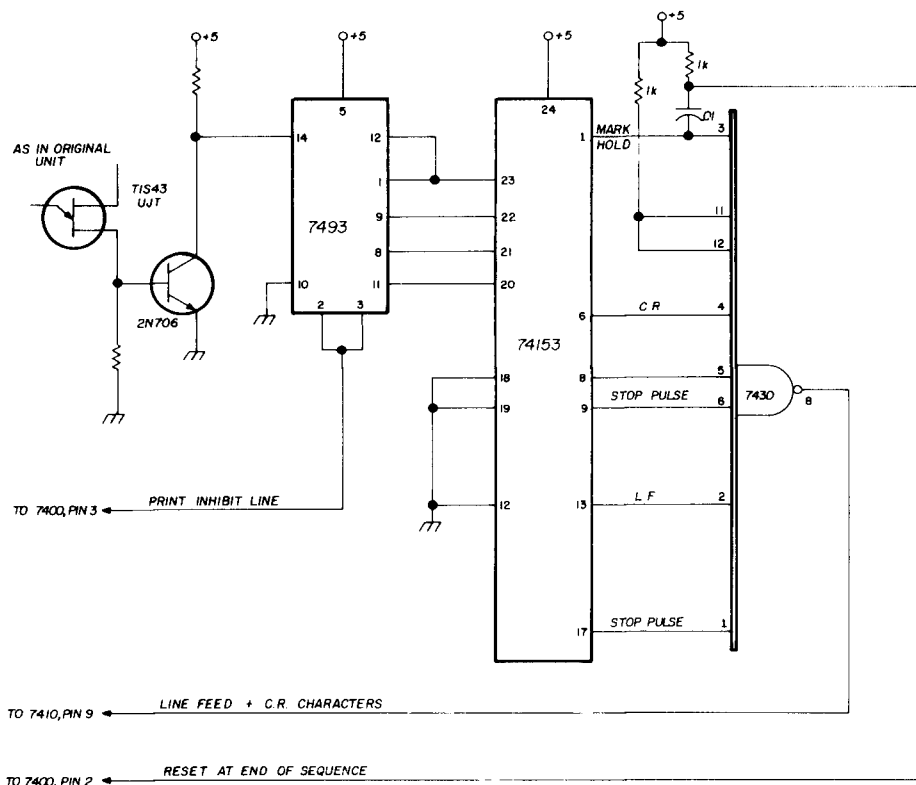


fig. 2. Simple modification for adding carriage return to the automatic line-feed generator.

carriage return signal in addition to the line-feed character. As the article explains, the digital device is actuated by a microswitch mounted in the printer so that it is tripped when the carriage approaches the end of a line. The logic then generates the electrical signals for carriage return and line-feed which are inserted in the printer loop, actuate the mechanism, and the printer then returns to normal print. The prevents overstrikes at the right margin.

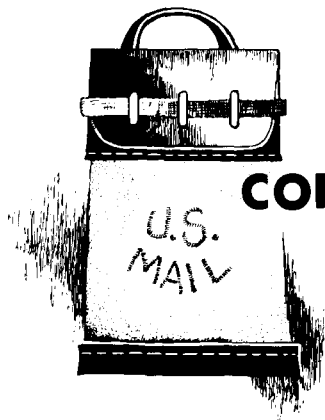
The carriage return modification does not add to the cost and eliminates the

logic board can be made with existing equipment in the station. This is provided for in the TTL autostart unit described in the June, 1973, issue of *ham radio*.

The modification involves substituting a 7493 and a 74154 for the 7490 and 7442 in the original unit, as shown in fig. 2. A plated epoxy board is available for \$7.00 postpaid in the USA.*

Bert Kelley, K4EEU

*Order from the author, Bert Kelley, K4EEU, 2307 South Clark Avenue, Tampa, Florida 33609.



comments

speech clipping

Dear HR:

I would like to make the following comments in response to W6VFR's letter in the August, 1973, issue of *ham radio*. If the i-f response of a receiver is measured with the agc system operating, any peaks will appear to be flattened out, but this, unfortunately, does not make it sound any better. The same applies to the case of clipping, which also produces the appearance of a flat response curve without altering the relative strength of the various components of the signal present at any given moment.

The apparent reduction of passband ripple, when the response is measured in the usual way, is therefore of no relevance. The passband ripple of all filters, at both the transmitting and receiving ends of the circuit, are fully additive in their effects.

Choice of filter bandwidth is a matter for compromise which, in the case of standard filters, embodies a lot of practical experience. What is optimum for a single filter must necessarily be non-optimum for a filter to be used in cascade, although results may still be acceptable. To establish that there is "no degradation," however, would require carefully controlled tests covering a wide range of conditions.

It seems important to me that the possibility of using standard filters should not divert attention from the need for

filters designed for the job, with the object of producing optimum performance at minimum cost. I feel that interest in rf clipping has now reached the point where the excuse of insufficient demand no longer applies.

Les Moxon, G6XN
Petersfield, England

Dear HR:

I can never understand why so many amateurs knock themselves out designing speech processors, clippers, etc. They really don't make that much difference *on the air* (I speak from experience). All they do is increase background noise and generally cause added and unnecessary confusion.

When I was using a National NCX1000, which had a pretty good rf speech processor, I ran many on-the-air tests. I called DX stations in pile-ups with and without the speech processor enabled, and I'm here to tell you that the speech processor didn't add one damn iota to the score of stations contacted.

I think speech processors are gadgets for guys who are bored and like to fool around with something new. When it comes down to the nitty gritty, the signal that is clean, loud, and in the clear is the one that gets results. A speech processor just eats up extra power. Maybe the speech processor gives the operator a psychological lift, and that's probably okay.

Anyway, the main thing in working hard-to-get stations is a matter of good operating practice, and all the electronic gadgets in the world aren't going to help the idiot-type operator who doesn't have *chutzpah!*

Alf Wilson, W6NIF
Encinitas, California

mexican repeater

Dear HR:

I would like to advise your readers of our new two-meter fm repeater in operation in the Mexico City area. The repeater has been in operation since last August and is the first fully automatic amateur repeater in Mexico. The repeater is sponsored by our club, "Asociación VHF de la Ciudad de México" (Mexico City VHF Association) and is maintained by dues of our members. The call is XE1VHF and frequency is 16/76. Although the repeater is for use by club members, all visitors are welcome. We are also planning a second two-meter repeater as well as a 450-MHz uhf repeater using the call XE1UHF.

Although there is no formal reciprocity agreement between the United States and Mexico, visiting amateurs can contact me at my home address below and perhaps a temporary permit can be arranged. In any event, bring a small rig or a walkie-talkie as a way can undoubtedly be found for a visitor to use the repeater.

Robert N. Green, XE1WS/W2GFO
Palmas 1460
Mexico City 10, Mexico
Telephone: 520-79-93

voltage regulators

Dear HR:

The popularity of the three-terminal voltage regulators (including the Fairchild 7800 series, the Motorola MC7800 series and the National Semiconductor LM 340-T series) has been increasing very rapidly as indicated in several recent *ham radio* and *QST* articles. This popularity manifests itself not only in the difficulty in obtaining these devices because of the heavy industrial demand, but also in these circuits having "unexplained" failures.

In the majority of these failures, the problem can be traced to the lack of non-inductive capacitors being placed at the device's input and output terminals. Because some of the integrated transistors have a f_T of several hundred megahertz, the failure mode is that the regulator

breaks into a high-frequency oscillation, resulting in overheating and ultimate device destruction in a matter of seconds.

The part that can cause great consternation for the constructor is that the unit will perform perfectly for hours, days or weeks before the fatal chain of events is initiated. The use of 0.1- μ F ceramic-disc capacitors at the input and output pins of the IC is sufficient to stabilize the system.

While the loss of one or two of these regulator chips is not in itself expensive, the resulting destruction of a whole project's complement of TTL or other ICs as a result of being subjected to voltage transients is down right disconcerting! The price of a couple of ceramic discs is indeed inexpensive insurance.

John Perhay, WA0DGW
Savage, Minnesota

aluminum antenna resistance

Dear HR:

I have been on vhf in the Chicago area since 1950, and find that dc antenna resistance is often totally disregarded—cutting signals as much as 50%. I use 300-ohm feedline to 50-, 144- and 220-MHz antennas and can check the dc resistance of line and folded dipole from the shack. It should be only a few ohms. After a windstorm this resistance may actually be more than a thousand ohms due to loss at joints where aluminum is used.

Aluminum power lines used by public-service companies have a special zu-zats put into these joints to avoid high resistance. This zu-zats should be used on all antenna joints where one or both sides are aluminum. If you use 300-ohm feedline and a folded dipole, test the dc resistance. It can be reduced by flashing through—use about 100 volts dc from a small transformer and diode with a 10- μ F capacitor in parallel. Flash through the feedline several times. This procedure apparently welds the joints together and, at times, has increased the output signal by as much as 50%.

Ben Hall, W90VL
Hammond, Indiana

Drake R4 frequency synthesizer

Dear HR:

Ever since I completed the design of the frequency synthesizer for the Drake R-4 receiver (*ham radio*, August, 1972, page 6), I have been looking for a means by which the spurious 10-kHz sidebands might be reduced.

Over the past two years a great deal of additional literature has been published covering phase-locked loops, and that which has come to my attention has been read with considerable interest. Despite all of this information, there appear to be only two basic methods of reducing the sidebands: raise the reference frequency or improve the loop filter (or both).

After reviewing the options, I came to the conclusion that raising the reference frequency would reduce the overall complexity of the synthesizer, at some increase in cost, while an improved loop filter was cheaper but more complicated. I therefore chose the simpler but slightly more expensive approach. A redesigned unit has been constructed and is now in use. The spurious sidebands are now displaced 100 kHz either side of the desired frequency, and are attenuated to an extent which makes them virtually inaudible.

Because of the many letters I have received indicating interest in this synthesizer, I will make available a set of schematics and brief supplementary notes to anyone submitting a self-addressed, stamped No. 10 envelope (4-1/8 x 9-1/2 inches) and \$0.50 to cover the reproduction costs.

Robert S. Stein, W6NBI
1849 Middleton Avenue
Los Altos, California 94022

windom antenna

Dear HR:

I noted W4VUO's article in the January, 1974, issue on the four-band, high frequency Windom antenna with considerable interest since I have used that antenna more than any other since Win-

dom first wrote about it. I have used it with great satisfaction on all bands from 10 to 80 meters, inclusive, except the 15-meter band.

My present antenna, used some ten years, is cut a bit longer than indicated by W4VUO's mathematics, 135 feet, 5 inches (41.28 meters) with the feeder attached 19 feet (5.8 meters) from the center. I do not fault the author's mathematics—I derived my length by cut-and-try, and have found the length anything but critical. In fact, in one location I had to drop the ends of the same wire eight feet (2.4 meters) due to the short space available. I noted no loss of efficiency in so doing.

However, the author got out of the band entirely when he called a two-wire feeder, off-center-fed Hertz a *Windom*. The *Windom* is only a single-wire fed antenna, and reference to the ARRL *Antenna Book* (9th Edition, 1960, bottom of page 191), confirms that statement. It calls the twin-lead, off-center-fed antenna a "miscalled *Windom*." It further states, "... and probably in many cases the line acts more like a single-wire feeder than a parallel conductor one." I would expect it to be a splendid antenna, too, possibly as good as the single-wire fed version.

John E. Waters, DDS, W6EC
Hemet, California

rf clipper

Dear HR:

In all fairness to potential users of the rf clipper for the Yaesu FT-101, Mark 2, described in the *new products* section of the July issue, I should point out that the unit does not work without *any* modifications to the FT-101. Although no modifications are required to any of the circuit boards, the unit does require that a few leads be re-routed via the spare pins on the vfo socket. The modifications can, however, be done in such a way that they are easily reversible, so users do not harm the resale value of their equipment.

Harry Leeming, G3LLL
Holdings, Ltd.
Blackburn, England



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antech introduces wide-spaced element 20-meter beam

The Antech 20-4 features the same rugged construction and maximum performance offered by the Antech 20-3, and is offered at a special introductory price of \$139.95 during September instead of the regular \$149.95. The new Antech 20-4 offers 10-dB forward gain, 20-dB front-to-back ratio and flat vswr across the 20-meter band. To order the Antech 20-4 or to obtain complete antenna line specifications and prices, write Antech Labs, 8144 Big Bend, St. Louis, Missouri 63119. Bank Americard or Master Charge accepted.

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Hy-Gain Electronics Corporation, 8601 Northeast Highway Six, Lincoln, Nebraska 68507.

TPL repeater amplifiers



All TPL amplifiers can be ordered in a repeater configuration, designed to mount in a standard 19" (48.25 cm) rack, and is 5 1/2" (14cm) high. The amplifier is rf shielded and is equipped with BNC input and type-N output connectors. It may be ordered with or without power supply and carrier operated forced-air cooling. The extruded rack mounting panel must be specified when ordering, as it cannot be retrofitted to an existing TPL mobile amplifier. TPL Communications, Inc., 13125 Yukon Avenue, Hawthorne, California 90250.

new bidirectional wattmeter from dycomm



The model 34 bidirectional wattmeter reads both forward and reflected rf power. It can be left in the line for continuous monitoring and does not require calibration with varying power levels. The taut-band meter movement provides ± 3 percent accuracy over four power ranges: 0-10, 0-50, 0-100 and 0-500 W. Bandwidth, defined as the frequency range over which ± 3 dB accuracy is maintained, is ± 15 percent of center frequency. Any center frequency can be specified from 30 MHz to 470 MHz. Price, \$59.95.

ESE moves to larger quarters

ESE, manufacturer of digital clocks, timers, frequency counters and multimeters, is moving to larger quarters in September. Look for ESE at 505 1/2 N. Centinela Avenue, Inglewood, California 90302. The move is brought on, in part, by the enthusiastic response of hams to their digital kits.

The ES 220 and ES 221 are 40-MHz frequency counters; the ES 112 is a 12-hour clock, and the ES 124 is a 24-hour clock; the ES 210 is a 5-range multimeter. All are in stock, ready to ship.

ESE has introduced a *special offer*, consisting of a printed-circuit board and six 0.6" displays, along with instructions, so that the ham who has a drawer-full of ICs can build a 6-digit clock for much less than the \$46.95 ESE charges for a complete clock kit.

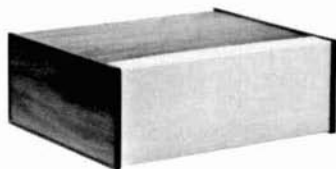
swan's world of amateur radio

"The World of Amateur Radio" is a new 20-page catalog from Swan Electronics presenting the company's line of transceivers, linear amplifiers, fixed and mobile antennas and compatible accessories for the amateur.

Highlighted are three transceivers: the Champion with 700 watts of PEP input on ssb; the 5-band portable Cygnet de novo with 300 watts PEP; and Mono-banders in a choice of 75 or 160 watts for mobile 40- or 80-meter operation. Other equipment includes completely solid-state, 5-band transceivers and a 2000-watt linear amplifier.

Described are 2- and 6-meter transceivers, a deluxe 600-watt station and several commercial ssb transceivers for two-way requirements. Finally, a line of fixed and mobile antennas are shown along with other accessories. Copies may be obtained from Swan Electronics, a subsidiary of Cubic Corporation, 305 Airport Road, Oceanside, California 92054.

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electronics bench manual

The *Electronics Bench Manual* is a massive collection of data commonly required during the bench phases of electronic experimentation and construction. This device-oriented document contains sections on electronic components (semiconductors, electron tubes, electrostatic devices) as well as mechanical movements and actuators, hardware, finishes and housings, application diagrams, construction techniques, bench layout and support facilities, and much more. A high-density document with large-page format packed at an equivalent of about 2000 words per page; the semiconductor section itself contains almost 100,000 words of description. Each section of the manual is an independent booklet, removable for use at the bench. The entire publication is mounted in a rugged, practical looseleaf binder. 432 pages, 823 illustrations, 86 tables; priced at \$17.95 (ppd/U.S.) from Technical Documentation (Tdoc), Box 340, Centreville, Virginia 22020.

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regency offers two-meter hand-held radio



A new 5-channel, 2-meter narrow band fm hand-held transceiver is now available from Regency Electronics, Inc., Indianapolis-based manufacturer of a complete line of FM radios.

Designated the HRT-2, the radio is the portable and convenient answer to two-way radio needs. A double-conversion, superhetrodyne receiver design employs two ceramic filters. The transmitter and receiver sections both employ bandpass circuitry. Complete operation from 3 simple controls, plus high-low power switch. The radio boasts "American Made quality with Regency reliability." Regency Electronics, Inc., 7707 Records Street, Indianapolis, Indiana 46226.

new comcraft CSP50

The Comcraft Company announces the introduction of a new all solid state, 2-band frequency synthesized fm transceiver. The new transceiver, called the CSP50, features operation on both 2 meters and 1 1/4 meters with 25 watts output and 5-kHz frequency-synthesized channel steps. Operating modes provided include simplex, split transmit and receive with all of the popular repeater offsets. For further details write the Comcraft Company, P.O. Box 266, Goleta, California 93017.



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dual-mode keyboard



HAL Communications Corp. has introduced the DKB-2010 Dual Mode Keyboard. This keyboard features both Morse and RTTY capability, and also incorporates new features such as N-key rollover, 3-character buffer memory, identifier providing one key for call letters, and two keys which can be programmed for any 3 characters. Optional 64 and 128 character buffers, which can be loaded off line and released when desired, are available. Complete information available from HAL Communications Corp., Box 365H, Urbana, Illinois 61801.

SPEC II synthesized fm transceiver



Now you don't have to wait for full 2-meter coverage in 10-kHz steps, (extended range model also available for MARS, etc.) The SPEC II combines proven Motorola portable transceiver circuitry with the quality RP synthesizer. Output is typically 2 watts with receiver sensitivity typically $.25\mu\text{V}$ across the entire band. For full information contact Spectronics, Inc., 1009 Garfield, Oak Park, Illinois 60304.

compact vhf power amps



Though new to amateur circles, Vibratrol is well-known as a major supplier of commercial-service solid-state power amplifiers. Vibratrol's broad line of high- and low-band amplifiers are quite competitive in price, and unusually compact due to their uniquely effective heat sinking.

For high-band — 2 meters — Vibratrol offers six models with outputs to 150W. Three are low-drive models (3 W maximum); the others require 10 W for rated output, though all will operate with only 1 W. Vibratrol, 505 Harvester Court, Wheeling, Illinois 60090. (312) 541-5110.

little giant antenna for use in small areas

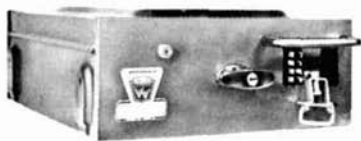
Stan Byquist's Little Giant antenna is not exactly new — he received his patent on it back in the 1950s and he has recently resurrected the design.

In brief, the Little Giant is a highly compressed single-band antenna that can be used in situations where conventional antennas are out of the question. The largest model, for 80 meters, is only 27-inches (68.6-cm) high and 32-inches (81.3-cm) wide; even smaller models are available for use on 40 through 10 meters. Bandwidth is necessarily small, as would be expected of such a small and, therefore, high-Q antenna. User reports have been quite favorable considering that any drastically shortened antenna is bound to be a compromise in performance. Amateurs with a space problem should contact Stan at Apollo, Vaughnsville, Ohio 45893.

More Details? CHECK-OFF Page 126



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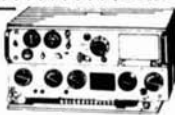
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ascom LED vswr indicator ASM-104



A product of advanced space age technology, the ASM-104 indicator is a go - no go device for marine and amateur radio systems. The indicator is designed to be left in the line at all times. When the transmitter is keyed, one red LED (light-emitting diode) lights; if an antenna mismatch exists the other LED will light, indicating that the system should be checked. The ASM-104 does not introduce any losses or mismatch to the system. Frequency range is 144 to 225 MHz. Power handling capability is 25 watts. Suggested Resale Price \$19.95. Contact your local Antenna Specialists distributor or write: The Antenna Specialists Co., 12435 Euclid Avenue, Cleveland, Ohio 44106.

visual display unit



The HAL RVD-1002 provides a visual display of 5-level (Baudot) code TTY when driven from HAL ST-6 or other terminal unit. It features operation at 60, 66, 75 and 100 wpm, selectable unshift on space, and 1000 character display. Output is standard 75-ohm TV video. Use as a read-only display for ham and commercial RTTY, or combine with the new DKB-2010 for a complete machine replacement. Complete information available from HAL Communications Corp., Box 365, Urbana, Illinois 61801.

gregory specializes in fm mobile equipment

Gregory Electronics Corporation has added to its vast inventory the General-Electric Transistorized Progress Line used fm two-way mobile communication equipment. These TPLs are available for use in six- and two-meter frequency bands.

Gregory Electronics is the largest distributor in the world specializing in used fm mobile communication equipment.

Gregory Electronics is interested in purchasing used late model equipment, manufactured by General-Electric, Motorola, and RCA.

Readers of *ham radio* may still write for the current 1974 catalog. A new 1975 catalog will be available in late fall. Gregory Electronics Corporation, 249 Route 46, Saddle Brook, New Jersey 07662.

tri-tek — new or surplus components

Tri-Tek would like to take this opportunity to thank the many *ham radio* subscribers who have become our good friends and customers. We're happy to have been able to help with your past projects and will do our best to continue to offer the finest in new and surplus components and materials at reasonable prices.

For our latest complete listing, send a 10¢ stamp to Tri-Tek, Inc., P.O. Box 14206, Phoenix, Arizona 85063.

switchable keyer

A front-panel switch in Matric's Model 10A Electronic Keyer permits both self-completing dots and dashes or only self-completing dots. The isolated output reed relay handles up to 100 Vdc at 20 watts, ideal for low-power rigs, particularly with an idle current of 3 mA and operating current of 12 mA.

A perfect companion is the Model 11A Paddle with easily adjusted spacing, a damped lever and weighted base.

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Besides saving hams a lot of money, we contribute a good full line of quality amateur radio antennas designed for easy installation. No professional help is needed -- just take out of the box and household tools will do the rest simply and quickly. When we develop a basic antenna, we follow through with a complete line to satisfy popular demand. Distributors worldwide stock Cush Craft Antennas.

Thanks for your support and encouragement. Cush Craft, 621 Hayward Street, Manchester, New Hampshire 03103.

new digital dial

Matric's new Model 22 Digital Dial provides a 100-kHz readout to 100 Hz. Modular construction enables the use of an interchangeable input module to match the requirements of most ham gear.

A crystal time base ensures 100-Hz accuracy while a non-blinking display gives five up-date readings per second. Two switched inputs are provided along with a calibrate control for set-up.

A one-wire connection to your vfo buffer or output jack plus either 115 vac or 12 Vdc is all that is required. The input requires 70 mV rms to a 1-megohm, 20-pF circuit.

new concept in two-meter antennas

Hy-Gain Electronics announces a new 2-meter gain antenna for the mobile, fixed or marine operator. The antenna, Hy-Gain Model 270, is designed to overcome the difficulties of current gain mobile antennas. It eliminates hard tuning, high swr, whip-flex fade and pattern distortion due to irregular ground plane.

It is optimized for the fm operator with less than 1.5:1 VSWR from 146 to 148 MHz (actual 2:0 vswr bandpass is 144 to 150 MHz). The design develops 6 dBi gain through the use of two 5/8-wave sections with their own decoupling system. By operating the antenna independent of car body ground it can be factory pre-tuned. Also, the Hy-Gain 270 has minimum pattern distortion due to irregular ground plane. Because it is all fiberglass, whip-flex fade is gone.

Additionally, because the Hy-Gain 270 is sealed in fiberglass, it will deliver outstanding performance month after month. No deterioration of performance due to corrosion of the antenna or feedpoint.

The Hy-Gain 270 can be used fixed, mobile, marine or even as a repeater antenna. For fixed usage a 271 mast bracket is available. The Hy-Gain 270 is the first gain 2-meter system that can be used anywhere without problem. Ham net is \$39.95 for the 270 and \$4.95 for the 271.

Madison

Madison Electronics has in stock a wide range of antennas, towers, rotators and other important antenna accessories.

They're featuring the Hy-Gain TH6DXX 6-element tribander these days and suggest that you call or write for a quotation. Madison also has Tri-Ex towers, Belden coax and Ham-II rotators, all at attractive prices.

Also be sure to ask for a free flyer from Madison Electronics Supply, Inc., 1508 McKinney Avenue, Houston, Texas 77002

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2N5589	3 Watts Out	\$ 3.50	2N6080	4 Watts Out	5.00
2N5590	10 Watts Out	6.00	2N6082	25 Watts Out	10.00
2N5591	25 Watts Out	12.00	2N6084	40 Watts Out	15.00

All are Silicon NPN and power output ratings are good to 175 MHz. Hurry! Some quantities are limited.

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DPDT Center Off \$2.14

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4	24	68	200	500
5	27	75	220	510
6	30	82	240	560
7	33	91	250	620
8	36	100	270	680
10	39	110	300	820
12	43	120	330	910
15	47	130	360	1000
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ORDER IN MULTIPLES		110pf	360pf	1.80 10
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Designed to handle 200 watts to 450 MHz, 12 VDC. coil, DPDT. The nicest RF relay we have ever had. Only about 1.14" cube. Super low VSWR. Satisfaction guaranteed.

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Model	Drive	Output	Price
RFL-301	3W	40W	\$ 99.95
RFL-401	3W	60W	149.95
RFL-701	10W	75W	99.95

All cases 2½" H x 4" W x 4" D, anodized.

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Model	Drive	Output	Price
RFL-501	3W	110W	\$199.95
RFL-801	10W	100W	149.95
RFL-901	10W	150W	199.95

All cases 2½" H x 4" W x 8" D, anodized.

All models will operate with reduced output from as little as one watt drive. Amplifiers are supplied pre-tuned for band portion in which they are to be used. For SSB and CW use, delayed dropout is available — add "SSB" to model number and \$5.00 to price. Comparable models for 6 and 10 meters also available.

Dealer and Distributor Inquiries solicited

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larsen features trunk mount mobile antenna



This Trunk Mount mobile antenna gives a 3-dB gain over a quarter-wave whip. It comes complete with mounting screws, stainless-steel bracket antenna mount, and can be secured complete with coax if desired. Designed for maximum efficiency and minimum wind drag; it will handle a full 150 watts with no difficulty. Requires no coil tuning or special mounting adapters. All Larsen antennas are fully guaranteed. Models are available for both 2 meter and 432 MHz from Larsen Electronics, Inc., 11611 N.E. 50th Avenue, Vancouver, Washington 98665.

new expanded stock

This autumn the fellows at M. Weinschenker will be able to supply components and service for both amateurs and experimenters better than ever before. This summer they have been working to improve their stock both in variety and depth to better give you the backup you want.

Weinschenker has tried hard to keep up with the rapidly changing world of electronics, particularly by supplying quality U.S.-made electronics for your special projects.

A check of their new Catalog number 10 and their latest ads in *ham radio* will show many interesting items; for example, the wide variety and low cost of LED readouts in many colors to help the builder turn out professional looking and performing projects at budget prices.

Each month be sure not to miss the Weinschenker ad in *ham radio*.

**electro-monitor
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feature unique simo**



"Get In On The Action" best describes the new Electro-Monitor FM monitor receivers featuring "SIMO," the only multiple frequency simultaneous fm receivers on the market today. It monitors any two fm frequencies, high or low, at the same time enabling you to hear two public service transmissions simultaneously — or both sides of a duplex communication.

Electro-Monitor receivers come complete with crystals and receive low band, high band or uhf frequencies. Additional information from Electrosonics, 34 E. Logan Street, Philadelphia, Pennsylvania 19144.

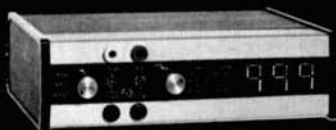
**BC electronics —
a history of serving
the amateur**

Ben Cohn of BC Electronics was one of the few early dealers in military surplus to cater to hams. Ben started in business as Quad Electrical Supply in a large, cheap, loft space on the northwest side of Chicago. In the early 1950s a move was made to South Michigan Avenue to create a surplus electronics center. Today, BC Electronics, 1249 Rosedale Avenue, is the last surplus dealer in Chicago catering to hams and one of the few remaining original surplus dealers still serving amateurs.

More Details? CHECK-OFF Page 126

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Dependable solid state components and circuitry. Easy reading, 7 segment display tubes with clear, bright numerals. These products operate from 117 VAC, 60 cycles. No moving parts. Quiet, trouble free printed circuit.
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 many product lines**

The Antenna Mart, owned and operated by George McKercher, W0MLY, has been located in Pippay, Iowa for eleven years and has over 6,000 square feet of floor space. Products manufactured include the RX1 heavy duty rotator, SW5 remote coax switch and the MX1A plug-in mixer for Collins receivers. Distributor for HyGain, Newtronics, Mosley, KLM, Wilson Antennas, CDR Rotators, Rohn, Heights and Tri-Ex Towers. Specializes in parts, government electronic surplus and custom work. Antenna Mart, Box 7, Rippey, Iowa 50235.

electronics center, inc. dallas, texas



You ought to be part of our monthly sidewalk sale, held on the first Saturday of each month. Electronics Center institutionalized this event that brings more than 400 hams and traders to the center of ham activity for the Southwest.

The staff and facilities are operated by Walt, W5ZYA, Al, W5PXH, Larry, WA5BEN, John, K5HIH, Pete, WB5IGL, and Danny, WB5DNT. Come see us and all of the popular hf, vhf and uhf gear at 2929 N. Haskell, Dallas, Texas 75204.

ye olde ham spirit

Whether you are local, from another part of the USA or anywhere in the world, feel free to hang your hat at Barry Electronics, 512 Broadway in New York City. All hams are welcome whenever they're in the big city and an extra special greeting awaits any overseas amateur when he is visiting. Come on in, look around and talk, you'll find a warm reception from Barry, W2LNI, and his trained courteous staff.

Barry has a very unique collection of miscellaneous ham gear that you will not usually find elsewhere. Heavily stocked on tubes, especially Eimac, Barry also has miscellaneous parts for anything. He stocks Millen, Barker & Williamson, and two-meter fm transceivers including the IC-230 and Clegg FM 27B.

Be sure to make Barry's part of your next visit to New York.



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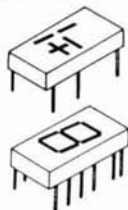
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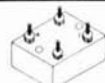
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USED TEST EQUIPMENT

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

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Boonton 202B Sig Gen AM-FM 54-216 MHz	325
Boonton 202D (sim. to above) 175-250 MHz	225
HP100D-Freq. stand. w/scope-Acc. 1ppm	85
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HP202A Function Gen. .008-1200Hz	95
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HP330B Dist anal 20 Hz-20kHz 1%	205
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HP540B Trans osc. for 524 to 12.4gHz	185
HP608D (TS510A/U) sig. gen. 10-420MHz	450
HP610B Sig Gen .45-1.2gHz calib attn	365
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Polarad R uwave rcvr 4-84gHz with plug-in AM, FM, CW, Pulse - less plug-in	225
Polarad TSA Spec. Anal .01-44gHz with plug-in less plug-in	125
Soliton 200A SCR tester-checks anode, gate volts,current,leakage and holding	165
Stoddart NM10A (URM-6) RF intens mtr 10- 250 kHz, complete with acc.	630
Stoddart NM20A (PRM-1) RF intens mtr .15- 25MHz, complete with acc.	655
Stoddart NM52A-RFI mtr, .375-1gHz, w/acc.	985
Tek RM 15-DC-15MHz GP scope	265
Tek 181 Time mark generator	95
Tek 190A Const. Ampl. Sig. Gen .35-50MHz	125
Tek 565 dual beam 10MHz scope, less plug-ins	625
TS-403A-Sig. Gen. (HP616) 1.8-4gHz	385
URM 7 RI-FI mtr. (sim. NF-105) 20-400MHz	750

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CX-11 from signal one



Signal One Corporation announces the new CX-11 completely solid-state integrated station, designed to be the ultimate in desirable features and reliability. It uses gold-plated sockets and pins for easy removal of all transistors, integrated circuits, and circuit boards. New features include: five bandwidths of selectivity, variable notch filter, short-proof power supply, solid-state broadband final that requires no tuning, six-digit LED frequency counter and a new concept in front end design making all other commercial ssb equipment obsolete.

These specifications and other features make the CX-11 unequaled in communications technology.

QRP rig from matric

The new Model 50 CW Transmitter by Matric includes an ac power supply, antenna relay and full break-in keying.

This crystal-controlled, 15-watt input rig will cover 160, 80 and 40 meters. It has plug-in toroid coils and features zener-regulated, chirpless keying and clean T-network rf output.

Also look soon for the Model 40 CW Transceiver, a totally portable 2-watt design.

**new keyboard and
encoder kit available**

Here is a top-quality, fully professional data-entry keyboard at a reasonable price. A 49-key system with internal ASCII encoder and switch debouncer. Shift and control keys are provided along with two user-defined keys. Keyboard uses all

brand new keyswitches and a modern IC and diode encoder circuit.

Output is a standard parallel ASCII type code that can be used with almost any type computer system. The circuit board is double sided with plated-through holes for quick, easy—no jumper—construction. Requires +5 and -12 volts dc for operation. Standard TTL logic levels at the output.

For terminals, calculators, TV typewriters, RTTY displays, video titlers, teaching aids. KBD-1 Kit . . . \$39.95 post-paid from Southwest Technical Products, 219 Rhapsody St., San Antonio, Texas 78216.

versatile circuits ease system design

Dodd Digital Design announces the "Series 100" line of etched-circuit cards, which provide the amateur with state-of-the-art logic circuits. Each of the 14 cards performs one complete function; several cards may be interconnected to construct equipment such as an automatic logging system, a CW/RTTY generator, a large memory, etc.

The plug-in cards are of professional-quality construction. For a catalog, send 50¢ to Dodd Digital Design, 234 Waples Park, Fairfax, Virginia 22030.

new wide band yagi from KLM

KLM introduces the 140-150-12C circularly-polarized wide band Yagi. While primarily designed to work with the new OSCAR 7 super satellite, this antenna offers flexibility of 2-meter operation that is hard to match. Exceptional performance is offered whether the stations on the end are horizontal or vertically polarized. The antenna features 12 elements on a seven-foot boom, complete with phasing harness, balun, and all stainless steel hardware. Options are a circular 6-element 432-MHz "add on" kit for the complete OSCAR system on one boom.

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In/out switch and gain control for ease of operation. Matric, RD #1 Pone Lane, Box 185A, Franklin, Pennsylvania 16323.

collins expands amateur operation

Collins Radio is placing increased emphasis on amateur activities with formation of a new amateur radio business operations group. Manager of the new operation is Joe H. Beler, W5WY/0, with Collins 14 years in various management positions. A ham more than 30 years, he has an extra-class license. Formerly a Colonel in the Air Force, Beler was re-

sponsible for introducing operational hf ssb to the Strategic Air Command.

Jerry Carter, WA0ZRW, a ham 11 years, is in charge of amateur sales. His business phone is 319-395-4507.

Arnold Verdow, W0LIJ, longtime Collins employee and active ham, joins the new operation, responsible for product support. His phone is 391-395-3393.

The amateur radio business operation is part of Collins' Telecommunication Equipment Division, Cedar Rapids, Iowa. Collins is a Group of Rockwell International Corporation.

G&G offers free catalog of military surplus

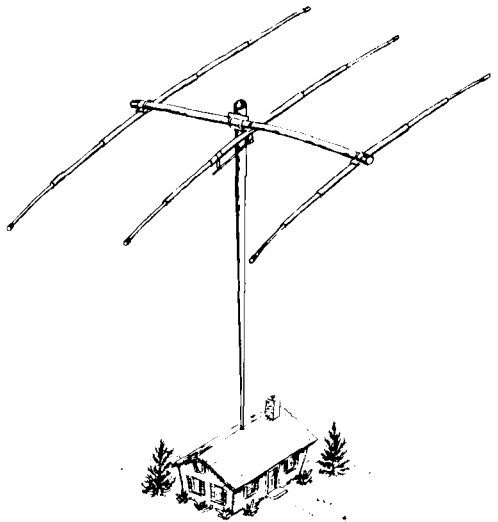
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Catering only to radio amateurs, Erickson Communications offers over-the-counter service to hams in greater Chicago while also serving the mail-order field. Erickson maintains a good stock of vhf uhf equipment and accessories at all times, and since owner Jim O'Connell (W9JZK, ex-KR6NR) also works the low bands, Erickson covers that market as well.

Erickson services and installs all lines they handle. Erickson is convenient to Eden's Expressway in north suburban Skokie. Erickson Communications, 3501 West Jarvis, Skokie, Illinois 60076. (312) 677-2161.



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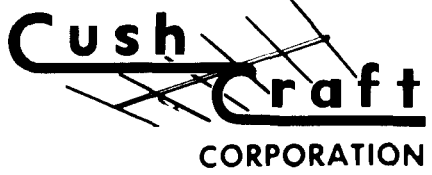
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Hy-Gain Electronics announces two new "rubber-ducky" antennas specifically tuned for the ham. The new Model 274 is a plastic-coated helical flexible antenna which terminates in a male BNC fitting and will fit directly on the many hand-held units employing BNC output connectors such as the Wilson, Clegg, VHF Engineering and other popular units. Ham net for the Model 274 is \$9.00.

The new Model 275 is terminated in a metal shell PL-259 fitting for two-meter units which previously could not use a flexible antenna. It is tuned specifically for the Drake TR series and similar portable units. Ham net for the Model 275 is \$7.00.

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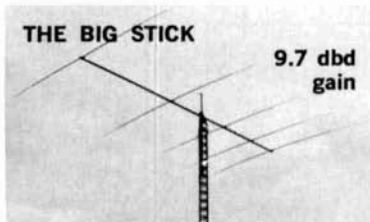
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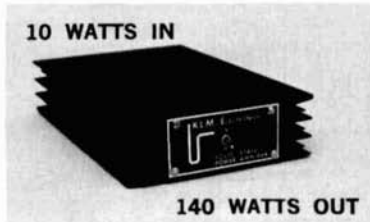
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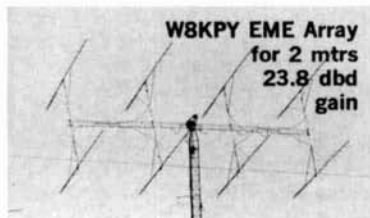
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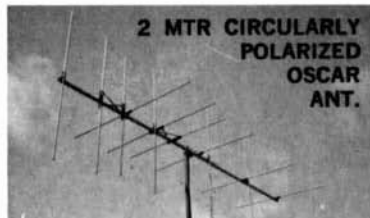
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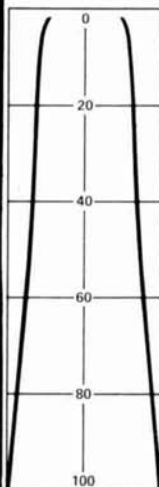
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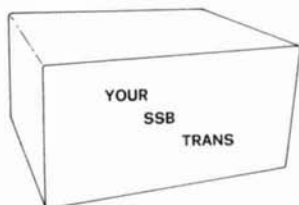
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SNT704	.24	.22	.18
SNT705	.26	.24	.20
SNT706	.45	.42	.35
SNT707	.49	.46	.38
SNT708	.27	.25	.20
SNT710	.24	.22	.18
SNT711	.31	.29	.24
SNT712	.31	.29	.24
SNT713	.89	.84	.70
SNT714	.49	.46	.38
SNT720	.42	.40	.33
SNT721	.55	.52	.43
SNT722	.31	.29	.24
SNT723	.31	.29	.24
SNT724	.33	.31	.26
SNT730	.24	.22	.18
SNT732	.38	.36	.30
SNT733	.38	.36	.30
SNT734	.32	.30	.25
SNT744	.24	.22	.18
SNT745	.19	.18	.15
SNT746	.12	.11	.09
SNT747	.12	.11	.09
SNT748	.12	.11	.09
SNT749	.12	.11	.09
SNT750	.12	.11	.09
SNT751	.12	.11	.09
SNT752	.12	.11	.09
SNT753	.12	.11	.09
SNT754	.12	.11	.09
SNT755	.12	.11	.09
SNT756	.12	.11	.09
SNT757	.12	.11	.09
SNT758	.12	.11	.09
SNT759	.12	.11	.09
SNT760	.12	.11	.09
SNT761	.12	.11	.09
SNT762	.12	.11	.09
SNT763	.12	.11	.09
SNT764	.12	.11	.09
SNT765	.12	.11	.09
SNT766	.12	.11	.09
SNT767	.12	.11	.09
SNT768	.12	.11	.09
SNT769	.12	.11	.09
SNT770	.12	.11	.09
SNT771	.12	.11	.09
SNT772	.12	.11	.09
SNT773	.12	.11	.09
SNT774	.12	.11	.09
SNT775	.12	.11	.09
SNT776	.12	.11	.09
SNT777	.12	.11	.09
SNT778	.12	.11	.09
SNT779	.12	.11	.09
SNT780	.12	.11	.09
SNT781	.12	.11	.09
SNT782	.12	.11	.09
SNT783	.12	.11	.09
SNT784	.12	.11	.09
SNT785	.12	.11	.09
SNT786	.12	.11	.09
SNT787	.12	.11	.09
SNT788	.12	.11	.09
SNT789	.12	.11	.09
SNT790	.12	.11	.09
SNT791	.12	.11	.09
SNT792	.12	.11	.09
SNT793	.12	.11	.09
SNT794	.12	.11	.09
SNT795	.12	.11	.09
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WANTED - USED FM 2-way radio communications equipment and test equipment. Mot., GE and RCA etc. No doggies please, CAL-COM Systems, Inc., 701-51A Kings Row, San Jose, Calif. 95112, Tel. 408/998-4444.

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WANTED: Commercial test equipment catalogs, 1955 or earlier thru 1972. Alfred, Ballantine, Fluke, General Radio, Hewlett-Packard, Lambda, L&N, Kintel, Measurements, Tektronix, etc. Short-time loan for research project. All items will be returned if requested. Jim Fisk, WIDTY, editor-in-chief, ham-radio, Greenville, NH 03048.

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QSL's, Sample catalog 20¢. N & S Print, P. O. Box 11184, Phoenix, Ariz. 85061.

1000 PIV AT 2.5 AMP. HEP-170 diodes. 10 for \$2.50, 50 and up 22¢ each, 100 and up 20¢ each. Postpaid U.S.A. IN4007 1000 PIV at 1 amp. 18¢ S.A.S.E. for list. K. E. Electronics Mfg., Box 1279, Tustin, California 92680.

FREE: 12 Extra crystals of your choice with the purchase of a new Regency HR-2B at \$229. Send cashier's check or money order for same-day shipment. For equally good deals on Collins, Drake, Kenwood, Standard, Clegg, Swan, Icom, Genave, Hallicrafters, Tempo, Midland, Ten-Tec, Venus, Hy-Gain, CushCraft, Mosley, and Hustler, write to Hoosier Electronics, your ham headquarters in the heart of the Midwest. Become one of our many happy and satisfied customers. Write or call today for our low quote and try our individual, personal service. Hoosier Electronics, R. R. 25, Box 403, Terre Haute, Indiana 47802. (812)-894-2397.

250MHz PRESCALER BOARD. Drilled, with instructions \$3.50. Davis Electronics, 6 W. Oakwood, Buffalo, N. Y. 14214.

TECH MANUALS for Govt surplus gear, \$6.50 each — R-220/URR, R-389/URR, URM-25D, TS-382D/U, ALR-5, BC-348JNQ; following manuals \$8.50 each: R-388/URR, 51J4, FR-114/U, USM-50; following manuals \$10.00 each: SRR-11, 12, 13, R-390A/URR, USM-32, USM-24, RBA, UPM-45, URR-35. Thousands more available. Send 50¢ (coin) for large list. W3IHD, 7218 Roanne Drive, Washington, D.C. 20021

MANUALS for most ham gear made 45/65, some earlier. Send SASE for specific quote. Hobby Industry, W0JJK, Box H-864, Council Bluffs, Iowa 51501.

TESLA PAPERS. Set of eight articles on the great inventor, Nikola Tesla, including a copy of his famous article, "Transmission of Electric Energy Without Wires," published in 1904. \$5.00, postpaid, from Nick Basura, 3414 Alice Street, Los Angeles, CA. 90065.

WANTED: GENERAL CLASS (or higher) hams to join 4,500 member Morse Telegraph Club. Hundreds of hams already belong. Send modest \$3 annual dues (includes subscription to great slick paper newspaper "Dots and Dashes") to GST A. J. Long, 520 West Schwartz Street, Salem, Ill. 62881 for membership card and assignment to nearest chapter.

FOR SALE: Hallicrafter SR2000. Very good condition. Will deliver up to 200 miles. Bob Smith, W5FRC, 422 Summit, Richardson, Texas 75080.

EXCLUSIVELY HAM TELETYPE 21st year, RTTY Journal, articles, news, DX, VHF, classified ads. Sample 30¢. \$3.00 per year. Box 837, Royal Oak, Michigan 48068.

GRAND RAPIDS SWAPFEST. September 21, 8:00 a.m., Hudsonville Fairgrounds, M-21 at 40th, three blocks West of Hudsonville traffic light. \$1.75 admission, no charge for tables and trunk sales.

15TH ANNUAL NEW JERSEY QSO PARTY. Aug. 17-18. Rules from Englewood Amateur Radio Club, 303 Tenafly Rd., Englewood, NJ 07631.

ATTEND 100th ANNIVERSARY HOMECOMING at Valpo Tech, formerly the Dodge Inst. of Telegraphy, on 19 Oct. 74. Oldest electronics school in western world.

PC's. Send large S.A.S.E. for list. Semtronics, Rt. #3, Box 1, Bellaire, Ohio 43906.

STOLEN — 1 Drake TR-22 # SN620272 and 1 VHF Engineering 15 watt amplifier, model 1501-2 meter, both have name and Soc. Sec. #221 26 5439 engraved on back. E. H. Smith Jr., 101 Winterbury Cir., Wilmington, Del. 19808.

LEARN DESIGN TECHNIQUES. Electronics Monthly Newsletter. Digital, linear construction projects, design theory and procedures. Sample copy \$1.00. Valley West, Box 2119-C, Sunnyvale, Calif. 94087.

CINCINNATI HAMFEST: 37th annual, Sunday, September 15, 1974 at the New Stricker's Grove on State Rt. 128, one mile west of Ross (Venice), Ohio. Flea market, contests, model aircraft flying, food and beverages all day. \$7.00 covers everything. For further information: Ray Clark, WB8BUF, Box 1521, Cincinnati, Ohio 45201.

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WANTED: ARC-51, 618T-1, ARC-102, FM-633, ARC-131, 807A Wilcox, Transceivers. Pay Cash. Bob Sanett, 616 S. Holmby Ave., Los Angeles, CA. (213) 279-1275.

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1974 MIDWEST DIVISION CONVENTION at the Marina Inn in South Sioux City, Nebraska, Oct. 4-5-6, 1974. The events planned include: QCWA dinner, QCWA meeting, demonstrations of portable repeater, SSTV, fast scan TV, \$30 counter from Jan. 1974 QST, AMSAT demonstration, QRP session, HandiHam session, SCM meeting, satellite locator per May 1974 QST, Grand Island monitoring station presentation, ARRL forum, 2 meter repeater forum, traffic forum, and DX and MARS sessions. Something for everyone. Large flea market, all indoors in a 40 x 80 room. Special events are planned for the ladies. Banquet tickets are \$6.00 each. Pre-registration to Oct. 1 \$6.00; afterwards \$7.00 — no charge for XYL if she chooses not to be included in prize drawings. Talk in frequencies .34/.94, 94 and 3900 kHz. Send registrations to WØEQN, Cliff Taylor, 3818 - 5th Ave., Sioux City, Iowa 51105. For motel information write WØFZO, Dick Pitner, 2931 Pierce St., Sioux City, Iowa 51104.

RTTY EQUIPMENT FOR SALE including machines, parts, gears. Send us a list of your teletype needs. Atlantic Surplus Sales, 1902 Mermaid Ave., Brooklyn, N. Y. 11224.

FINDLAY HAMFEST — Sept. 8, Riverside Park: Findlay, Ohio. Write Clark Foltz, W8UN for tickets specifying quantity. \$1.00 advance, \$1.50 at park.

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MEMPHIS AREA HAMFEST, Sunday, October 6 at State Technical Institute, conveniently located at Interstate 40 and Macon Road (Exit 11). Demonstrations, displays, FM forum, MARS meetings, flea market, XYL entertainment, prizes. Informal dinners Saturday night. Dealers and distributors welcome. Talk-in on 3980, .34-.94 and MARS. Contact Harry Simpson, Box 27015, Memphis, TN 38127, phone 901 358-5707.

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MIX PLEASURE WITH PLEASURE at the Hamburg International Hamfest near Niagara Falls on September 21. For information contact Lin Brownell WB2HCL, 210 Buffalo, Hamburg, N. Y. 14075.

RICHMOND AMATEUR TELECOMMUNICATIONS SOCIETY will be at the Atlantic Rural Exposition, Richmond, Virginia, from September 19 through 29. A special events call, WE4ARE, will be used for operations around 3988kHz, 7288 kHz and 146.88 MHz. QSL with SASE to: R.A.T.S., POB 842, Richmond, Virginia 23207. Visitors to the booth, in the Better Living Center, will be eligible for prizes, including an electronic calculator, QST subscription, and a 2 meter beam.

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HAMFEST "74", October 5th and 6th, 1974 at the International Inn, Winnipeg, Manitoba, Canada. Pre-registration thru VE4RL or Saturday morning Oct. 5th, \$1.00 per person, maximum of \$3.00 per family. Dinner and Dance, Saturday, October 5th, \$4.00 per person. Hotel pre-registration thru VE4OL. Major raffle, cocktail party around the pool, dinner and dance Embassy ball room. Swimming, QSL display board, films, transmitter hunt, mobile contest, homebrew contest, XYL bake sale, XYL hospitality room. DX club hospitality room, door prizes, swap and shop auction, Sunday at 1:00 p.m. Contact VE4AI.

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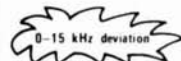
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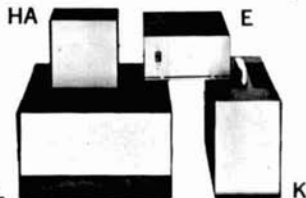
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