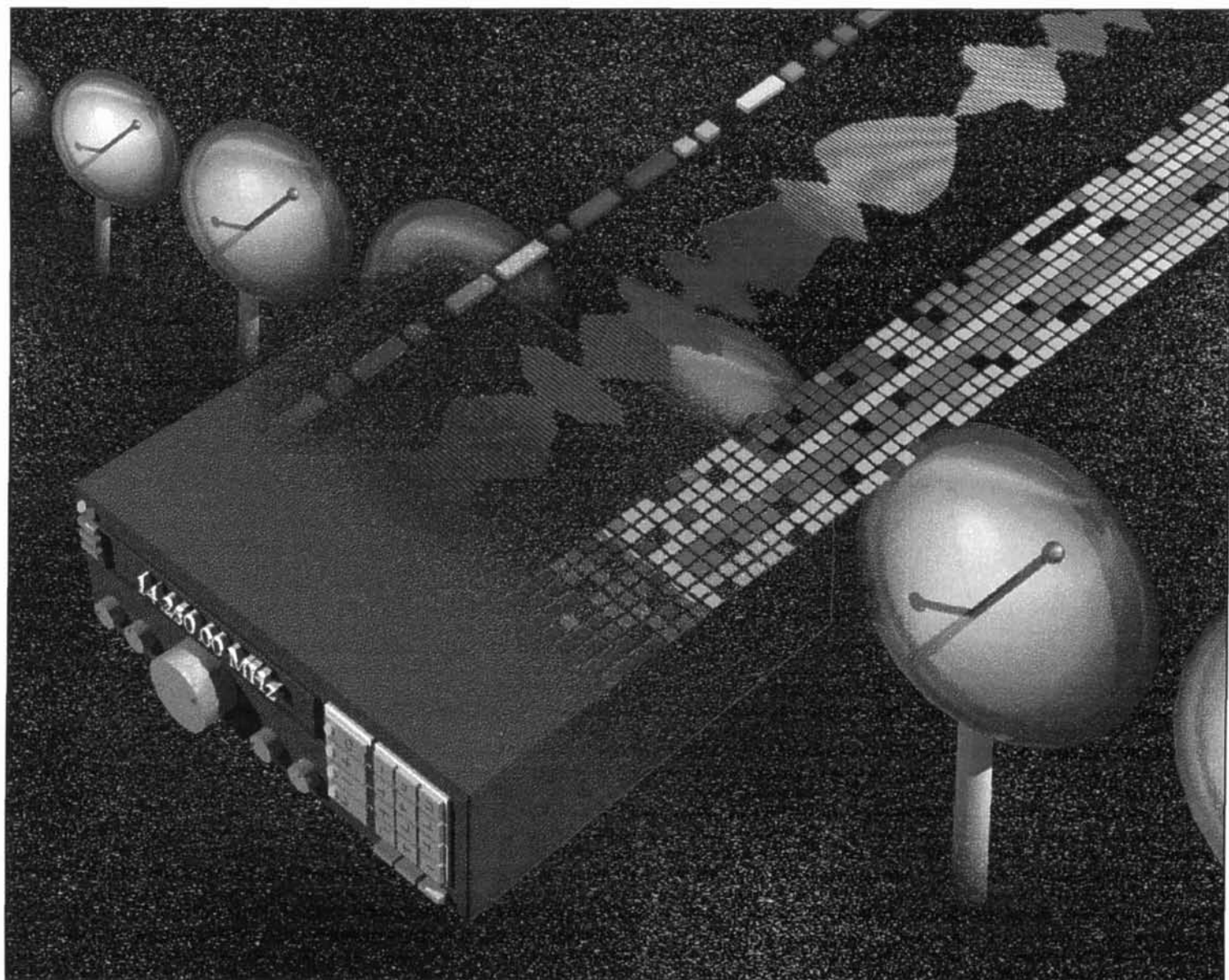


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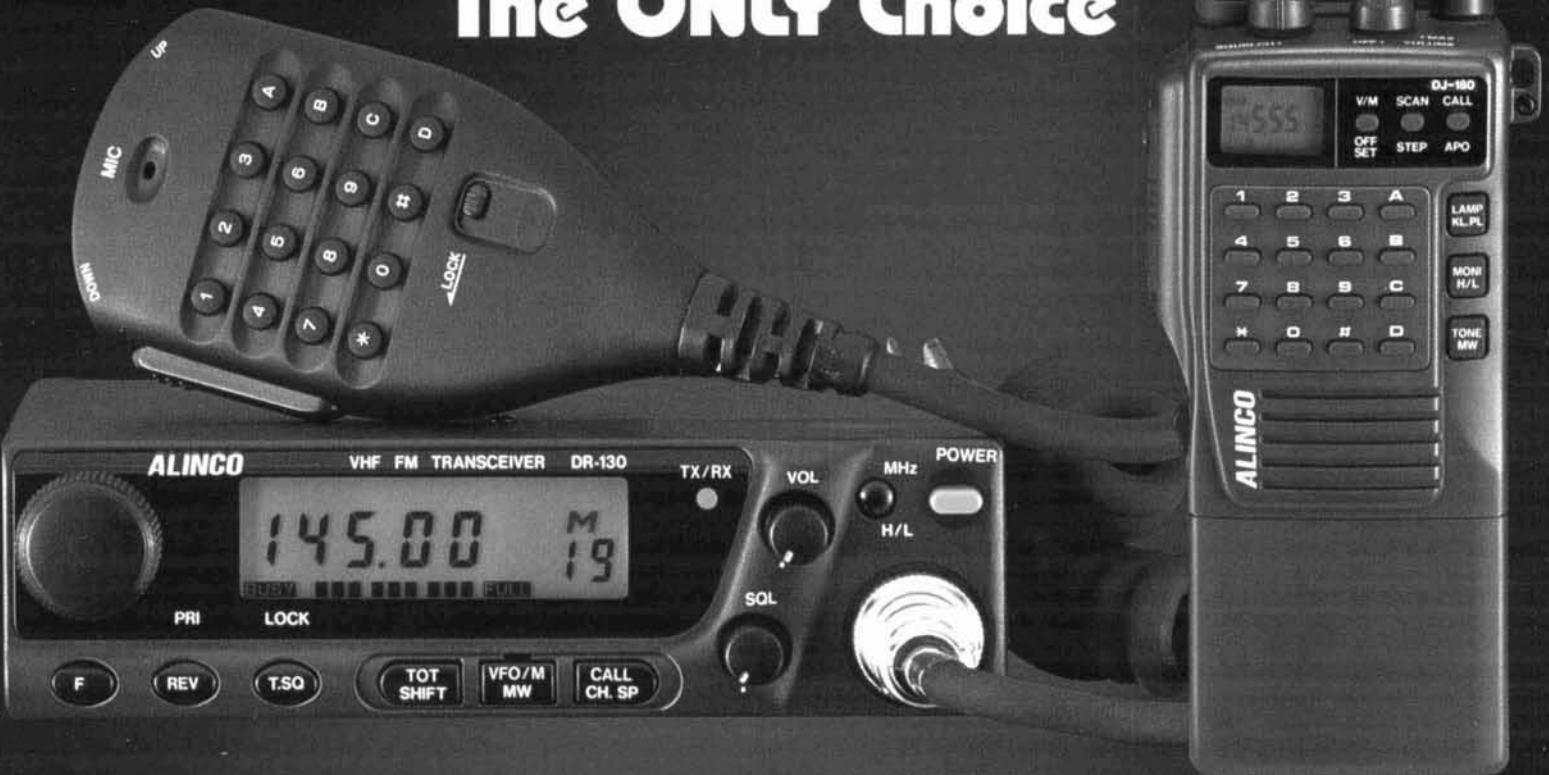
Fall 1994

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- Technical Conversations
- A Unique Approach to AM Synchronous Detection
- Super Regeneration
- CD-ROMS For the Radio Amateur
- The Solar Spectrum
- A 1.8 to 30-MHz 100-Watt SSB Transmitter
- Quarterly Devices
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- Quarterly Computing
- Communications Quarterly Article Index—  
Fall 1990–Summer 1994

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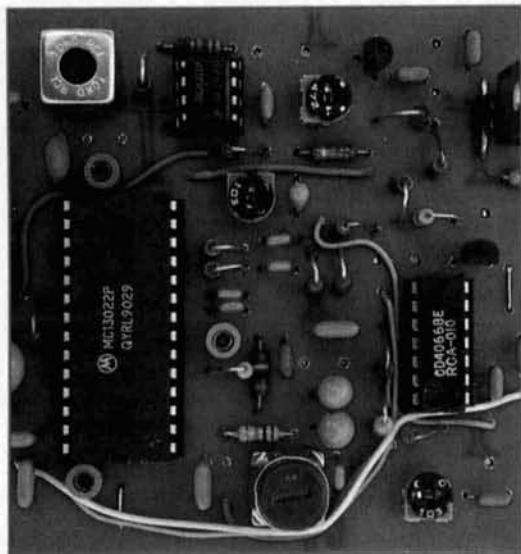
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Cover Photo: Many *CommQuart* readers are interested in receiver technology. In this issue, we present articles on receiver-based topics. Our cover photo, by Bryan Bergeron, NU1N, reflects our theme.

# EDITORIAL

## Hams Ride the Information Superhighway

Once upon a time, computers were alien to the ham shack. Many hams claimed they would *never* include such a thing as part of their radio equipment. During the years I edited *Ham Radio* magazine, disparaging letters would roll in *unfailingly every time* we ran a computer-related article. Now, years later, I'll wager that most us have some form of computer wedged in next to our ham equipment—be it an old C-64 (yes, they're still around) or one of the new Pentiums™.

I think hams who have incorporated computers into their radio setups would agree that it was a smart move. Computers can be real timesavers in the shack. Contest buffs can use logging programs to keep track of contacts, print out labels for QSL cards, and even control their radios; antenna designers can choose from an array (no pun intended) of antenna programs that simulate new designs before building them, RF CAD programs are available to aid in circuit design—the list is endless.

Not only can our computers help us save time, they can provide a means for expanding our knowledge of the hobby. Hams whose systems come equipped with a modem have the option of subscribing to one of the online computer services. Many of these feature ham nets; even local bulletin boards often contain amateur radio information, which you can download for later use. There's CompuServe, America Online, Prodigy, Internet...and let's not forget the much-heralded "information superhighway" promised for the future.

We've even jumped on the bandwagon—*Communications Quarterly* can now be reached on America Online. America Online's "Ham Radio Club" now includes a special reader-feedback area for *Communications Quarterly* in the "Manufacturers, Dealers & Vendors" section of its Message Center. Readers can post questions, comments and suggestions here, which will be forwarded regularly to the appropriate editor or writer. Plus, readers can help each other with their own online "Technical Conversations." If you're not a member of AOL, but have access to Internet e-mail, you can still reach us (send messages to our Online Coordinator, NW2L@aol.com), but you won't be able to join in the discussions in online message area.

Your computer can also become an electronic library if you pick up one of the latest system additions—the CD-ROM (Compact Disk/Read Only Memory) drive. This drive enables you to access the information on CD-ROM disks, which in turn offer a tremendous amount of data on subjects including amateur radio. Like library reference books, these CD-ROMs can become a lasting source of information you can return to again and again. Sitting on their shelves in little plastic cases, these "info-disks"

take up less room than some of our hefty radio handbooks—leaving more space for equipment!

But you don't have to take my word for it. Brad Thompson, AA1IP, has written a comprehensive article called "CD-ROMs for the Radio Amateur." It appears in this issue and covers both CD-ROM technology and some of the disks now on the market. If you thumb further through our pages, you'll also find Brad's new column "Quarterly Computing"—a forum for examining computer technology relating to amateur radio.

Brad is no stranger to the world of computers. For four years he served as contributing editor for *Computer Shopper* magazine. Brad is currently a full-time freelance writer, shareware reviewer, and electronic design consultant. He is also contributing editor for *Test & Measurement World* magazine, and his assignments include a quarterly column and projects involving computer-controlled instruments and RF measurements. Brad also has a workshop full of computers, electronic components, antique radios, and test equipment (fortunately, his wife is a "collector," too). And, of course, he has an interest in ham radio.

Why a column on computing? There are several reasons. First, I think that most of us have overcome our "compu-phobia" and are interested in learning about current amateur radio-computer links. Second, we can use our computers as a tool to expand our knowledge of the hobby—be it through software, CD-ROMs, or online services. Finally, computers can be an enticement that can draw others into the hobby. Let me give you an example.

One area high school student is excitedly pursuing his ham ticket. He works at the local Radio Shack, and his efforts are enthusiastically supported by his store manager. This young man became interested in amateur radio through a friend, and has plans to take all the tests up to General, so he'll have more privileges right away. What does all this have to do with computers? His first love was computers, and his interest in ham radio was fueled by a desire to operate packet radio.

I know it's been said time and time again, but the use of computers in ham radio is a sure-fire way to get today's young people involved in the hobby. If this is true, then it stands to reason that we should continue to expand our knowledge of computers to keep up with the next generation of amateur radio operators. So, if you're not on the ham radio/computer bandwagon, climb aboard. If you are, keep up with the latest developments. The combination of these two hobbies will take us places no one has ever gone before!

**Terry Littlefield, KA1STC**  
Editor

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# TECHNICAL CONVERSATIONS

The article "A New Method for Measuring Cable Loss," by A.E. Popodi AA3K/OE2APM (Spring 1994) generated letters from two of our readers.

**Dear Editor:**

Equations 4 and 6 in "A New Method for Measuring Cable Loss," A.E. Popodi, Spring 1994 issue, have not been simplified sufficiently and they can be presented in a much more convenient form, which is identical for the two cases!

Taking Equation 4, if one multiplies the second term under the square root sign by unity in the form of:

$$\frac{-R_{\max} - Z_0}{R_{\max} - Z_0}$$

one obtains:

$$a = \frac{1}{2} \ln \left\{ \frac{Z_0}{R_{\max} - Z_0} + \sqrt{\frac{Z_0^2}{(R_{\max} - Z_0)^2} + \frac{R_{\max}^2 - Z_0^2}{(R_{\max} - Z_0)^2}} \right\}$$

Bringing the terms under the square root together results in a perfect square, which then enables the square root to be removed. One, then, has two terms with a common denominator. Thus:

$$a = \frac{1}{2} \ln \frac{R_{\max} + Z_0}{R_{\max} - Z_0}$$

Equation 6 can be treated in the same manner and results in the same, much more usable, expression for the attenuation constant.

**S.F. Brown, G4LU**  
Shropshire, England

**Dear Editor:**

This is to compliment you on your willingness to publish a little algebra in your articles, but at the same time to chastise you for not reading the text before you publish it.

The subject article ("A New Method for Measuring Cable Loss," Spring 1994) is like several I have found interesting: fraught with errors.

Page 99, third paragraph, right-hand column: Directly proportional means linearly related,

not square root, square, log, or other complexity. Just related would do, or a function of, if you want to be elegant.

Page 100, left-hand column: Equation 2 is not illustrated anywhere, especially not in Figure 2, which shows an open coaxial line. In (a+jb) one does not add nepers to degrees, even at right angles. b is the length of the line in radians, not degrees.

Page 100, top of right-hand column: "This shows" is crazy, because it doesn't show that at all. It should say, "We know that..." and you could put a period at the end of the sentence. Fortunately, the algebra that follows is correct, down through Equation 4.

Page 101, middle of the left-hand column: Don't be silly: "Although Equation 6...it delivers exactly the same results." Use Equation 6 for open lines and Equation 4 for shorted lines. They otherwise give vastly different results.

Page 101, last paragraph: "Thus Equation 1 becomes," should say Equation 4. Gee whiz.

In other words, please get somebody to act as an editor. I like your magazine, hope you continue to be successful, but would prefer your stuff to be corrected before publication.

**Jack L. Schultz, W2GGE**  
Huntington, New York

*A reader had the following response to a letter by David Barton, AF6S, which appeared in "Technical Conversations," Spring 1994.*

**Dear Editor:**

I enjoyed David Barton's comments on measuring the velocity factor for transmission lines and his clever use of the MFJ 249. I usually use my noise bridge and receiver to find the frequencies that fit an integer number of half waves on the line and a computer program, "Cricket Graph" to fit the graph of frequency versus number of half waves with a straight line.

I did this with Mr. Barton's data (see Figures 1 through 4), breaking it into four cases and treating each separate: open circuit termination and an even number of quarter wavelengths on the line, short circuit and even, open and odd, short and odd. In each case, the graph of frequency versus number fell just beautifully on a straight line, exactly what one would expect from theory.

The slope of this line is just the speed of

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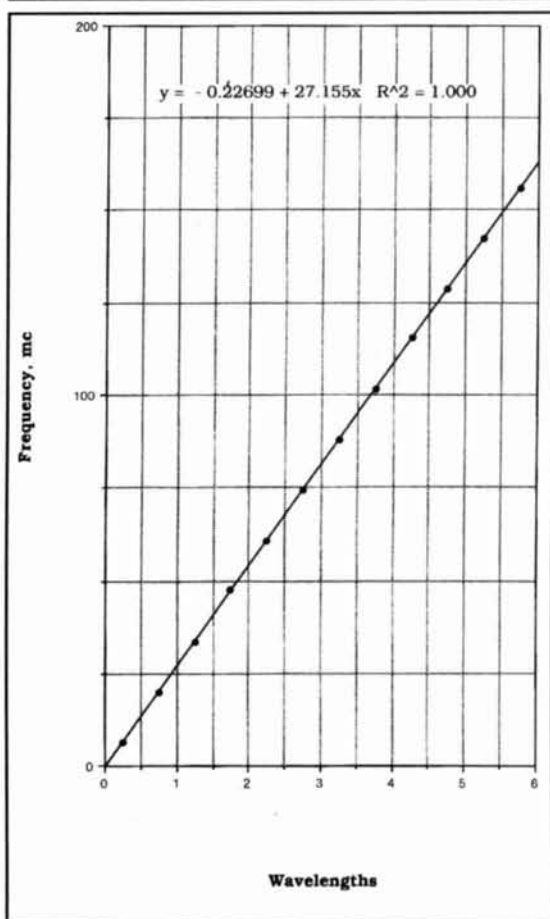


Figure 1. Data from "AF6S.Data Open, Odd quarter."

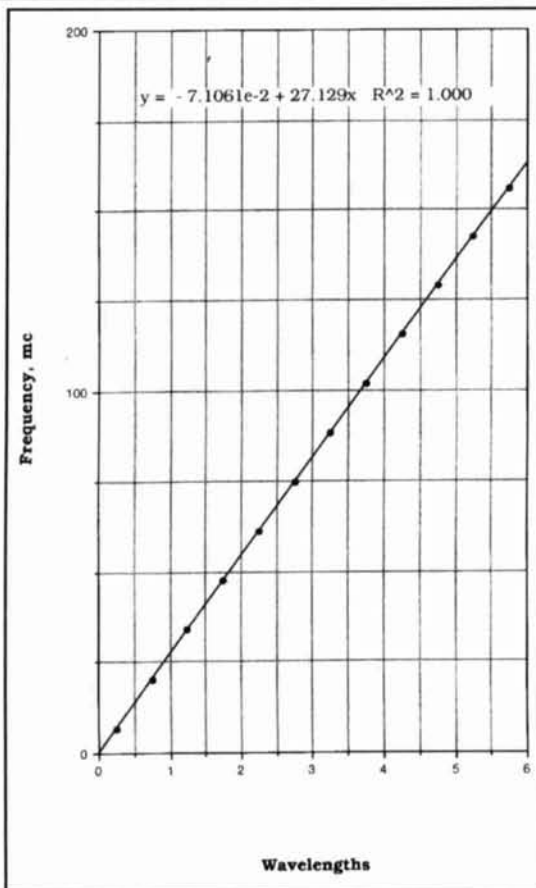


Figure 2. Data from "AF6S.Data Short, Odd Quarterwav."

propagation divided by the length of the transmission line, so it gives the velocity factor if you know the length. The slopes I got from fits to Mr. Barton's data are:

|             |        |
|-------------|--------|
| Open, Even  | 27.076 |
| Short, Even | 27.056 |
| Open, Odd   | 27.155 |
| Short, Odd  | 27.129 |

Note that in each case, the slope for the shorted case is slightly less than that for the open case. I assume that Mr. Barton's "perfect short" is about like mine, and is 30 mm long. Whether it lengthens the line by the full 30 mm is questionable, but lengthening the line will surely decrease the slope. In fact, we can use this decrease in slope to measure the increase in the line length. The open slope times the open line must be equal to the shorted slope times the shorted line length because the speed of propagation does not change.

Try that with an open line length of 7.437 m and see if you don't find that the shorted line is 5 mm longer when there are an even number of quarter waves on it and 7 mm longer when the number is odd. I don't argue that 5 differs from

7 by more than the noise, but 6 mm—the average of 5 and 7—is only one fifth of 30—the actual length of a PL259—which is a pretty big difference, and it makes a difference in the velocity factors, too.

Using a cable length of 7.437 m and 300 for the speed of light in m/μs, and an extra 30 mm or 6 mm when the cable is shorted, the data indicate the following velocity factors:

|             | Extra<br>30 mm | Extra<br>60 mm |
|-------------|----------------|----------------|
| Open, Even  | 0.6631         | no change      |
| Short, Even | 0.6653         | 0.6631         |
| Open, Odd   | 0.6650         | no change      |
| Short, Odd  | 0.6671         | 0.6649         |

Using the extra 6 mm, which the slope told us is correct, instead of the extra 30 mm, which is the actual length of the fitting, brings the open and short circuited measurements into outstanding agreement, but leaves a three-tenths of one percent disagreement between the even and odd quarter-wave measurements.

Where could this come from? What is different about the odd number of quarter-wave-

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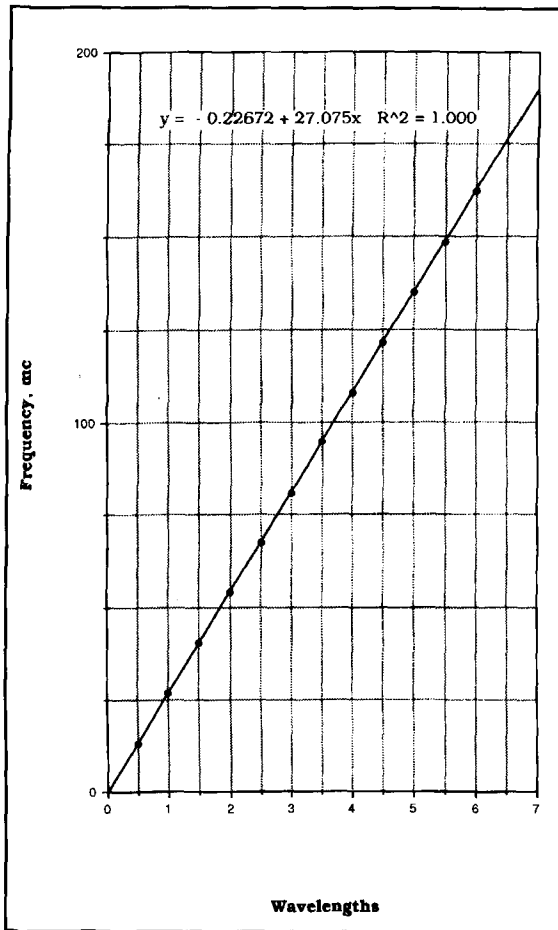


Figure 3. Data from "AF6S. Data Open, Halfwave."

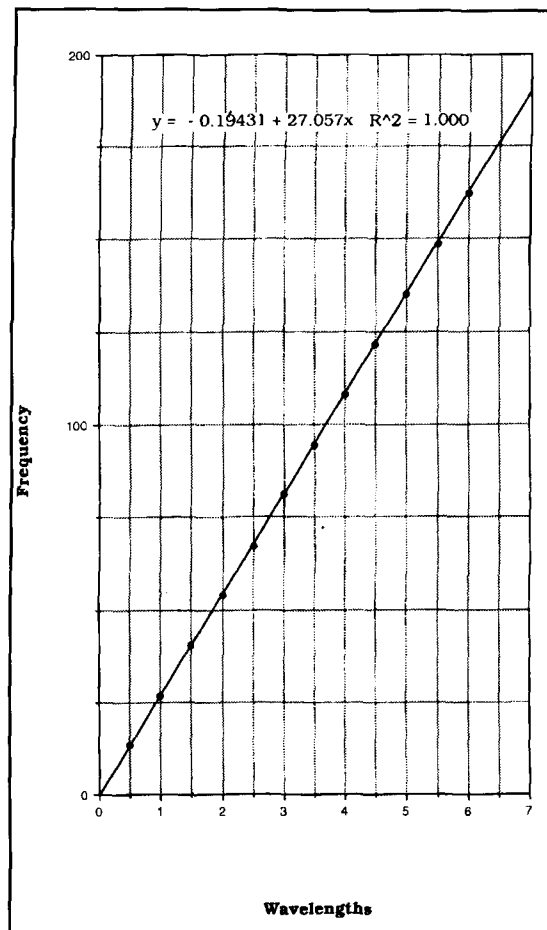


Figure 4. Data from "AF6S. Data Short, Halfwave."

lengths? The answer may be in the MFJ-249. If it is similar to my MFJ-247, then it produces a noticeable second harmonic.

A line that is an odd number of quarter wavelengths long at the fundamental is an even number of quarter wavelengths long at the second harmonic. If terminated with a short circuit, it will appear as an open circuit to the fundamental, but as a short circuit to the second harmonic. If terminated into an open circuit, it will appear as a short circuit to the fundamental, but as an open circuit to the second harmonic. On the other hand, lines whose lengths are an even number of quarter wavelengths of the fundamental appear shorted or open to both fundamental and second harmonic, according to how they are terminated. This is the only difference I have been able to think of. There must be some reader out there who understands the problem and can give us the solution.

Let me make one final comment before closing. Don't try to find the velocity factor with a single measurement, not even a number of single measurements. Get back to basics. The basic idea is that you are going to set up a

standing wave on a transmission line. You are going to detect this condition with a minimum or maximum SWR when, from the SWR bridge, there appears to be an integer number of quarter waves on the line. You can then express the length of the line as "n" wavelengths where n=0.25, or n=0.5, or n=3.75, for example.

Now, you had better allow for the possibility that what you think is "n" waves is in reality "n" plus or minus a little bit, an "end effect." Express that little bit as a fraction "a" of a wavelength, and write the length of the line as:

$$L = n\lambda + a\lambda$$

Recall that wavelength times frequency gives the speed of propagation, or  $\lambda f = v$  and substitute for  $\lambda$  to get:

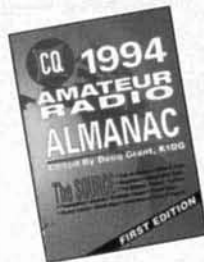
$$f = n(v/L) + a(v/L)$$

In this equation, v, a, and L are constants. You don't yet know the value of v or a, but they won't change as you change the frequency

(Continued on page 108)



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| SL-11S    | •      | •     | 7                      | 11          | 2 1/2 x 7 1/2 x 9 1/4 | 12                  |
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| RM-35A                         | 25                     | 35          | 5 1/4 x 19 x 12 1/2 | 38                  |
| RM-50A                         | 37                     | 50          | 5 1/4 x 19 x 12 1/2 | 50                  |
| RM-60A                         | 50                     | 55          | 7 x 19 x 12 1/2     | 60                  |
| • Separate Volt and Amp Meters |                        |             |                     |                     |
| RM-12M                         | 9                      | 12          | 5 1/4 x 19 x 8 1/4  | 16                  |
| RM-35M                         | 25                     | 35          | 5 1/4 x 19 x 12 1/2 | 38                  |
| RM-50M                         | 37                     | 50          | 5 1/4 x 19 x 12 1/2 | 50                  |
| RM-60M                         | 50                     | 55          | 7 x 19 x 12 1/2     | 60                  |

### RS-A SERIES



MODEL RS-7A

| MODEL  | Colors     | Continuous Duty (Amps) | ICS* (Amps) | Size (IN) H x W x D   | Shipping Wt. (lbs.) |
|--------|------------|------------------------|-------------|-----------------------|---------------------|
|        | Gray Black |                        |             |                       |                     |
| RS-3A  | •          | 2.5                    | 3           | 3 x 4 1/4 x 5 1/4     | 4                   |
| RS-4A  | •          | 3                      | 4           | 3 1/4 x 6 1/2 x 9     | 5                   |
| RS-5A  | •          | 4                      | 5           | 3 1/2 x 6 1/2 x 7 1/4 | 7                   |
| RS-7A  | •          | 5                      | 7           | 3 3/4 x 6 1/2 x 9     | 9                   |
| RS-7B  | •          | 5                      | 7           | 4 x 7 1/2 x 10 3/4    | 10                  |
| RS-10A | •          | 7.5                    | 10          | 4 x 7 1/2 x 10 3/4    | 11                  |
| RS-12A | •          | 9                      | 12          | 4 1/2 x 8 x 9         | 13                  |
| RS-12B | •          | 9                      | 12          | 4 x 7 1/2 x 10 3/4    | 13                  |
| RS-20A | •          | 16                     | 20          | 5 x 9 x 10 1/2        | 18                  |
| RS-35A | •          | 25                     | 35          | 5 x 11 x 11           | 27                  |
| RS-50A | •          | 37                     | 50          | 6 x 13 3/4 x 11       | 46                  |
| RS-70A | •          | 57                     | 70          | 6 x 13 3/4 x 12 1/4   | 48                  |

### RS-M SERIES



MODEL RS-35M

| MODEL                           | Continuous Duty (Amps) | ICS* (Amps) | Size (IN) H x W x D | Shipping Wt. (lbs.) |
|---------------------------------|------------------------|-------------|---------------------|---------------------|
| • Switchable volt and Amp meter |                        |             |                     |                     |
| RS-12M                          | 9                      | 12          | 4 1/2 x 8 x 9       | 13                  |
| • Separate volt and Amp meters  |                        |             |                     |                     |
| RS-20M                          | 16                     | 20          | 5 x 9 x 10 1/2      | 18                  |
| RS-35M                          | 25                     | 35          | 5 x 11 x 11         | 27                  |
| RS-50M                          | 37                     | 50          | 6 x 13 3/4 x 11     | 46                  |
| RS-70M                          | 57                     | 70          | 6 x 13 3/4 x 12 1/4 | 48                  |

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| MODEL                                | Continuous Duty (Amps) |        |       | ICS* (Amps) | Size (IN) H x W x D | Shipping Wt. (lbs.) |
|--------------------------------------|------------------------|--------|-------|-------------|---------------------|---------------------|
|                                      | @13.8VDC               | @10VDC | @5VDC | @13.8V      |                     |                     |
| VS-12M                               | 9                      | 5      | 2     | 12          | 4 1/2 x 8 x 9       | 13                  |
| VS-20M                               | 16                     | 9      | 4     | 20          | 5 x 9 x 10 1/2      | 20                  |
| VS-35M                               | 25                     | 15     | 7     | 35          | 5 x 11 x 11         | 29                  |
| VS-50M                               | 37                     | 22     | 10    | 50          | 6 x 13 3/4 x 11     | 46                  |
| • Variable rack mount power supplies |                        |        |       |             |                     |                     |
| VRM-35M                              | 25                     | 15     | 7     | 35          | 5 1/4 x 19 x 12 1/2 | 38                  |
| VRM-50M                              | 37                     | 22     | 10    | 50          | 5 1/4 x 19 x 12 1/2 | 50                  |

### RS-S SERIES



MODEL RS-12S

- Built in speaker

| MODEL  | Colors     | Continuous Duty (Amps) | ICS* (Amps) | Size (IN) H x W x D   | Shipping Wt. (lbs.) |
|--------|------------|------------------------|-------------|-----------------------|---------------------|
|        | Gray Black |                        |             |                       |                     |
| RS-7S  | •          | 5                      | 7           | 4 x 7 1/2 x 10 3/4    | 10                  |
| RS-10S | •          | 7.5                    | 10          | 4 x 7 1/2 x 10 3/4    | 12                  |
| RS-12S | •          | 9                      | 12          | 4 1/2 x 8 x 9         | 13                  |
| RS-20S | •          | 16                     | 20          | 5 x 9 x 10 1/2        | 18                  |
| SL-11S | •          | 7                      | 11          | 2 1/4 x 7 1/2 x 9 1/4 | 12                  |

# A UNIQUE APPROACH TO AM SYNCHRONOUS DETECTION

*A simple way to enhance full-carrier  
AM reception*

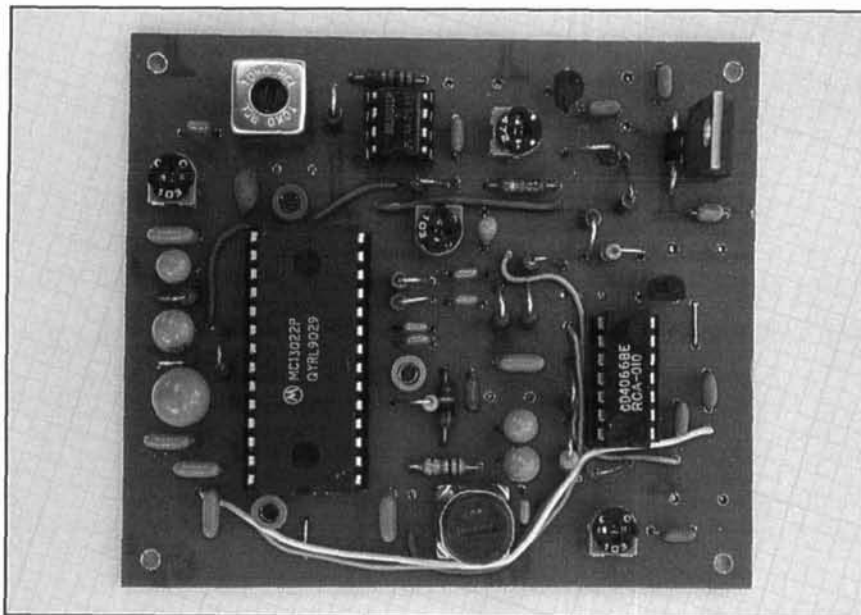
Amplitude modulation is almost as old as the radio art itself. Since the era of the radio-frequency alternator, AM has been used to convey intelligence throughout the RF spectrum. Even today, AM is hard at work in the standard broadcast band, the shortwave broadcast bands, and aviation communications.

For years now, the envelope detector has been the traditional method of demodulating AM. The envelope detector is a simple, low-cost device that provides relatively good performance under most conditions, but it is by no

means a high-performance demodulator. For instance, the envelope detector suffers from extreme distortion during selective fading—a common occurrence on the medium and short wave bands.

Fortunately, there is a solution: synchronous detection. The synchronous detector (also known as a coherent detector) offers these advantages:

- Provides low-distortion audio during carrier fades when receiving skywave-propagated signals.



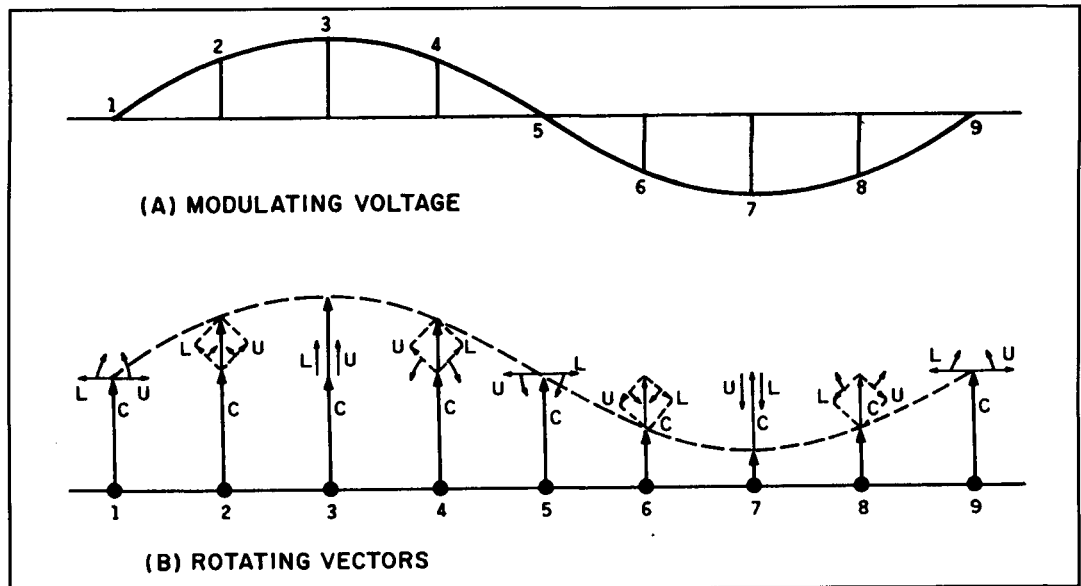


Figure 1. Rotating vectors are the easiest method of visualizing the phase relationships in amplitude modulation. Reprinted from Frederick Terman, *Electronic and Radio Engineering*, 1955, McGraw-Hill, permission of McGraw-Hill Books.

- Minimizes the effects of any quadrature components in the received signal caused by propagation anomalies, receiver mistuning, IF filter asymmetry, receiver phase noise, transmitter PM, etc.
- Provides a S/N ratio consistent with the actual S/N ratio of the incoming signal, regardless of its strength.

Until recently, most commercial receivers have not included a synchronous detector for AM, primarily because of its cost and complexity. The unique and simple circuit presented here was designed to offer the following features:

- Wide IF frequency range. Will work with any IF between 50 and 500 kHz, at any IF level between 10 mV and 1 volt RMS.
- Audio switching between an envelope detector and the synchronous detector is on-board, and is controlled by the presence of a ground signal.
- Audio distortion is less than 1.5 percent THD.
- An on-board notch filter with variable Q attenuates adjacent-channel heterodynes while providing high-frequency tone control. The notch filter can be set up to operate at 5, 9, or 10 kHz.
- An on-board LED driver is included to indicate detector phase lock.
- An on-board regulator permits the use of any input voltage between 7.3 and 35 volts DC, while eliminating the adverse effects of power supply ripple and VCO feedthrough.
- The board's small size (3.5 x 3 inches) allows its installation into almost any communications receiver.

Before we delve into the specifics of this circuit, let's spend some time looking at the AM demodulation process, and how a synchronous detector solves the problems associated with conventional envelope detection.

## Amplitude modulation—a tutorial

In order to understand synchronous detection, it's best to explain the physics of amplitude modulation. If we view an AM signal in the time domain using an oscilloscope, we can see the superpositioning of the modulating waveform on the carrier, resulting in modulation of the envelope of the wave. If we view the AM signal in the frequency domain using a spectrum analyzer set up with the appropriate resolution bandwidth and dispersion, we see the carrier and two identical sidebands spaced the distance of the modulating frequency from the carrier. If we vary the percentage of modulation, we would see the amplitude of the sidebands change relative to the carrier. Viewed this way, the AM process looks to be quite simple. However, there are phase relationships between the carrier and the sidebands that play an important part in the modulation process. We must be aware of these to understand how synchronous detection works.

Rotating vectors (see Figure 1) are the easiest method of visualizing the phase relationships in amplitude modulation. In Figure 1, the three vectors C, L, and U represent the amplitude and phase relationships of the carrier, lower sideband, and upper sideband, respectively. For clarity, the carrier vector C can be



considered our stationary reference; however, it actually rotates counterclockwise at a rate of  $\omega_c$  (where  $\omega_c$  represents angular frequency, or  $2\pi f_{\text{carrier}}$ ). Vectors L and U rotate in phase, as indicated by the arrows. The L vector always rotates clockwise (decreases in phase) and the U vector always rotates counterclockwise (gains in phase). The L and U vectors combine to create one in-phase resultant that either adds to or subtracts from the carrier vector, which corresponds to the amplitude modulated envelope.<sup>1</sup> The degree of positive modulation (positive modulation index) is expressed as the ratio between the magnitude of the resultant vector minus the magnitude of the unmodulated carrier vector, divided by the magnitude of the unmodulated carrier vector. The negative modulation index is defined as the unmodulated carrier vector magnitude minus the magnitude of the resultant vector divided by the unmodulated carrier vector magnitude. For full-carrier AM the negative modulation index cannot exceed unity.

In **Figure 1**, the Y-axis of the rotating vectors corresponds to the in-phase or "I" component, while the X-axis corresponds to the quadrature or "Q" component. At point 1 in the figure, the single-tone modulating voltage is zero, and the L and U vectors are in quadrature. As we move to the right, we find the vectors L and U add together in phase to produce a combined

vector of increasing magnitude until we reach point 3, where the trend begins to reverse itself—eventually reaching the reference carrier magnitude at point 5. From this point, the negative portion of the modulating waveform causes the L and U vectors to add in-phase in the negative direction, subtracting from the C vector until we reach maximum negative modulation (minimum carrier amplitude) at point 7, where the trend reverses itself once again until we reach point 9 and begin another cycle of the modulating waveform.

The rotating vectors in **Figure 1** assume that the receiver's detector sees the same symmetrical waveform that modulated the carrier. However, the symmetry of the upper and lower sidebands can be destroyed during propagation, often in a completely random fashion. **Figure 2** illustrates this effect, where the upper sideband has been propagated in such a fashion as to reduce the magnitude of the U' vector in relation to the L' vector.<sup>1</sup> Notice that as these vectors are rotated, the resulting amplitude waveform becomes extremely distorted. In addition, the L' and U' vectors are no longer in phase, causing amplitude and phase modulation in the output waveform.

If instead of sideband amplitude distortion, we were to encounter propagation that allows the sidebands to be propagated at approximately their normal amplitudes while the carrier is

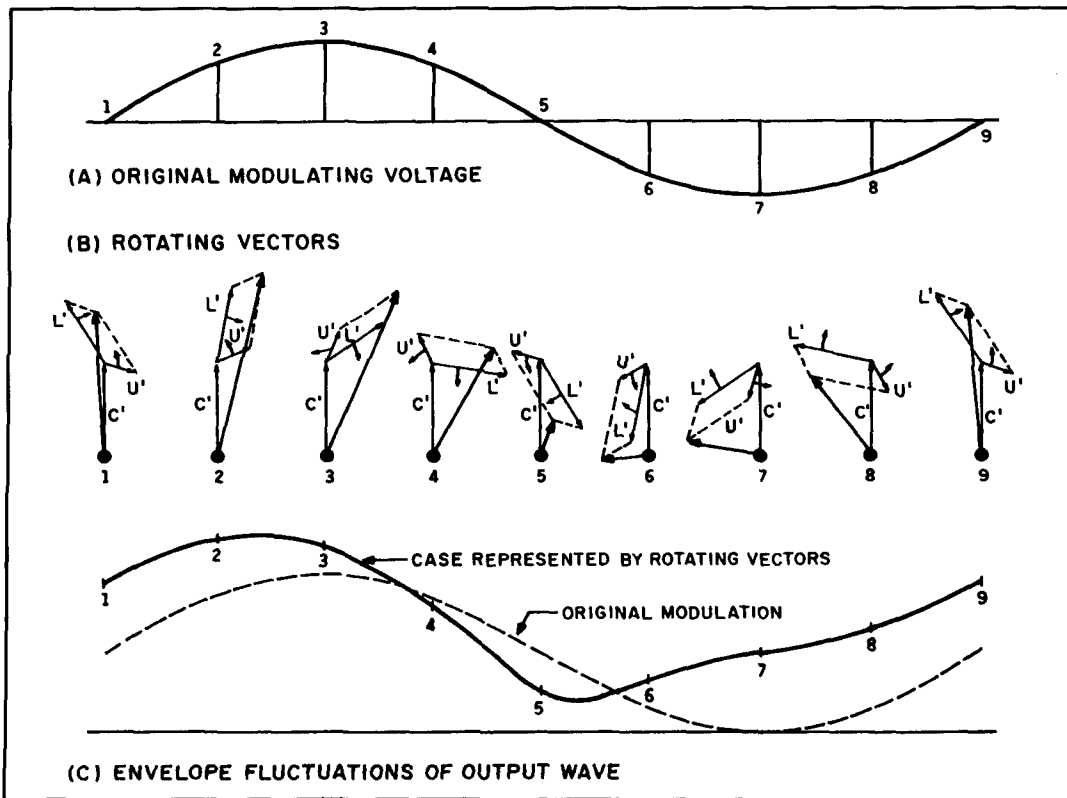


Figure 2. The symmetry of the upper and lower sidebands can be destroyed during propagation. Reprinted from Frederick Terman, *Electronic and Radio Engineering*, 1955, McGraw-Hill, permission of McGraw-Hill Books.

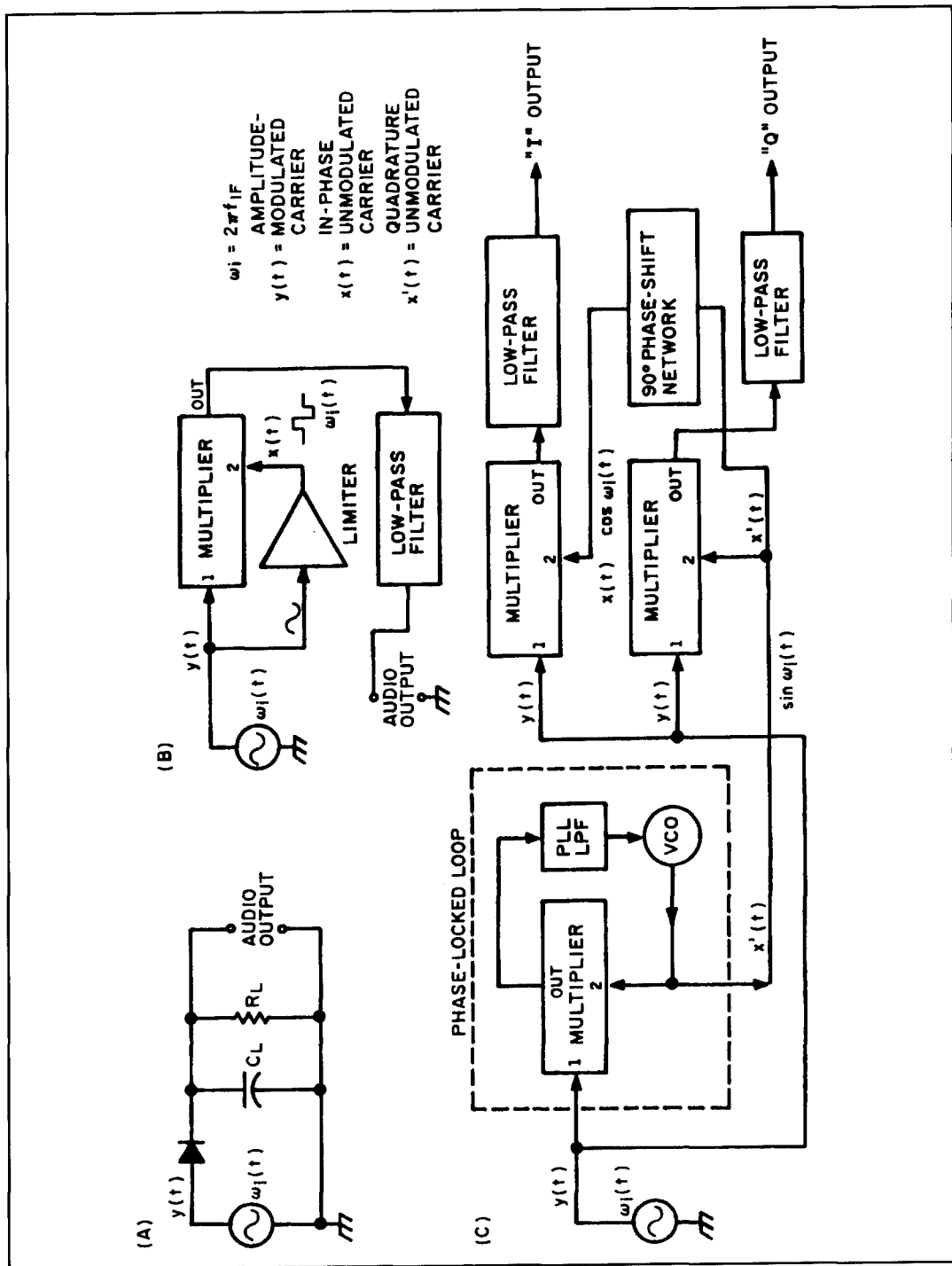


Figure 3. (A) Diode envelope detection. (B) Product detector. (C) True synchronous demodulation.

reduced in amplitude, the ratio of the magnitude of the  $L'$  and  $U'$  vectors and the  $C'$  vector during periods of maximum negative modulation (point 7) may create a modulation index that exceeds unity at the receiver causing extreme envelope distortion. In addition, rapid phase reversals occur as the modulating waveform crosses zero, causing a high degree of phase modulation.

## AM demodulation

There are three basic types of AM demodulation: diode envelope detection, product detection (sometimes called quasi-synchronous detection),<sup>2</sup> and true synchronous detection. The differences between these three types are summarized below:

- **Diode envelope detection.** This is the old-



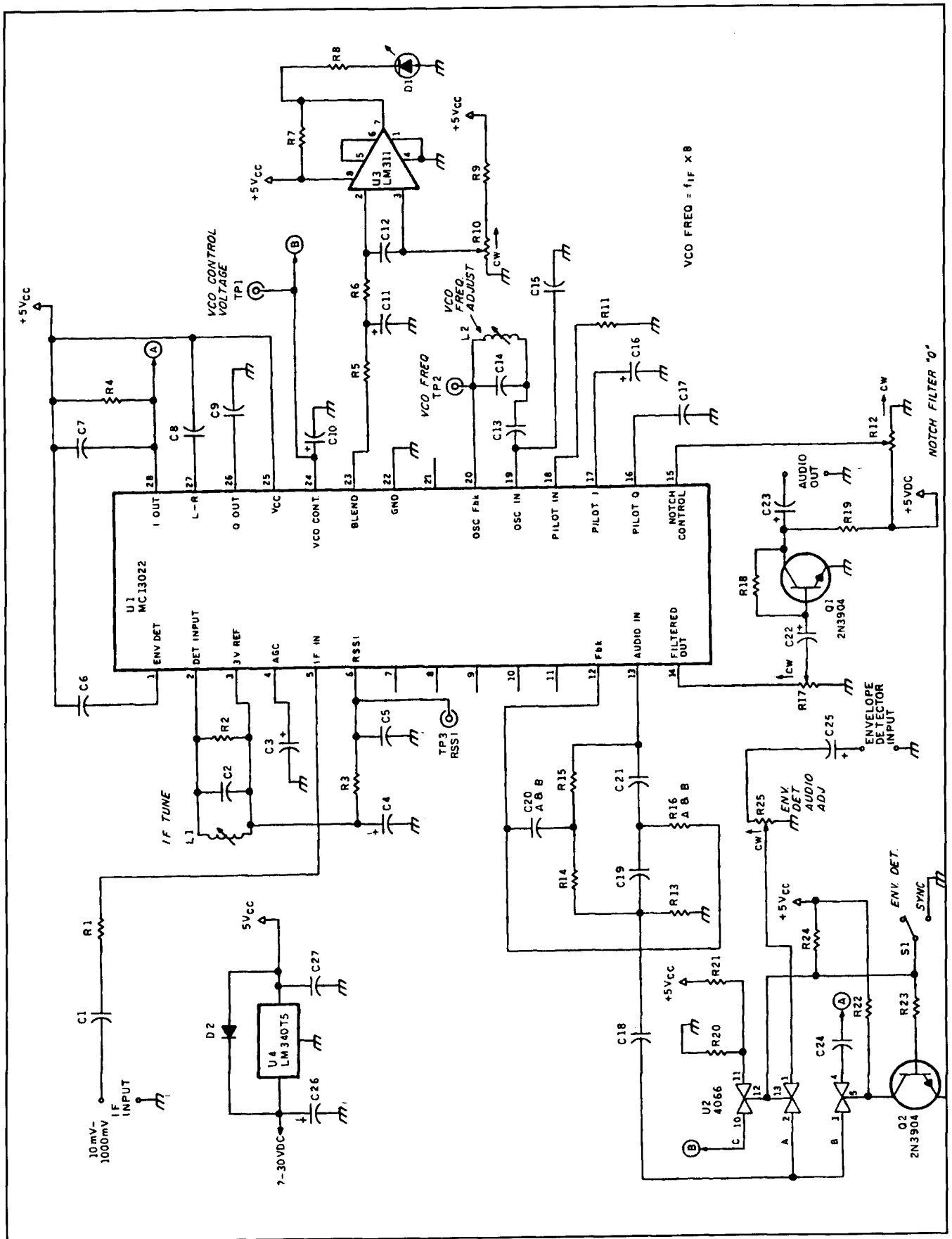


Figure 5. Synchronous detector circuit.



envelope detector has been used in communications receivers for decades, primarily because of its low cost. Today, however, the diode envelope detector has been replaced by product detection.

• **Product detection (quasi-synchronous).**

This term is actually a misnomer, as all demodulators produce an  $x(t)y(t)$  product of the carrier and modulated carrier frequencies. However, the term has come into such common usage that it now denotes the use of a multiplier instead of a simple diode rectifier.<sup>3</sup> In the product detector, the IF signal is fed into a limiter stage, where the modulation is stripped from the waveform (see **Figure 3B**). The resulting square wave of frequency  $\omega_c$  is fed into one port of a multiplier to serve as a carrier,  $x(t)$ , while the other input of the multiplier is fed with the original amplitude-modulated IF signal,  $y(t)$ . Product detection has the advantage of producing less distortion than a simple diode envelope detector under strong signal conditions, but it fails to offer any advantages as the signal strength decreases or the modulation index exceeds unity—as the  $x(t)$  carrier level will drop as well. Product detectors typically require far less input signal to produce an output, so the drive requirements are reduced.

• **True Synchronous.** The premise of true synchronous demodulation is quite simple. Instead of depending upon the received carrier to maintain the proper carrier vector magnitude (and therefore a modulation index of unity or less), we will instead design the receiver so it generates its own carrier  $x(t)$  of the proper magnitude in-phase with the received carrier. This carrier is injected as an LO signal into one port of an in-phase (I) multiplier, with the modulated IF signal  $y(t)$  feeding the second multiplier input (see **Figure 3C**). The product that results from this process has several advantages over a simple diode envelope detector:

- 1) During periods of carrier fading, the receiver's synchronous carrier takes the place of the missing carrier for the duration of the fade. In so doing, the audio distortion from the detector is greatly minimized when the modulation index exceeds unity, unless the sideband amplitudes are altered severely.
- 2) The multiplier only responds to the in-phase or amplitude component of the signal, minimizing the detector's response to the phase component.
- 3) The synchronous detector continues to demodulate regardless of the level of the incoming signal, eliminating the threshold effect seen in diode envelope detectors
- 4) The phase-locked VCO can eliminate the frequency-modulation associated with two

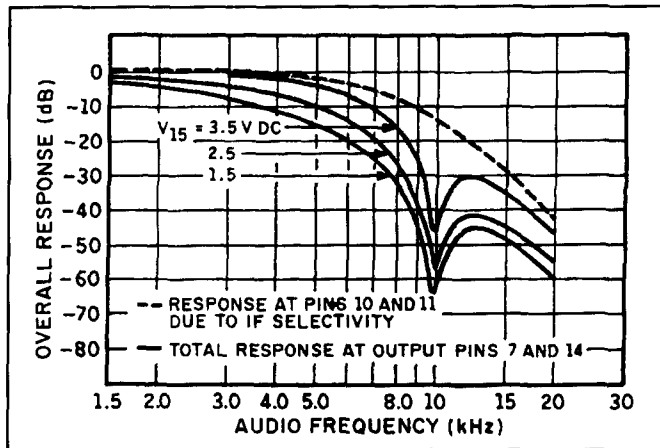


Figure 6. R3 and C5 provide the necessary R/C circuit for the RSSI line, who's output voltage varies according to the log of the input signal.

carriers near the same frequency (provided the carrier offset is outside the range of the lowpass filter in the PLL loop).

5) True synchronous detectors can also be used to demodulate single sideband reduced carrier transmissions, designated SSB-12.

## Overview of the Motorola MC13022 AM stereo decoder chip as a synchronous detector

Over the years, several means of providing synchronous detection have been developed, but in many cases the circuits were complicated and difficult to integrate into a wide range of receivers. Others were critical in their adjustment, and some required a very specific IF signal level. Still other circuits suffered from IF "breakthrough," where strong signals (such as local broadcast stations) would ride into the detector due to its high gain. I felt that there must be a simple way to provide synchronous AM detection in almost any receiver with an IF in the 50 to 500 kHz range without the problems associated with other designs. I found the answer in the Motorola MC13022 AM stereo decoder chip.

The real beauty of using the application-specific Motorola MC13022 as a synchronous detector is that a high percentage of the necessary components already reside on the chip. The MC13022 includes a low-distortion envelope detector, in-phase and quadrature multipliers, and an internal VCO. The chip also includes an AGC-controlled IF amplifier with 60 dB of dynamic range, and an audio notch filter to attenuate adjacent-channel heterodynes.<sup>4</sup> Although the chip was designed for an IF in the 260 to 455 kHz range, my tests indicate that it works just as well at any IF between 50 and 500 kHz—making it adaptable to a high percentage

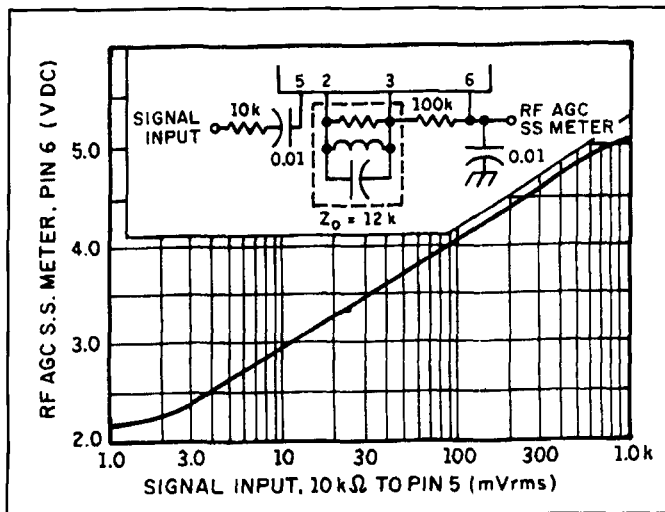


Figure 7. Notch depth/high frequency response versus pin 15 voltage.

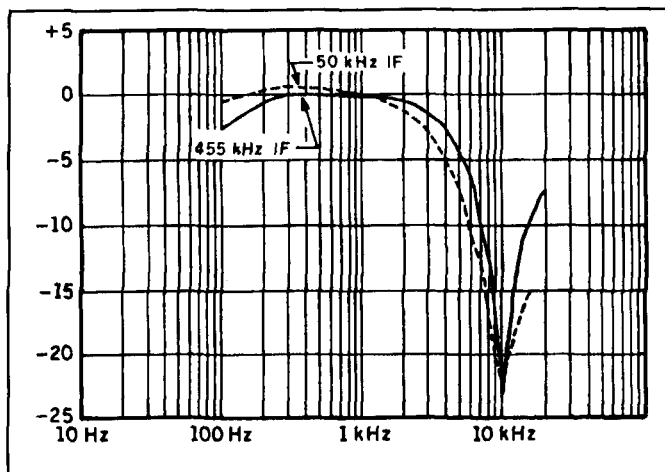


Figure 8. Frequency response.

of the communications receivers on the market. The high input impedance of the internal IF (>10 k), and low IF signal requirements (10 mV minimum) mean that the circuit is easily fed from almost any IF strip, or it can be used as an IF amplifier/synchronous detector in your next homebrew project.

Let's take a closer look at the circuit in **Figure 4**. The IF input of frequency  $\omega_i$  from the receiver is fed in on pin 5. From there, the IF signal is amplified and appears on pin 2. An external L/C circuit resonates the IF amplifier output, and the IF signal is internally coupled to the envelope and I/Q phase detectors. AGC voltage developed in the IF amplifier is fed back to a shunt attenuator on pin 5 to maintain an optimum signal amplitude to the multipliers and PLL. This AGC circuitry also feeds an internal signal quality detector that provides an external logarithmic signal strength indication, in addition to providing a signal quality indication to be used in activating the PLL fast-lock circuitry<sup>5</sup>.

The amplitude-modulated IF signal  $y(t)$  from pin 2 is fed into a buffer, and then into the multiplier/PLL input bus. The MC13022 uses multipliers for both the I/Q outputs and the envelope detector. By so doing, the envelope detector is actually a product detector (quasi-synchronous). The MC13022's I and Q multipliers are identical; the only difference between them is the LO signal injected into each from the VCO. Since the I multiplier demodulates the in-phase component, the VCO must supply it with an  $x(t)$  carrier of  $\cos \omega_i(t)$ . The  $\cos \omega_i(t)$  carrier generates maximum voltage when  $\cos \theta=1$  ( $\theta=0$  degrees). By the same token, the quadrature multipliers are fed with an  $x'(t)$  carrier of  $\sin \omega_i(t)$ . With this carrier, the output voltage is maximum when  $\sin \theta=1$  ( $\theta=90$  degrees).<sup>6</sup> These LO signals are developed in an internal phase-shift network on the output of the MC13022 VCO.

The VCO in the MC13022 operates at eight times the frequency of the IF and an internal divider brings the VCO down to the IF frequency. In the chip's original application, this was done to assure that the VCO would always be above the frequency of the standard broadcast band, even when the chip was used in an automobile receiver with a 260 kHz IF. In my application, this "feature" serves no purpose, other than to restrict the upper frequency limit of the IF input signal. The VCO employs a fast-lock circuit and an IF frequency discriminator that can sense whether the VCO is too high or too low in frequency and rapidly adjust the VCO lock voltage accordingly. Finally, VCO lock is fed back to the signal quality detector, where it provides an output voltage that I used to operate an LED to indicate PLL lock.

## Circuit description

The support circuitry for the MC13022 is quite simple, and only minor modifications to the chip's standard configuration were necessary to allow its use as a synchronous detector (see **Figure 5**). The IF signal from the receiver is coupled through DC-block C1 and R1 to the IF input on pin 5. R1 raises the input impedance, since this is variable with the setting of U1's internal shunt attenuator. The amplified IF signal appears at pin 2, and is applied to the IF resonant circuit consisting of L1, C2, and R2. R2 is used to lower the "Q" of L1/C2, improving the frequency response of the IF.

Capacitor C3 provides internal AGC filtering, and C4 serves as a AC bypass for the 3 volt regulator on pin 3. R3 and C5 provide the necessary R/C circuit for the RSSI line, whose output voltage varies according to the log of the input signal (see **Figure 6**).

Moving on to the detector portion of the

| Component      | 5 kHz notch | 9 kHz notch | 10 kHz notch |
|----------------|-------------|-------------|--------------|
| R14,15,16A,16B | 68,000 ohms | 47,000 ohms | 43,000 ohms  |

**Table 1. Component values for various notch-filter frequencies.**

chip, capacitors C6, C7, C8, and C9 serve as bypass capacitors for the  $2\omega_i(t)$  component present on these pins. The values of these capacitors vary according to the IF frequency, with a value of 0.01  $\mu\text{F}$  for a 50 kHz IF and 0.001  $\mu\text{F}$  for a 455 kHz IF. The values of these capacitors were carefully chosen to provide the necessary  $2\omega_i(t)$  filtering while minimizing their effect on the audio frequency response. It's very important that the same value capacitor be used on all four multiplier outputs, as an imbalance can cause distortion and VCO locking problems. Resistor R4 is used to supply a small DC bias voltage to the internal voltage comparators that monitor the degree of negative modulation on the output of the I multiplier. During deep carrier fades the degree of negative modulation can be very high, triggering the MC13022's internal modulation comparators and causing a loss of VCO lock. The bias supplied by R4 minimizes this effect.

In the VCO section, C10 serves as the loop filter capacitor, and a value of 68  $\mu\text{F}$  was chosen to maximize the ability to retain lock during deep carrier fades. For proper performance, C10 must be a low-leakage capacitor, preferably a tantalum. The VCO resonant circuit consists of L2 and C13-15. The values of these components can become quite critical, especially when the MC13022 is used at an IF frequency below its design limit of 260 kHz.

In order to provide a means of determining when the VCO is in lock, I modified the "Blend" circuit on pin 23. In U1's original application, this circuit was intended to slowly blend the left and right channels together during periods of poor signal quality, or to kill the stereo conversion process altogether when receiving a monaural station. It can also serve as an indicator of VCO lock, although its effectiveness in this regard is minimized by the application of a DC bias voltage through R4 on the I multiplier output. The blend voltage goes low (around 0.5 to 0.6 volts) when the VCO is out-of-lock, and goes high (around 0.7 volts) when locked with a good signal. R5 and C11 provide a short R/C time constant, and the filtered blend voltage is fed into a simple voltage comparator consisting of R6-R10, C12, U3, and D1. C12 prevents oscillation in U3, and R10 is used to set the comparator level for proper sync light operation. Components R11, C16, and C17 are included to prevent the internal stereo

decoding circuitry from interfering with my application of the MC13022.

The audio circuitry includes a Twin-Tee notch filter with variable feedback made up of C19, C21, R14-R16. This notch filter can be set for any notch frequency between 5 and 10 kHz as determined by the values of these components (see **Table 1**). R13 serves as a DC return for an internal capacitor on pin 13. The "Q" of the notch filter can be altered by changing the voltage on pin 15 via R12. Graphs showing the notch depth/high frequency response versus pin 15 voltage are shown in **Figure 7**. The output impedance of the MC13022 is very low, and will not provide an efficient match to the audio stage of most receivers. A simple self-biased audio amplifier stage consisting of C22, C23, R17-R19, and Q1 solves this problem.

In order to make the detector simple to install into any receiver, on-board audio switching is provided through bilateral switch U2. Sections A and B of U2 allow the selection of either envelope detector or synchronous audio. A logic high at pin 13 selects envelope detector audio, while a high at pin 5 selects synchronous detector audio. Transistor Q2 serves as a logic inverter for the B section of U2. When envelope audio is selected, the audio can be derived from the receiver's internal envelope detector via C23 and R25. R25 allows balancing of the audio level between synchronous and envelope detector audio. Instead of using the receiver's envelope detector, audio can be derived from the envelope detector on pin 1 of U1, and R25 is not needed. However, C25 is necessary to serve as a DC block. When synchronous audio is selected, the output of the I multiplier in U1 feeds pin 4 of U2B via C24. Finally, section C of U2 was included to force the VCO to a center resting frequency when the envelope detector is in use. I found that the MC13022 has a propensity for pulling itself to an extreme of the control voltage range when first powered up, or when the receiver is tuned off of a strong station. Occasionally, it took some time and effort to pull the VCO back within the capture range of the PLL; consequently, R20 and R21 are switched in while the envelope detector is in use, pulling the VCO to a frequency within the PLL capture range.

Power for the synchronous detector board is supplied by regulator chip U4, a garden-variety 5-volt regulator. U4 serves two important func-

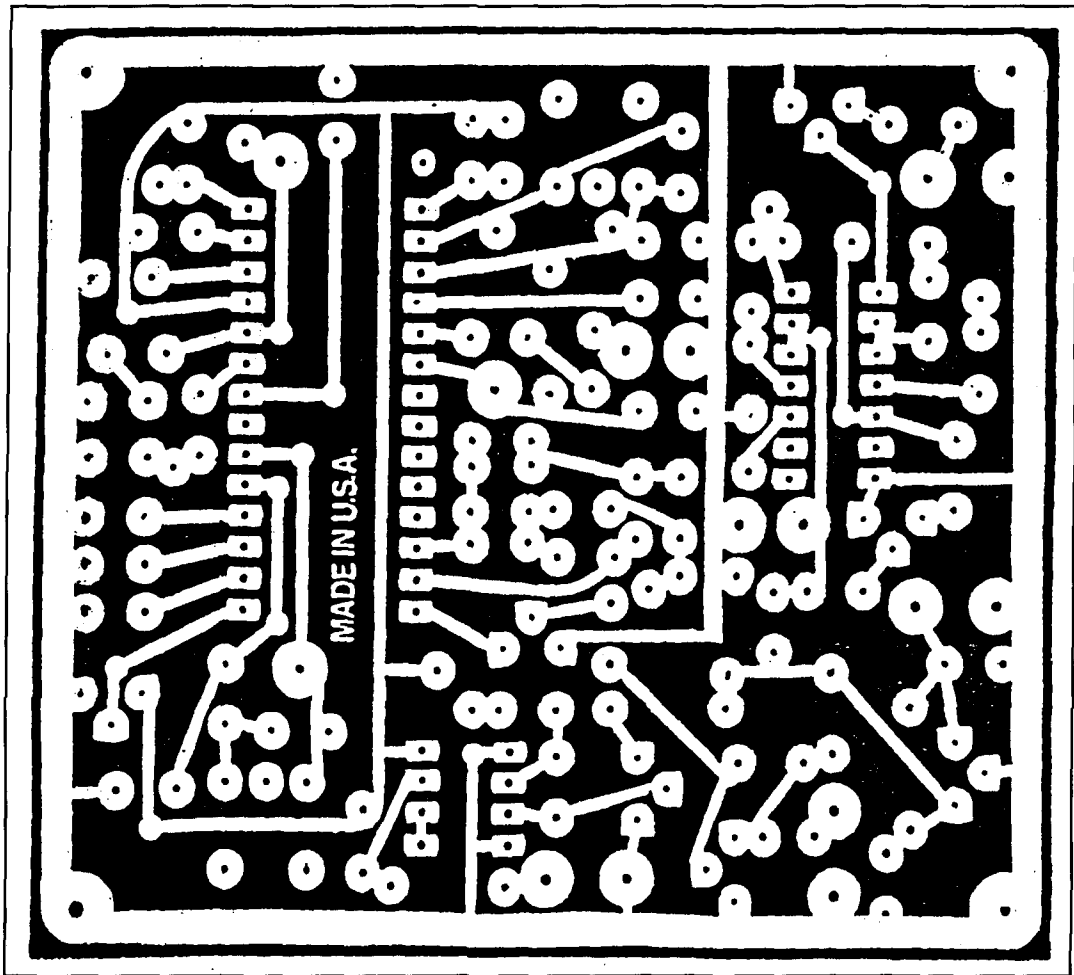


Figure 9. Synchronous detector board layout.

tions: 1) It supplies a low-ripple regulated voltage to the circuitry on the card, allowing it to operate from almost any DC power source in the 7.3 to 35 volt range, and 2) It greatly attenuates the fundamental and harmonics of the MC13022's internal VCO that would otherwise "ride out" on the power supply leads.

### Pre-construction notes

Before constructing the synchronous detector described in this article, there are a few aspects of its design that you should be aware of:

- The receiver in which you plan to install the synchronous detector must be stable, with very low local oscillator FM. For instance, several consumer-grade shortwave receivers I tested tend to vary the local oscillator frequency according to the AVC voltage. While the degree of FM may be small (100 to 200 Hz), it may be enough to cause brief detector loss-of-lock during rapid changes in AVC voltage.
- Because the MC13022 is an application-specific chip, modifying it for use as a synchronous detector involves some compromises.

One of these compromises is finding an effective manner in which to sense detector lock and operate an external indicator. The comparator included in this circuit (U3) works well in receivers with an AGC system, such as the Drake R-7 or SPR-4, but it does not work well in a receiver with a simple AVC circuit. U3 and its associated circuitry may be deleted if you don't need the sync indicator.

- The audio frequency response of this circuit has been tailored for communications use (200 Hz to 4 kHz). The detector will not provide a wideband audio output unless the notch filter is bypassed. Even then, the frequency response will be limited by the "Q" of the tuned circuit on pin 2 and the response of the IF stages preceding the detector (see **Figure 8**).

- I mentioned earlier that a synchronous detector can be used to demodulate SSB-<sub>12</sub> transmissions. With SSB-<sub>12</sub> only the upper sideband is transmitted and the carrier is reduced 12 dB below the sideband PEP. This provides just enough carrier for synchronous detection (although the phase modulation inherent in an SSB signal can make carrier-



lock difficult). SSB<sub>-12</sub> is just now coming into use on the shortwave broadcast bands, and will become the standard for shortwave broadcasting by the year 2016. While my application for the MC13022 as a synchronous detector works well for full-carrier, DSB transmissions, the MC13022 may not reliably hold lock on SSB<sub>-12</sub> transmissions because of its internal design. However, the primary design objective for this detector is to combat the effects of selective fading, and by so doing greatly minimize the listener fatigue associated with the reception of ionospherically propagated full-carrier AM signals.

## Construction

Construction of the synchronous detector is noncritical. I highly recommend using the circuit board artwork included in this article (see **Figures 9 and 10**);\* however, any method of construction may be used. The only sensitive portion of the circuit is the VCO L/C circuit on pins 19 and 20. These leads should be kept as short as possible to maximize stability and mini-

mize microphonics. If you decide to make any component substitutions in this circuit, keep in mind that I spent quite a bit of time determining the values of inductors L1 and L2, as well as the associated capacitors. You may find that the VCO will not run if substitutions are made, especially when the MC13022 is used an IF frequency below 260 kHz. Also, be sure to use the same value of capacitor for C6-C9, as an imbalance in values will cause distortion or difficult VCO locking.<sup>7</sup> All of the remaining components may be substituted as your needs require.

## Initial tests

Initial testing of the synchronous detector is quite simple. Begin by applying power to the card, and check for  $5.0 \pm 0.2$  volts at the output of U4. Next, measure the voltage at pin 3 of U1; it should measure  $3.0 \pm 0.1$  volts. Place the circuit in the envelope detector mode (pins 12/13 of U2 at logic high) and check the voltage at TP1 (pin 24 of U1). This should measure

\*PC boards are available for \$4.50 plus \$1.50 shipping and handling from FAR Circuits, 18N640 Field Court, Dundee, Illinois 60118.

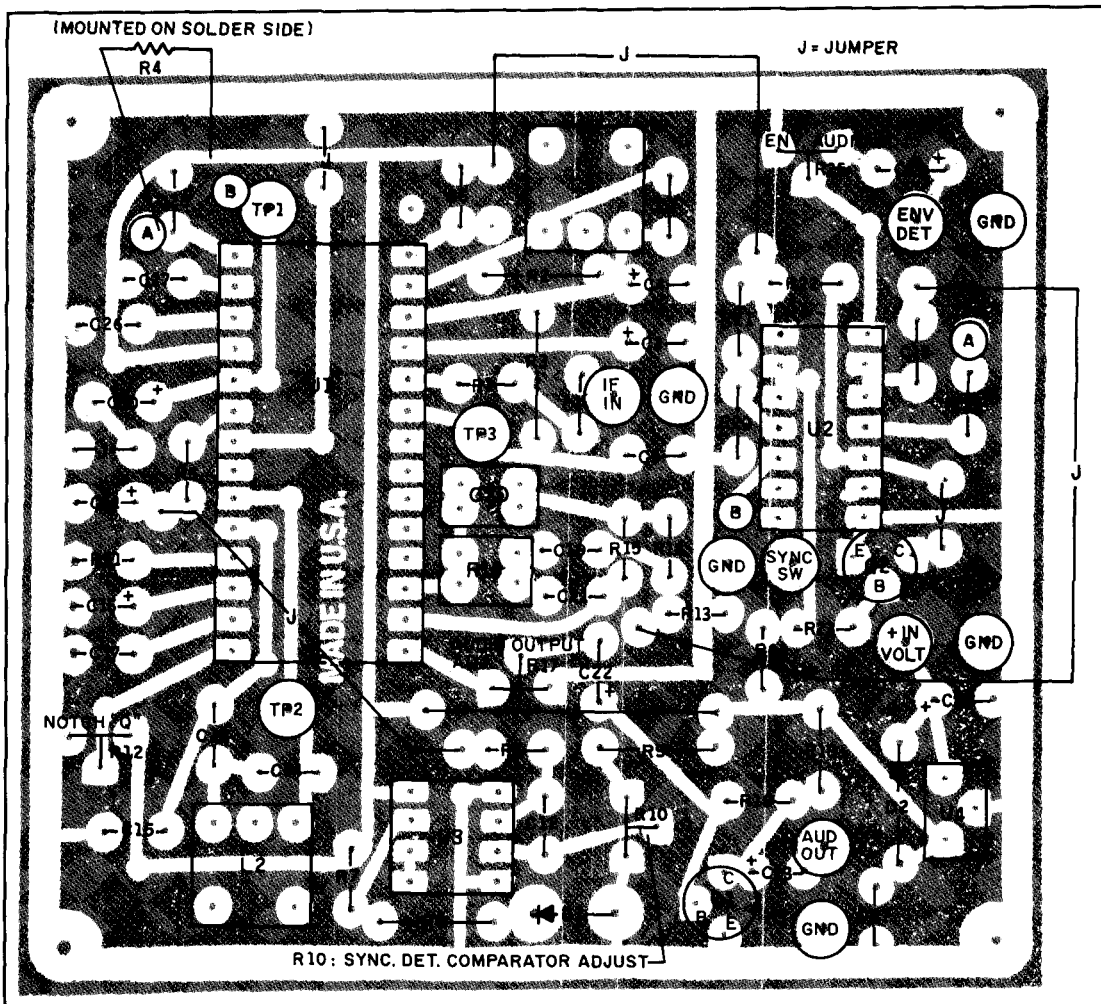


Figure 10. Parts placement.

about 2.8 to 3.1 volts. If all tests indicate proper operation so far, it's time to adjust the VCO resting frequency. To calculate the proper VCO operating frequency, multiply the IF frequency by eight. Attach a frequency counter to TP2 (pin 20 of U1) and adjust L2 until the frequency of the VCO is within 100 Hz of the calculated operating frequency. Next, adjust potentiometer R12 (notch filter Q) for 2.9 volts at pin 15 of U1 and adjust pot R10 (voltage comparator) to supply 0.72 volts to pin 3 of U3. You are now ready to install the card into your receiver.

## Installation

This synchronous detector was designed to be easily installed into almost any receiver. The AGC circuit in the IF amplifier allows the circuit to function quite well down to 10 mV of IF signal. Therefore, the IF sample can be taken from any convenient point in the receiver after any IF filters. For example, the IF sample can be taken from an unbypassed cathode bias resistor in the last stage of IF amplification. In some receivers, this level may be too high for the detector (the IF level must be kept below 1 volt RMS). If this is the case, simply substitute the existing cathode bias resistor with two resistors in a series voltage-divider configuration. Choose a division ratio that provides between 100 and 200 mV with a strong input signal (receiver AGC on). In a solid-state receiver, the IF sample can be taken from the input to the diode envelope or product detector. As with a vacuum tube receiver, a voltage-divider may be necessary if the IF level at this point is too high.

Power for the circuit can be taken from any point capable of supplying a minimum of 7.3 volts at about 30 mA. Make certain that you do not exceed the regulator's maximum input of 35 volts. In a vacuum tube receiver, you can derive the necessary power from the 6.3 or 12.6 volt filament circuit. Simply install a power supply consisting of a half-wave rectifier and a 500  $\mu$ F filter capacitor on the filament bus.

The only critical part of the installation of this card comes in determining its placement within the receiver. You must choose a location that will minimize the coupling of radiated energy from the VCO into the receiver front end. The easiest way to find a location for the card is to provide it with power and try placing it in potential locations within the receiver. Then tune the receiver to the VCO fundamental frequency as well as several harmonics, and note any presence of the VCO signal.

The board can be installed so that it uses either the on-board envelope detector for non-sync audio or the receiver's envelope detector. The choice is primarily dictated by the receiver design and your personal preference. This decision will also be influenced by your desire to

route either all audio through the notch filter, or only synchronous detector audio. If the receiver mode switch selects detected audio from two separate points when switching between AM and SSB, you can use either the receiver's envelope detector as an input to R25, or you can use the envelope detector on pin 1 of U1. However, if the receiver mode switch selects AM and SSB audio from the same point, you must feed receiver audio into R25.

Finally, you will need a means for switching between sync and non-sync audio from the front panel. Because the board requires nothing more than a ground to switch sources, this should be simple to do. If you don't want any additional holes in the front panel, look for unused switches. A prime candidate on many receivers would be the receive/standby switch. I used the calibrator switch on the Drake SPR-4, and the "Spkr" switch on the Drake R-7. In any event, make sure you disconnect and normalize any existing wiring to the switch you select prior to connecting the sync audio control line. If you would like specific information concerning the installation of this board into the Drake R-7, Drake SPR-4, or Hallicrafters SX-42, please send me an SASE at the address listed at the beginning of this article.

## Alignment

Connect a signal generator tuned to your receiver's IF frequency and to the input of the synchronous detector card. Set the generator for 30 percent modulation at 100 mV output. Connect a DVM to TP3 (pin 6 of U1) and measure the RSSI voltage. With 100 mV input, this test point should measure about 4.0 volts DC. If necessary, tune L1 for maximum RSSI voltage. This completes the alignment of the card in the non-sync mode.

To align the synchronous detector, you need only adjust the VCO frequency. Begin by connecting a signal generator to your receiver at any convenient frequency. Place the receiver in the narrowest bandwidth you would use for voice communication, and center the signal from the generator in the IF passband. Next, connect the synchronous detector card to the IF sample point. Check for proper RSSI voltage as before. Using a scope, also check for a sine wave at pin 1 of U1. Place the synchronous detector in the sync mode, and measure the voltage at TP2. Adjust L2 until this voltage reads  $2.9 \pm 0.1$  volts. Connect a scope to pin 28 of U1. You should now see a sine wave identical to that present on pin 1 of U1. Finally, with the detector locked on your test signal, adjust R10 until the sync light goes out, then back again until just slightly past the point where it comes back on. This sets the comparator threshold for your particular MC13022 blend line. The only remaining

alignment is the setting of audio levels.

If you have wired the detector so you will use the on-board envelope detector in the non-sync mode, the only audio adjustment you need to make is to R17. This pot should be adjusted so the audio level from the card matches the level of the detector the card replaced.

However, if you plan to use the receiver's envelope detector, there are a couple of additional steps. Connect the signal generator to the receiver, and tune both to a convenient frequency with 30 percent modulation of the carrier. Next, with the card in the sync mode, measure the audio output voltage from the board. Place the board in the envelope-detector mode, and adjust R25 for the same audio level at the output of the board as you had in the sync mode. Alignment of the card is now complete.

## Operation

Operating your receiver with the synchronous detector installed is quite simple. Begin by powering up the receiver with the detector in the envelope detector mode. Once the desired station has been selected, center the station in the receiver's passband and select the synchronous mode. If the station was properly centered, the sync LED will illuminate and the audio should be normal. If there is an audible heterodyne, retune the receiver towards zero-beat. The VCO should come into lock and the sync LED should illuminate. You may find that getting the detector into sync may be difficult on very weak stations, or stations with strong adjacent channel interference. However, careful tuning will bring these stations into lock. I highly recommend that you "browse" through the band with the synchronous detector turned off, as the heterodynes created prior to VCO capture tend to become very annoying. Also, occasionally you may find that you cannot achieve VCO lock, even on strong signals. This often happens when tuning through the band with the synchronous detector turned on. This rapid tuning may cause the VCO control voltage to sit at its lower limit. To correct this, place the detector in the envelope-detector mode, then switch back to synchronous. This will re-establish a favorable VCO control voltage, and the detector will come right into sync.

When you should use the synchronous detector is totally a matter of personal preference. I use the sync mode almost all the time, as its audio consistently sounds better than that of a conventional envelope detector. If you use the on-board envelope detector, there may be times on strong signals when you notice no difference between sync and non-sync audio, primarily because the on-board envelope detector is actually quasi-synchronous.

Finally, if you decide to use R12 as a vari-

able tone control, it's important that you do not allow the voltage to pin 15 of U1 to exceed 2.9 volts. The MC13022 generates high-frequency transients when the VCO locks up, causing an annoying "pop" in the audio. The high-frequency roll-off at this setting of R12 is sufficient to attenuate these transients.

## Conclusion

The synchronous detector presented in this article provides a simple means of greatly enhancing full-carrier AM reception. As with any unique application of a custom-designed chip, it has its drawbacks. For example, the circuit may not demodulate SSB-<sub>12</sub> transmissions, but this is of minimal consequence, as the vast majority of stations utilize full-carrier DSB, and will continue to do so for some time. I feel that this circuit meets the synchronous detection needs of most short and medium-wave listeners. I have installed this board in a Drake R-7, Drake, SPR-4, and Hallicrafters SX-42—all with equally impressive results. The significant reduction in listener fatigue during selective fading was this circuit's primary design intent, and it meets that objective quite satisfactorily.

I hope that by presenting this implementation of synchronous detection, we can begin to bring circuits of this type into common use, and spur others to design even more flexible circuits than what I have presented here. In addition, I look forward to hearing from readers who have designed other applications for this circuit. For instance, the output from the quadrature multiplier could be used to indicate the degree of phase modulation in a signal, which may be useful for some types of propagation measurements or in measuring phase noise. The quadrature output could also be used with a noise blanker or any circuit that could benefit from the lack of an in-phase modulation component.

## Acknowledgments

I would like to express my sincere appreciation to Mr. Don Wilson from Motorola Global Paging Systems for his assistance in providing detailed documentation and Mr. Rich Potyka from Motorola Semiconductors for information concerning specific aspects of the MC13022 internal circuitry. ■

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**Parts List: Synchronous detector using Motorola MC13022P.****Notes:**

\* = 50 kHz IF, \*\* = 455 kHz IF, a = 5 kHz notch, b = 9 kHz notch, c = 10 kHz notch.

**Capacitors**

|                                 |  |
|---------------------------------|--|
| C1, C5, C6*, C7*, C8*, C9*, C17 | 0.01 $\mu$ F/50 volts DC monolithic, Panasonic ECUS1J103JC, Digi-Key P4824   |
| C2*, C15*                       | 470 pF/50 volts DC monolithic, Panasonic ECU-S1J471JC, Digi-Key P480   |
| C2**                            | None, internal to L1   |
| C6**, C7**, C8**, C9**          | 0.001 $\mu$ F/50 volts DC monolithic, Panasonic ECU-S1J102JC, Digi-Key P4812   |
| C12, C18, C22, C24, C27, C28    | 0.1 $\mu$ F/50 volts DC monolithic, Panasonic ECQ-V1H104JL, Digi-Key P4525, Radio Shack 272-109  |
| C3, C4, C16, C23, C26           | 10 $\mu$ F/16 volts DC tantalum, Panasonic ECS-F1CE106K, Digi-Key P2038  |
| C25                             | 1.0 $\mu$ F/50 volts DC tantalum, Panasonic ECS-F1HE105K, Digi-Key P2073   |
| C10                             | 68 $\mu$ F/16 volts DC tantalum, Panasonic ECS-F1CE686, Digi-Key P2043   |
| C11                             | 47 $\mu$ F/16 volts DC tantalum, Panasonic ECS-F1CE476, Digi-Key P2042   |
| C13*, C14**                     | 100 pF/50 volts monolithic, Panasonic ECU-S1J101JCA, Digi-Key P4800-ND   |
| C13**                           | 47 pF/50 volts DC monolithic ECU-S2A470JCA, Digi-Key P4845-ND  |
| C14*                            | None, internal to L2   |
| C15**                           | 220 pF/50 volts DC monolithic, Panasonic ECU-S1J221JCA, Digi-Key P4804-ND  |
| C19, C20A, C20B, C21            | 470 pF (a) Panasonic ECU-S15471JCA, Digi-Key P4808; 380 pF (b) Panasonic ECU-S2A331JCB, Digi-Key P4855-ND (330 pF) and Panasonic ECU-S2A470JCA (in, Digi-Key P4845-ND (47 pF); 370 pF (c) Panasonic ECU-S2A331JCB, Digi-Key P4855-ND (330 pF) and Panasonic ECU-S2A390JCA, Digi-Key P4844-ND (39 pF) |

**Diodes**

|    |  |
|----|--|
| D1 | Red Miniature LED, Radio Shack 276-026 |
| D2 | 1N4003 Diode, Radio Shack 276-1102     |

**Inductors**

|           |  |
|-----------|--|
| L1*       | 22 mH, slug-tuned coil, Toko CLNS-T1034Z, Digi-Key TK1719        |
| L1**, L2* | 0.64 mH, slug-tuned coil, Toko RMC-2A7287HM, Digi-Key TK1303     |
| L2**      | 15 $\mu$ H, slug-tuned coil, Toko 154ANS-T1101Z, Digi-Key TK1209 |

**Transistors**

|        |   |
|--------|---|
| Q1, Q2 | 2N3904 transistor, Radio Shack 276-2016 |
|--------|---|

(Note: All fixed resistors 1/4 watt carbon or metal-film)

**Resistors and potentiometers**

|                      |   |
|----------------------|---|
| R1, R2, R23          | 10 k                                      |
| R3                   | 100 k                                     |
| R4                   | 47 k                                      |
| R5                   | 1000 ohms                                 |
| R6                   | 1 meg                                     |
| R7, R22, R24         | 1 k                                       |
| R8                   | 330 ohms                                  |
| R9                   | 15 k                                      |
| R10                  | 4.7 k, PCB-Mount Pot, Radio Shack 271-281 |
| R11                  | 22 k                                      |
| R12, R25             | 10 k, PCB-Mount Pot, Radio Shack 271-282  |
| R13                  | 4.7 meg                                   |
| R14, R15, R16A, R16B | (a) 68 k; (b) 47 k; (c) 43k               |
| R17                  | 1 k PCB-Mount Pot, Radio Shack 271-280    |
| R18                  | 270 k                                     |
| R19                  | 2.7 k                                     |
| R20                  | 4.7 k                                     |
| R21                  | 3.9 k                                     |

**Integrated circuits**

|    |   |
|----|---|
| U1 | Motorola MC13022P AM Stereo Decoder, Newark Electronics       |
| U2 | National CD4066P Quad Bilateral Switch, Digi-Key CD4066BCN-ND |
| U3 | National LM311N Voltage Comparator, Digi-Key LM311N-ND        |
| U4 | National LM340T5 5-Volt Regulator, Radio Shack 276-1770       |

**Miscellaneous**

|     |   |
|-----|---|
| TP1 | Green vertical test point, EF Johnson 105-0854-001, Digi-Key J122ND |
| TP2 | Red vertical test point, EF Johnson 105-0852-001, Digi-Key J120ND   |
| TP3 | Blue vertical test point, EF Johnson 105-0860-001, Digi-Key J312ND  |



# SUPER REGENERATION

## *The lost technology*

Today, handheld VHF receivers are commonly available, but it took many years of research to develop sensitive superheterodyne circuits that could be produced at relatively low cost. In the 1920s, frequencies much above 20 MHz were rarely used; however by the mid-1930s, practical 400-MHz receivers were being designed and built by radio amateurs. Ultimately, the conquest of the higher frequencies was brought about by the hard work and determination of these radio amateur "experimenters" using the very latest in high technology at the time: super regeneration. This article shows how we can personally relive early radio history by studying and building super regenerative radio circuits.

### Benefits of super regeneration

Aside from providing an insight into early radio history, super regenerative receivers still offer some very distinct advantages over more

modern types of circuits. The principle benefits are microvolt level sensitivity (even at extremely high frequencies), very low parts count, low cost, and low power consumption. Typical super regenerative detector gains approach one million, even at VHF and above—in a single stage—using only one active device. For all of these reasons, super regeneration deserves our examination.

### Early radio circuits

The first commonly used radios were "cat whisker" crystal diode receivers (a galena crystal with a very thin contact wire), many of which were homemade. These were replaced by radios using tube "grid leak" detectors that provided an increase in sensitivity. However, many technical problems remained. The most serious of these were the limitations of the amplifying devices being used. These early triode tubes could provide only meager gain at

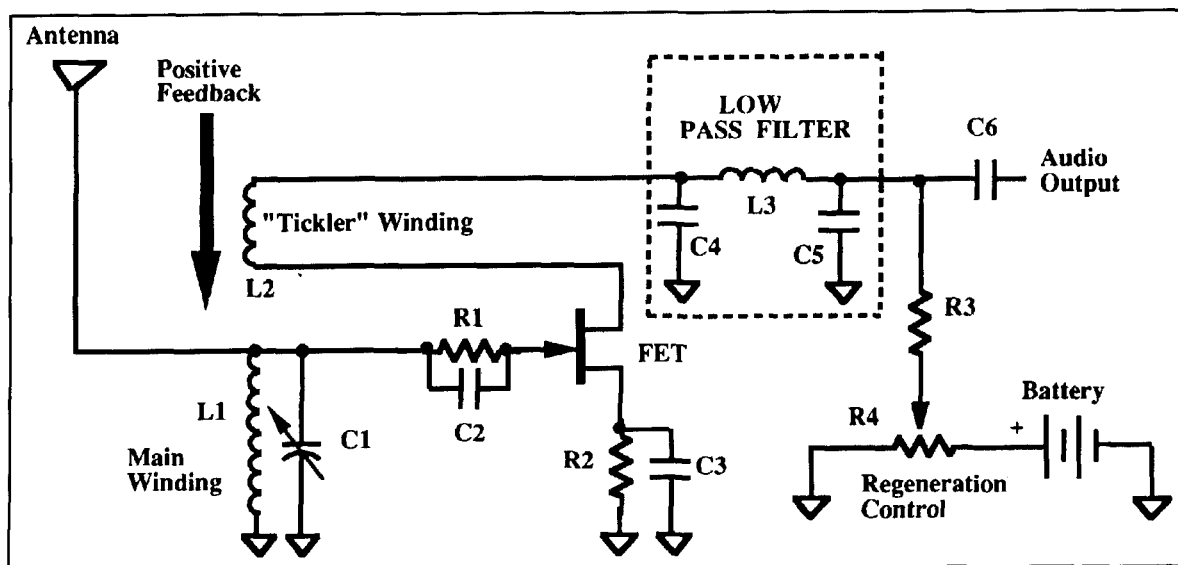


Figure 1. The modern equivalent of the basic regenerative detector circuit.

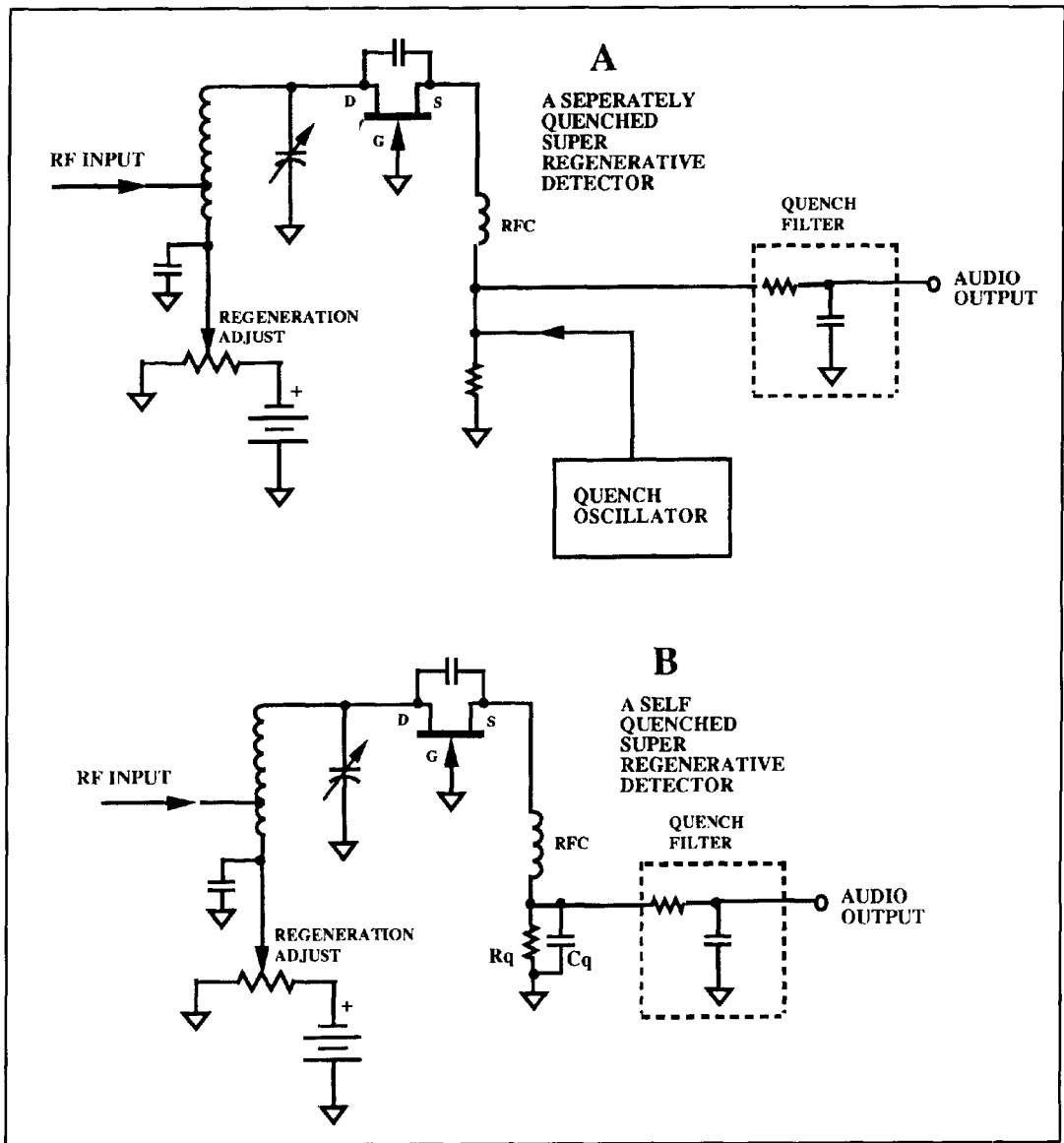


Figure 2. Two common methods of quenching a super regenerative receiver. (A) Separately quenched super regenerative detector; (B) self-quenched super regenerative detector.

the lower radio frequencies, and no gain at all at frequencies much higher than 30 MHz.

In 1914, Edwin Howard Armstrong invented the regenerative circuit—probably the most significant discovery in the history of radio.<sup>1</sup> As shown by **Figure 1**, regeneration feeds the output of a radio circuit back to its input, in phase, so the input signal is amplified over and over—up to the threshold of oscillation. This greatly increased both the sensitivity and selectivity of early radio sets.

The actual mechanism of regeneration is complex. Regeneration has the effect of introducing a negative resistance into a circuit. Because the circuit's selectivity or "Q" is equal to its net reactance divided by its net resistance, the circuit's selectivity is increased along with its gain when regeneration is introduced. When

the regeneration level is below self-oscillation, the circuit's negative resistance (produced by regeneration) is less than its fixed positive resistance. At this level, regeneration has the effect of providing a stable increase in both gain and selectivity.

With more regeneration, a very dynamic region is reached, just at the threshold of oscillation. Here, the circuit's negative and positive resistances are almost equal. This is a nonlinear (chaotic) operating region, where minute changes in input level or circuit voltages produce very large (nonlinear) changes in output level. The exact "balancing" point between a stable and unstable system cannot actually be achieved, as even the smallest random noise source, given time, will build up into a self-sustained free oscillation.

As regeneration is further increased, a curious “click” is sometimes heard in the headphones. This indicates that the circuit has reached the point where it exhibits a net negative resistance, causing the onset of free oscillations in the system. The amount of gain an individual regenerative stage can provide is limited by the introduction of these free oscillations into the circuit. The free oscillations, once started, will build up to the carrying capacity of the amplifying device. Therefore, in a straight regenerative receiver, the amount of feedback needs to be operator adjusted to a point just below self-oscillation if the highest gain and selectivity are desired. In the early 1920s, the regenerative circuit was used extensively, despite its limitations, for it provided high gain in an era where the cost of additional radio amplification stages was prohibitive.

## Super regeneration comes of age

In 1922, Armstrong came up with yet another invention based on regeneration, but whose actual mechanism opened up an entirely new field of research: the super regenerator. This was a modification of the straight regenerative circuit where regeneration was increased *beyond the point of free oscillation*. This time, the oscillation was periodically interrupted or “quenched” by a second oscillator operating at a lower frequency.

The circuit is essentially a modulated oscillator whose input is coupled to an antenna. The circuit is set to an oscillating condition and then periodically quenched. Small noise sources require greater periods of time to build up to a self-sustaining free oscillation than do signals that are much larger in amplitude. Therefore, given the limited time between quench intervals, the signal sources are amplified to a much greater extent before they are quenched out. Note that the oscillations must decay fully before being allowed to start up again, as even a small amount of residual signal will initiate a premature free oscillation—ending all useful amplification for that period.

## Types of super regenerators

Super regenerators are classified into two general categories depending on how their oscillations are interrupted: separately quenched and self-quenched. **Figures 2A** and **B** show the basic connection for each type, using modern JFET devices.

In **Figure 2A**, the separately quenched variety of super regenerator uses a separate quench oscillator to generate an alternating voltage (historically, a sine wave) that is above the

audio range, but still far lower than the signal frequency. This modulates the source voltage of the FET detector at the quench frequency. The FET is periodically biased on, then off, at the quench frequency rate.

Although the separately quenched variety provides higher sensitivity at lower operating voltages than self-quenched types—and permits the operator to adjust the quench rate and amplitude easily—it requires building, powering, and adjusting a separate quench oscillator. Historically, this added quite a lot of complexity to an otherwise simple circuit. Fortunately, modern ICs make a separate quench oscillator cheap and easy to construct.

**Figure 2B** shows the self-quenched type of super regenerative circuit. Note that the quench oscillator has been replaced by resistor/capacitor combination Rq,Cq. This RC time constant is deliberately set long enough so capacitor Cq cannot discharge fast enough (at the signal frequency rate) through Rq. As a result, a variable DC voltage is built up across Rq,Cq, which periodically interrupts the main oscillator.

Because of their extreme simplicity, low power consumption, and low cost, self-quenched receivers were very popular among radio hams of the 1930s and '40s until low-cost VHF superheterodynes were developed.

Super regenerative detectors are practical for wideband FM reception, as well as for AM. Unfortunately, the sidebands created by the quenching action limit a super regenerator's selectivity, making it impractical for detecting narrowband FM signals.

In addition to its practical use at VHF and above, super regeneration may be used on the lower frequencies, such as the shortwave bands, as well. However, because signal levels here are generally strong, with many stations crowded together, straight regeneration—providing less gain, but much higher selectivity—is more appropriate for these frequencies.

Because a super regenerator breaks into oscillation as part of its normal operating cycle, it will radiate its own signal out its input. In the past, when vacuum tubes were used for these detectors, serious interference sometimes resulted from their use. Today, the availability of modern low power semiconductor devices greatly reduces the potential for interference. Nevertheless, all present day super regenerative detectors should be preceded by an RF stage to isolate the detector from the antenna.

## The actual mechanism of super regeneration

**Figure 3** is adapted from a 1935 paper by Hikosaburo Ataka,<sup>2</sup> Meidi College of

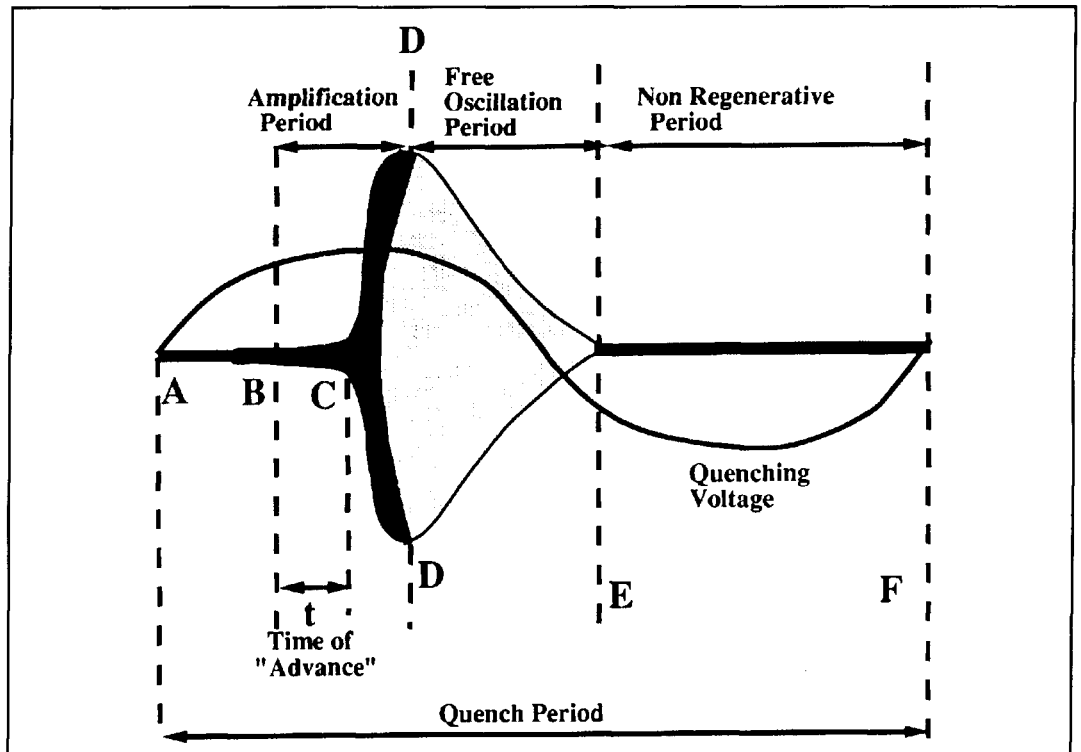


Figure 3. Characteristic RF envelope of a super regenerative detector.

Technology, Tobata, Japan. It provides a detailed representation of the oscillation envelope of a super regenerative detector circuit. The area within the shaded region of the envelope is that portion of the envelope in which the received signal is actually amplified. When there is no signal present, noise in the detector initiates a build up of a free oscillation, which starts around point "C" and builds up to the carrying capacity of the active device. The detector is now in a state of free oscillation, which continues until the circuit is quenched and the oscillations die out (point "E").

However, when an input signal is applied, the dynamics of the shaded region change. The build up of oscillation now starts sooner—at point "B." This added time of build up, "t," by which the oscillation starts early in the presence of a signal, Ataka<sup>2</sup> called the time of "advance." The greater the magnitude of the input signal, the greater the time of advance. The greater the time of advance, the longer the amplification time period ("B" to "D"). Note that the unshaded (oscillatory) portion of the envelope ("D" to "E") contains by far the greatest area—but does not contribute to any actual amplification of the signal. The nonregenerative time interval ("E" to "F") is that period of time when the quench signal has turned the oscillator off completely. Oscillations must be allowed to die out completely before recommencing—this is why super regeneration detec-

tors using high "Q" tuned circuits often fail to function properly. They hold the signal, preventing it from being totally quenched. As a result, super regeneration stops and the circuit oscillates continuously.

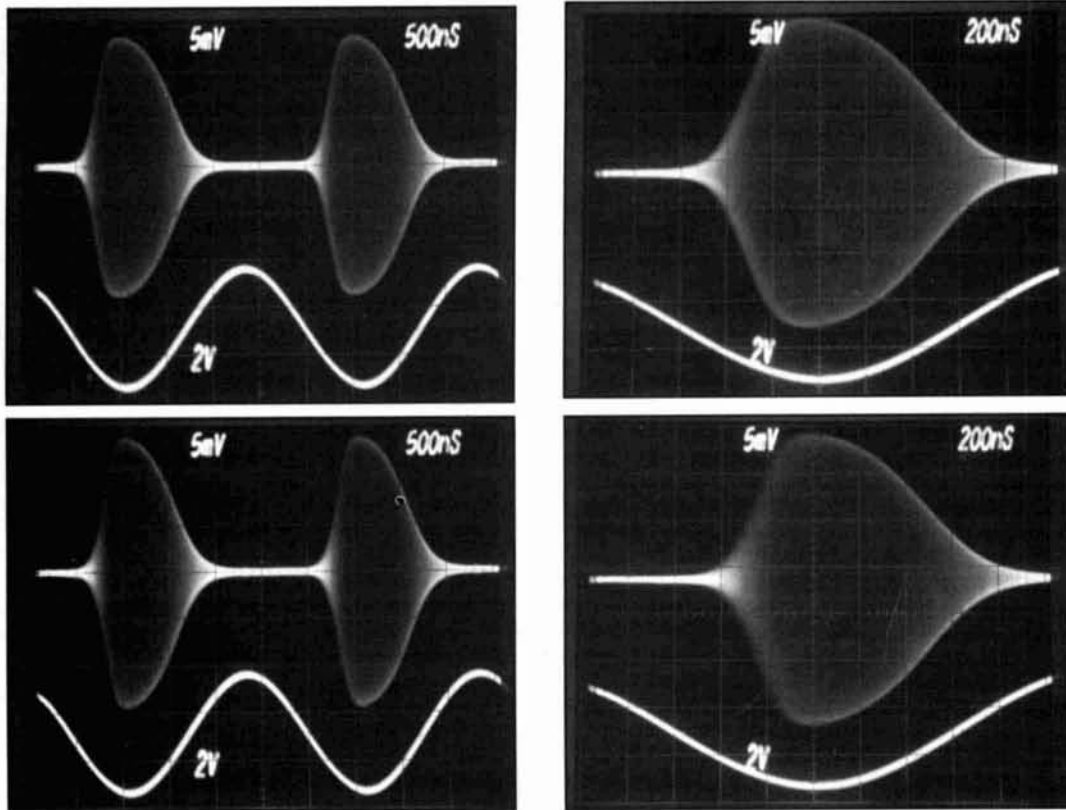
The output from the detector is directly related to the area of the shaded region ("B" to "D"). With no signal applied, the noise initiating the build up of the oscillations is random, and thus the time of advance, the area of the shaded region, and the output of the detector will also be random. This explains the characteristic background hiss—termed "mush"—of a super regenerative detector. It is very noticeable with conditions of no signal and disappears completely on strong signals.

**Photos A through D** are oscilloscope photographs of a super regenerative detector that is being separately quenched by a sine wave oscillator. These photos show the detector's RF envelope under conditions of no signal and an applied signal.

The applied signal pulls that oscillation envelope to the left and also makes the shaded region more distinct (less fuzzy). The time of advance directly affects detector sensitivity and is a function of the strength of the applied input signal and both the frequency and amplitude of the quench voltage.

Both the amplitude and frequency of the interruption or "quenching" rate are critical. Ideally, the detector should be quenched at a





Photos A through D. Oscilloscope photographs of the characteristic RF envelope of a super regenerative detector (Figure 2A) being separately quenched with a sine wave voltage. Upper traces are the RF envelope of the detector. Lower traces are that of the applied quench voltage. (A) Separately quenched, frequency: 400 kHz, 100  $\mu$ V signal, 145 MHz. (B) Separately quenched sine, frequency: 400 kHz, 100  $\mu$ V signal, 140 MHz. (C) Separately quenched, frequency: 400 kHz, no signal, 140 MHz. (D) Separately quenched sine, frequency: 400 kHz, no signal, 140 MHz.

point just after it has broken into free oscillation—just beyond point “D” in Figure 3.

Figure 4, also derived from Ataka’s<sup>2</sup> paper, shows that there is an optimum quench frequency for each received frequency that provides the greatest sensitivity (for a given quench amplitude). Also, except in the case of very low quench voltages, sensitivity does not increase as the quench frequency is reduced.

This effect is shown schematically in Figure 5. For a given received frequency, if we start at a low value just above the audio range, an increase in the quench frequency will increase the number of times the signal is allowed to build up to free oscillation level in a given time interval. As shown by the dotted line in Figure 5, the total sum of all the shaded areas increases directly with quench frequency until a critical point is reached where the free oscillation is quenched at a point just after it has started. This quench frequency will provide the optimum sensitivity for this particular received frequency and quench voltage level.

As the quench frequency is increased beyond that point, amplification decreases because the quenching now starts prematurely—before the signal has been allowed to build

up to maximum amplitude. Although there are now more shaded areas per second, the net size of each area is so diminished that the result is a loss in total area per interval and a net loss in circuit sensitivity.

### The self-quenched super regenerator

Despite some common misconceptions, the self-quenched super regenerator varies quite a bit from the separately quenched variety, both in circuit operation and performance. Photo E is an oscilloscope photo of the output envelope of a typical self-quenched circuit. Note that, after quenching has begun, the decay time of the self-quenched circuit is much longer than that of a comparable circuit separately quenched. The secondary (quenching) oscillations result in an oscillation envelope in which the oscillation starts rapidly, but decays very slowly.

In these circuits, an adjustment in the level of regeneration also causes a change in quench frequency, so only a single control needs to be adjusted. This makes the self-quenched receiver easier to use than the separately quenched

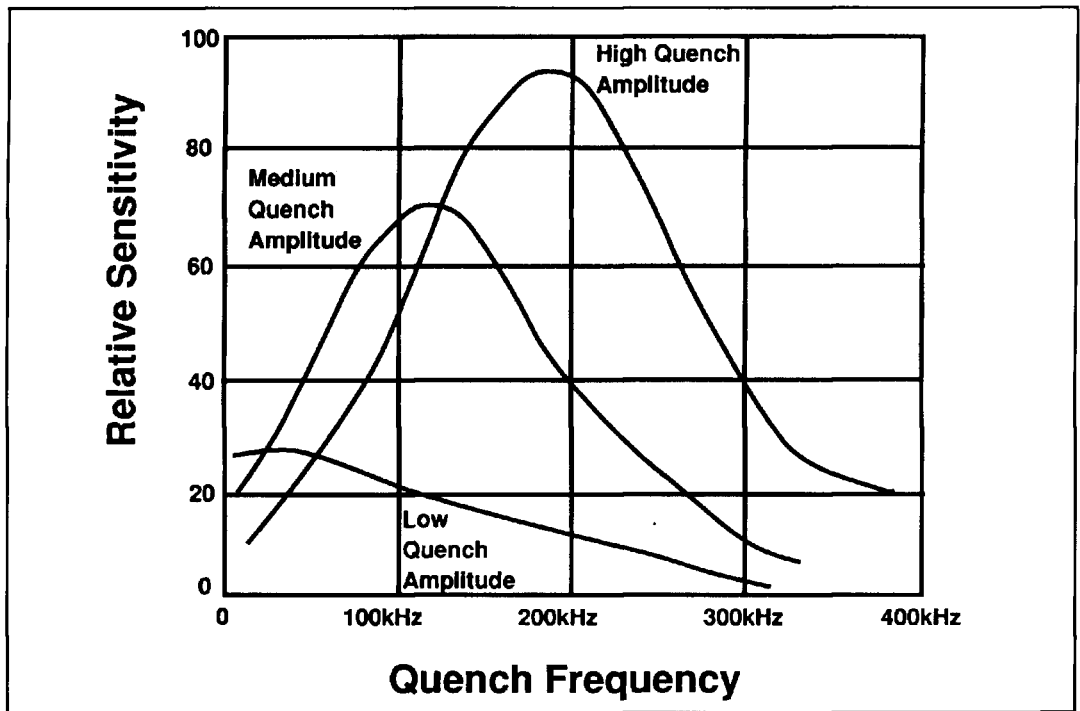


Figure 4. The effect of quench frequency and amplitude on receiver sensitivity.

variety. By carefully adjusting the regeneration control, the detector voltage and quench oscillation rate can be adjusted simultaneously for best sensitivity. However, note that, for the same level of sensitivity, the no signal background noise or “mush” level is higher in a self-quenched circuit than it would be using a properly adjusted separately quenched design.

### Choosing the optimum quench rate

From my own observations, I have found that separately quenched super regenerators work best when their quench frequencies are approximately 10 times higher than those of the self-quenched variety. Normal quench frequencies for both types are in the ranges of 30 kHz to 1 MHz. Approximate quench frequencies for VHF circuits in the 100 to 200 MHz range are 400 kHz for separately quenched and 40 kHz for self-quenched circuits. In all cases, it's best to experiment: the quench rate (and amplitude for separately quenched receivers) should be varied around the chosen value and the effect upon the circuit's sensitivity, selectivity, and audio quality observed.

### A self-quenched super regenerative aircraft receiver

Figure 6 is a good example of a practical modern circuit using super regeneration. This is

a VHF receiver covering frequencies between 118 and 160 MHz, which includes the 118 to 136-MHz aircraft band. The sensitivity of this receiver is excellent: a 1- $\mu$ V 30-percent modulated 123-MHz (midband) AM signal is easily discernible above the background noise. This receiver can be built for about \$20 and is very portable, as it can be made quite small—perfect for air shows! It draws less than 10 mA from its two 9-volt batteries.

The circuit consists of an RF stage, a super regenerative detector, and an audio amplifier. The antenna is coupled to the RF stage via a standard 75 to 300-ohm cable TV balun transformer. The transformer has a cable TV “F” connector at its 75-ohm end that makes it perfect for use with RG-59U 75-ohm cable TV type coax cable. For portable use, a vertical whip antenna mounted on the back of the receiver with a short connecting cable can be used. The balun provides a step-up in voltage to Q1's gate and its 5 to 900 MHz bandwidth also helps prevent any interference from local AM broadcast band stations. FET Q1 provides a little gain, but more importantly, it effectively isolates the detector from the antenna. This prevents the receiver from radiating its own signal out the antenna and helps to eliminate “dead” spots in the receiver's tuning range due to antenna resonance effects.

The capacitively coupled output of the RF stage connects to a tap on coil L1. The exact location of the tap should be determined by experimentation: the higher up the tap is on the coil, the greater the sensitivity, but also the

greater the loading on the detector. If the detector is too heavily loaded, it will fail to oscillate; or it will oscillate only over part of its tuning range, creating "holes" in reception. Capacitor C2 should be soldered at a point about one half turn from the bottom of L1 and the circuit tried. Next, the tap should be moved up and then down about a half a turn at a time, and the effect on detector operation noted.

The detector's operating voltage is set by the 5-k regeneration control, which also functions as the quench frequency adjust. A 2-pF capacitor provides RF feedback between the FET's source and drain to cause it to oscillate. It may be necessary to increase or decrease this capacitor's value by 1 pF or so to compensate for variations in circuit layout. A 100-μH RF choke keeps the FET's source above ground at RF frequencies.

The 50-μs time constant of resistor R8 and capacitor C9 causes the circuit to break into secondary oscillations that provide the desired self-quenching of this circuit. They also limit the audio output bandwidth, in this case to about 3 kHz. A 15-k resistor and 0.01-μF capacitor form a low-pass filter that removes the quench voltage from the detector's audio output. The output of the detector drives an op-amp audio amplifier stage, which directly drives a set of "Walkman"-type stereo headphones.

It must be noted that, even though this receiver's oscillator operates at less than 1 milliwatt, it still radiates a signal out its antenna. Under *no* circumstances should this receiver be operated on the aircraft band without its RF stage. To further reduce any RFI emissions, the entire radio should be placed inside a closed

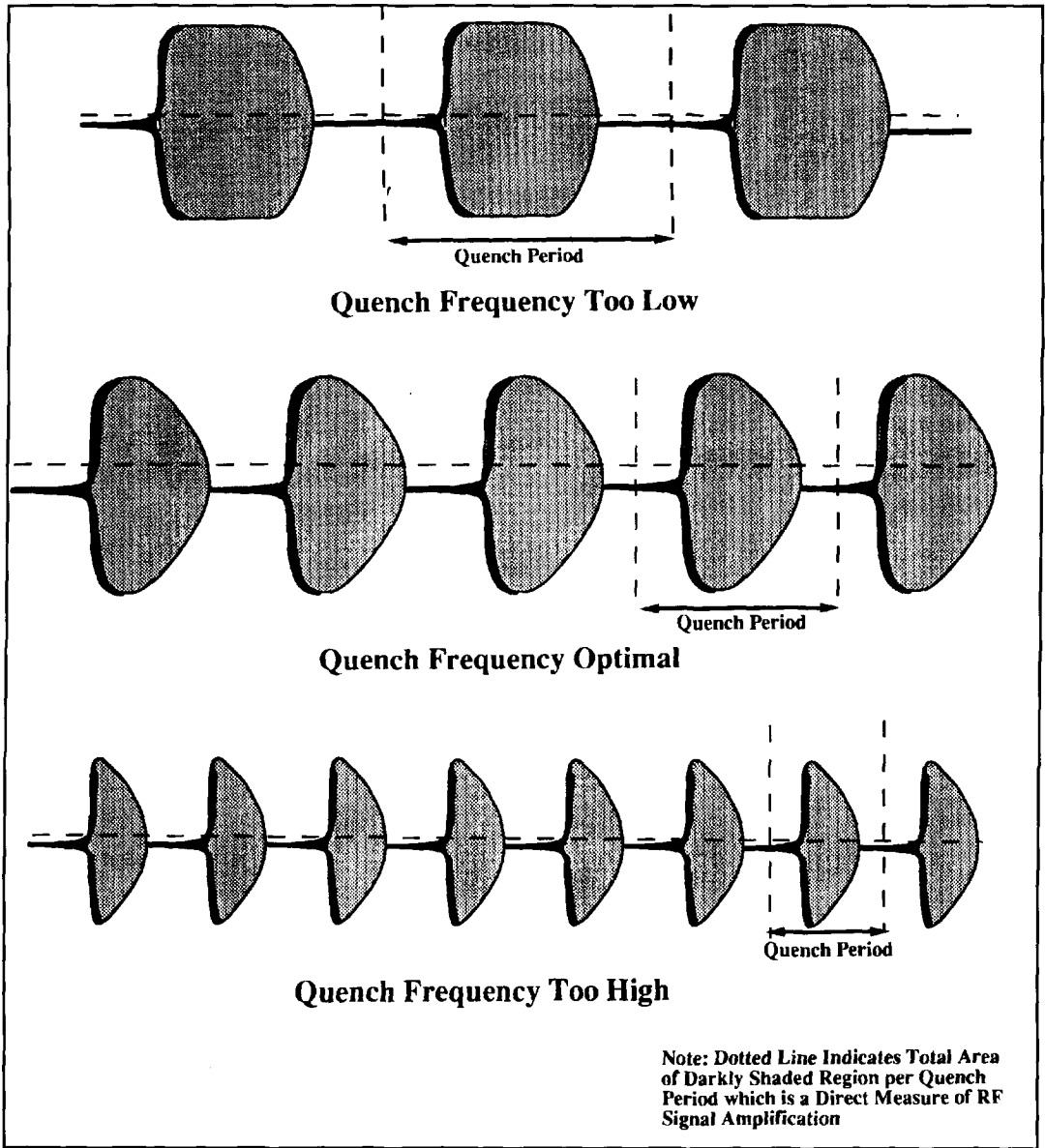


Figure 5. The effect of quench frequency on the shape of the RF envelope and on signal amplification.

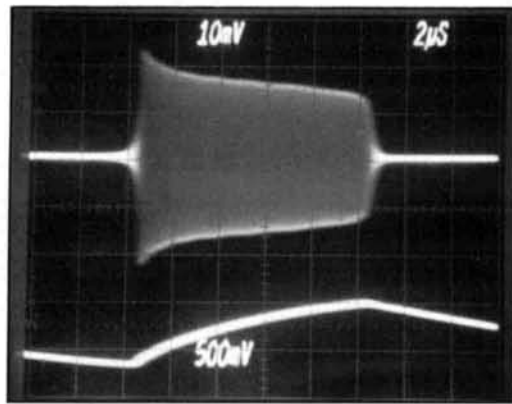


Photo E. An oscilloscope photograph of the RF envelope of a typical self-quenched receiver like that shown in Figure 2B. Upper trace is the RF envelope of the detector. Lower trace is the quench voltage appearing across source resistor  $R_q$ . (Self-quenched, 100  $\mu$ V signal, 145 MHz.)

metal box to further prevent any interference to communications on the aircraft band.

### A "poor man's" super regenerative FM broadcast receiver

Figure 7 shows an ultra simple receiver for the 88 to 108 MHz FM broadcast band that provides microvolt level sensitivity and can be built very inexpensively. The circuit is self-quenched and almost identical to that of Figure 6, with a few minor differences.

The self-quenching time constant, RX and CX, has been changed. CX has been decreased to 2,000 pF to provide greater audio bandwidth for the FM broadcast band. Despite its simplicity, this circuit performs quite well; it's sensitive, easy to tune and, although not "Hi Fi", will provide reasonable overall fidelity using "Walkman"-type headphones. This is an excellent project for experimenters who wish to learn super regeneration.

### The separately quenched super regenerative receiver

Figure 8 shows a typical "classic" circuit for a separately quenched VHF super regenerative receiver of the mid-1930s. As shown, it used low power acorn-type tubes for its RF and super regenerative detector stages to minimize detector radiation and overall power consumption. The circuit also used an audio interstage transformer (typically 1:3 ratio) to extract the detected audio. The quench oscillator for this receiver would have been built using a "quench

frequency oscillator unit" manufactured by the National Radio Company, Cambridge, Massachusetts. It consisted of a two-winding oscillator coil and companion shunt capacitor. This would have provided an easy-to-construct, 100-kHz quench oscillator. Unfortunately, these quench oscillators are no longer available.

Most of these classic circuits used the quench frequency oscillator coil with its windings reversed, so the plate winding had more turns than the grid. This provided the highest possible quench voltage output, allowing the detector to superregenerate at a very low supply voltage. It's important to note that the typical classic circuit shown here specifies a 5-megohm grid resistor and a 50-pF grid capacitor. This provides an RC time constant of 250- $\mu$ s in the grid circuit, which surely would have caused the detector to self quench (and disrupt the quench oscillator signals) if the regeneration control was turned up high enough. This further explains why the quench oscillator windings were used in reverse order.

### A modern separately quenched super regenerative aircraft receiver for automotive use

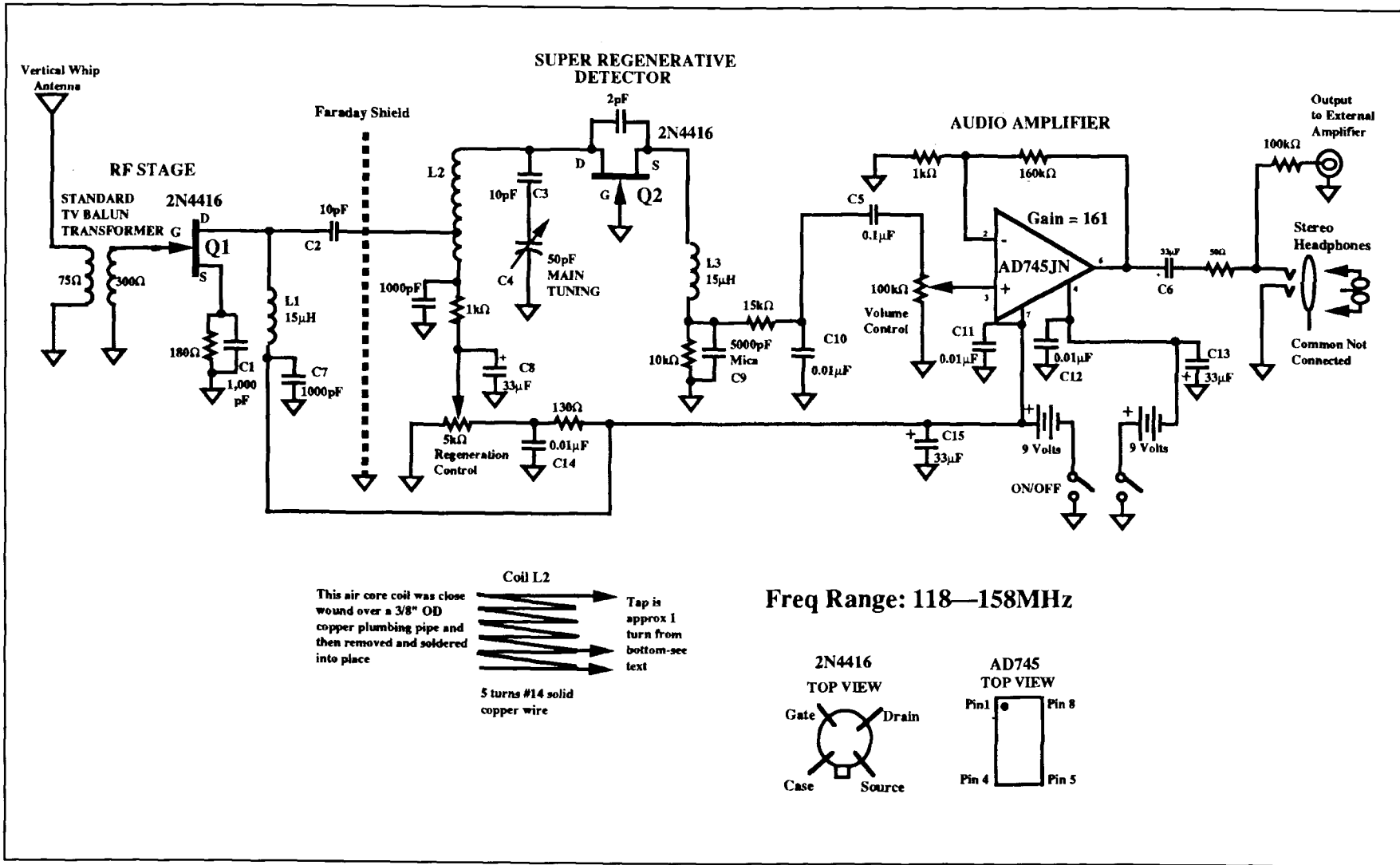
The circuit of Figure 9 is the modern equivalent of the separately quenched circuit of Figure 8. Like the circuit of Figure 6, it features 1  $\mu$ V or better sensitivity over the 118 to 136-MHz aircraft band. Separate quenching allows the user to adjust both the amplitude and the frequency of the quench oscillator and thus minimize the no signal "mush" noise. Intended for automotive use, this aircraft receiver is powered from a +10 volt to +16 volt DC supply and features an LM1875 power amplifier IC to provide ample drive for a loudspeaker.

This circuit uses an Exar 2206 function generator IC for its quench oscillator. The inexpensive (\$4) chip requires no coils or tuned circuits, and provides an output level sufficient to quench the super regenerative detector directly. Although a triangle waveform was chosen for quenching this receiver, the 2206 can easily be connected to provide a sine or square wave output as well.

When building separately quenched circuits, it's best to first test the detector circuit itself—in the self-quenched mode—to be sure it's functioning properly, before connecting the quench oscillator. In the circuit of Figure 9, this only requires temporary connection of a 5,000-pF mica capacitor across the detector's 10-k source biasing resistor. Once the detector is functioning properly, it can be removed and the quench oscillator connected and tested in its place.

The most difficult task when building a sepa-

Figure 6. A modern self-quenched super regenerative aircraft receiver.





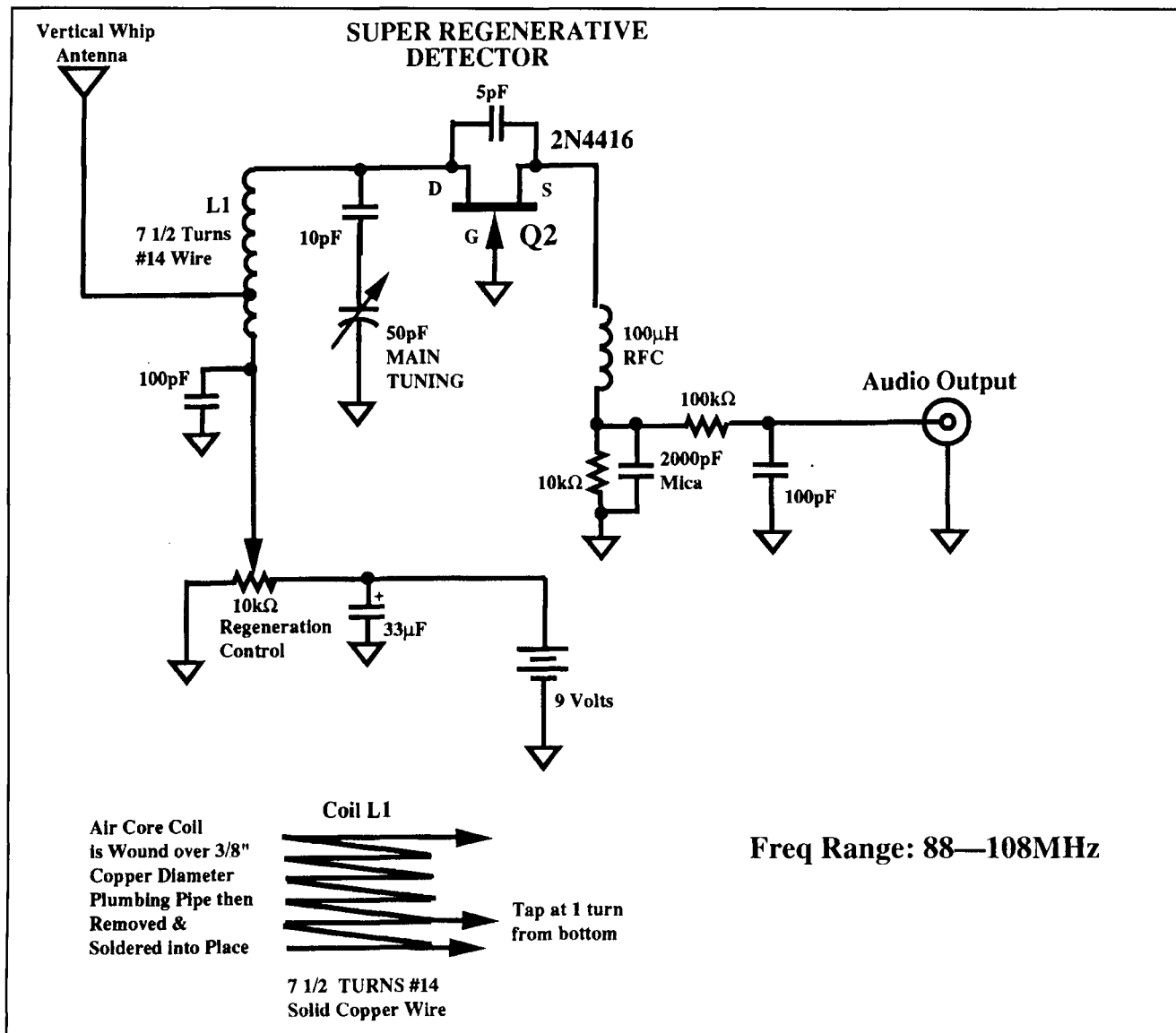


Figure 7. A "poor man's" super regenerative FM tuner.

ately quenched receiver is to construct a detector that's entirely free of parasitic oscillations. In the self-quenched circuits previously described, a lower frequency parasitic oscillation is absolutely essential as it provides the necessary quenching action. However, in a separately quenched receiver, any secondary oscillations that are present will reinitiate oscillations during the nonregenerative (quenched) period, thus preventing the detector from being turned off long enough to produce a useful super regenerative effect.

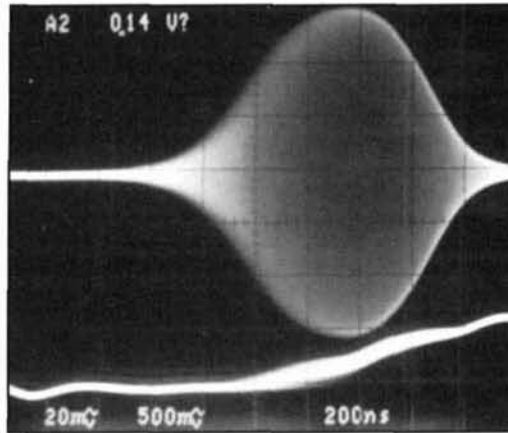
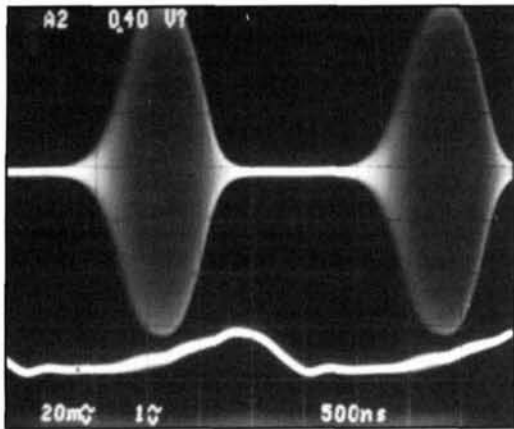
The easiest way to prevent parasitic oscillations is to avoid placing any capacitance in the detector's biasing circuitry. In the circuit of **Figure 9**, this was accomplished by simply not using a bypass capacitor across the detector's source resistor. The quench oscillator was then resistively coupled to the FET source and the

circuit tested, with the quench oscillator's power supply temporarily disconnected, to ensure that there were no parasitic oscillations (a wideband oscilloscope is very useful for this test).

**Photo F** is an oscilloscope photograph of the oscillation envelope of this receiver. Here, the quench oscillator frequency has been set to approximately 500 kHz.

### Practical construction hints for super regenerative receivers

The elimination of reception "holes"—portions of a receiver's tuning range when the detector stops oscillating over part or all of its tuning range—is a major construction problem. These are more apparent in a super regenerator, but occur in straight regenerative receivers as



Photos F and G. Oscilloscope photographs of the RF envelope of the separately quenched receiver of Figure 9.

well. Reception “holes” are caused by excessive loading of the detector—usually by what is connected to its input.

In simple detectors without RF stages, the antenna absorbs energy from the detector, preventing it from oscillating. The antenna places a variable load on the detector that changes with frequency. The loading varies at multiples of  $1/4$  wavelength, creating reception holes that come and go as the received frequency is varied. The cure is to decouple the detector from the antenna by adding an RF stage to the receiver. The isolation from antenna effects and the prevention of possible interference easily justifies the added effort and expense. In fact, all super regenerative receivers should be preceded by an RF stage to be effective—and legal!

Because super regenerative detectors are normally used at very high frequencies, stray circuit capacitances and multiple ground paths may also be responsible for reception holes. It is vitally important that the super regenerative detector’s tuning coil be physically located away from other objects—particularly chassis ground, the bottom and sides of the equipment box (if it’s metal), and any shielding that may be present. Often, just moving the main tuning coil to another location will cure the problem and restore proper operation.

Also related is the tradeoff between maximum sensitivity and detector loading. The easiest way to connect the RF input to a super regenerative detector is via a tap on its main tuning coil. The optimum point to tap the coil is then found quickly and simply by experimentation. It is usually best to begin by feeding the input to the detector at a point  $1/4$  or  $1/2$  turn from the grounded side of the tuning coil. Simply solder the input to a point on the coil and note how the receiver operates. Connecting too far above ground prevents the detector from oscillating. If the detector oscillates over its entire tuning range without holes, but needs more sensitivity, the tap can gradually be moved higher up the coil.

## A Glossary of Lost Terms of Super Regeneration

**Quenching:** Quenching refers to the periodic interruption of an RF oscillator, which characterizes a superregenerative detector.

**Mushing:** “Mush” noise is the characteristic background noise of a superregenerative detector. The mush level decreases with increasing signal strength.

**Squegging:** Squegging refers to an oscillator that is oscillating at two different frequencies simultaneously. A self-quenched superregenerative is a practical example of this phenomena.

**Blocking:** Blocking refers to an oscillator locking into synchronism with a received signal such that the oscillator tracks the frequency of the signal, even if it varies. In general, this is advantageous in superregenerative circuits which are characteristically nonselective—blocking acts as a poor man’s automatic frequency control (AFC). However, in shortwave straight regenerative circuits, where many received signals are close together in frequency, it can cause the receiver to jump from station to station (it will lock onto whichever station is stronger).

The method of grounding the detector’s main tuning capacitor is also critical—multiple ground paths must be avoided. I recommend screwing down the tuning capacitor directly to the ground plane of the breadboard and then passing the capacitor shaft through an oversized hole in the front panel. Grounding the shaft by mounting it directly to the front panel often prevents oscillation of the detector over some or all of its tuning range. Plastic knobs also help by isolating any hand capacitance from the tuning shaft.

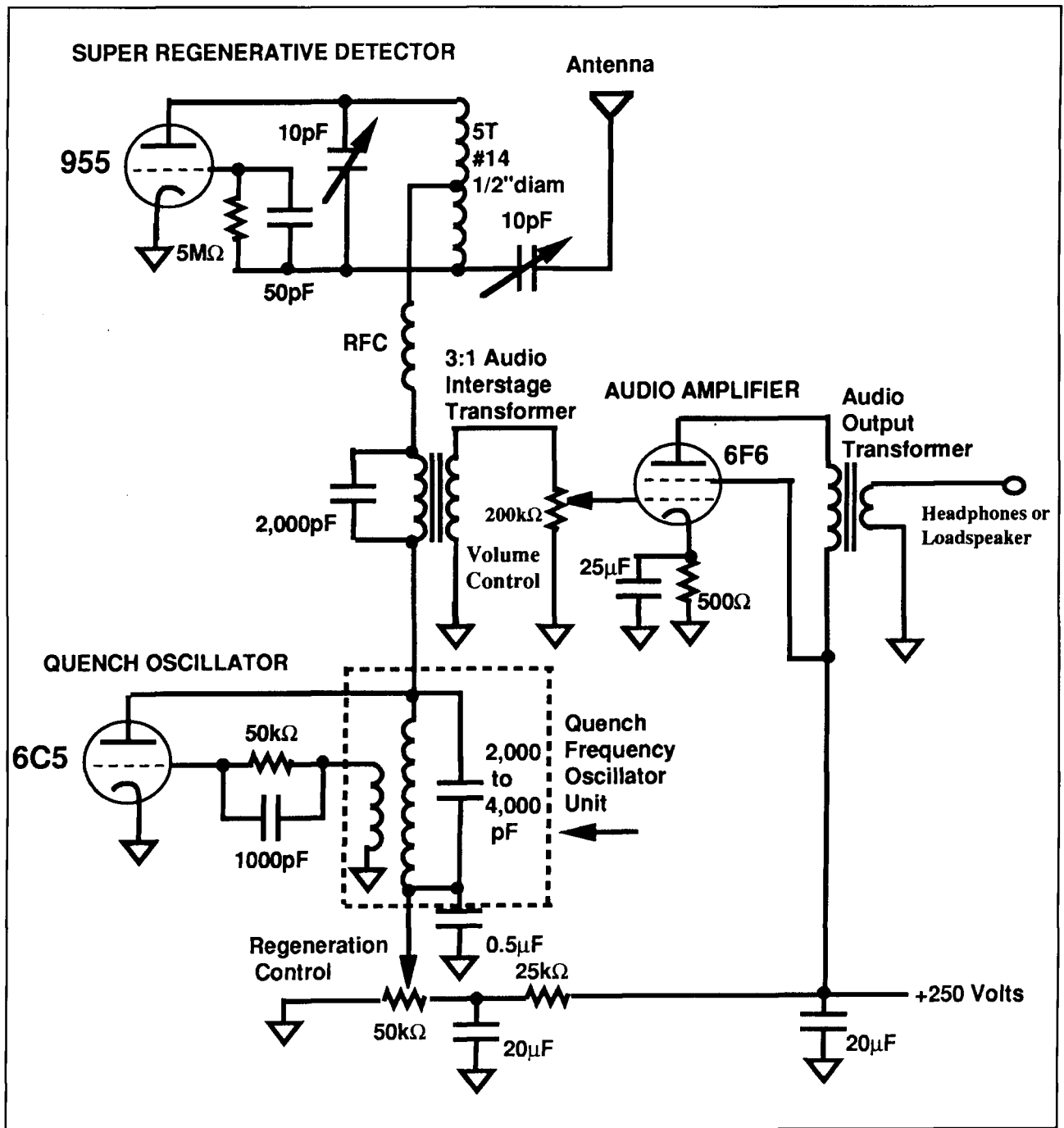


Figure 8. A "classic" separately quenched VHF super regenerative receiver.

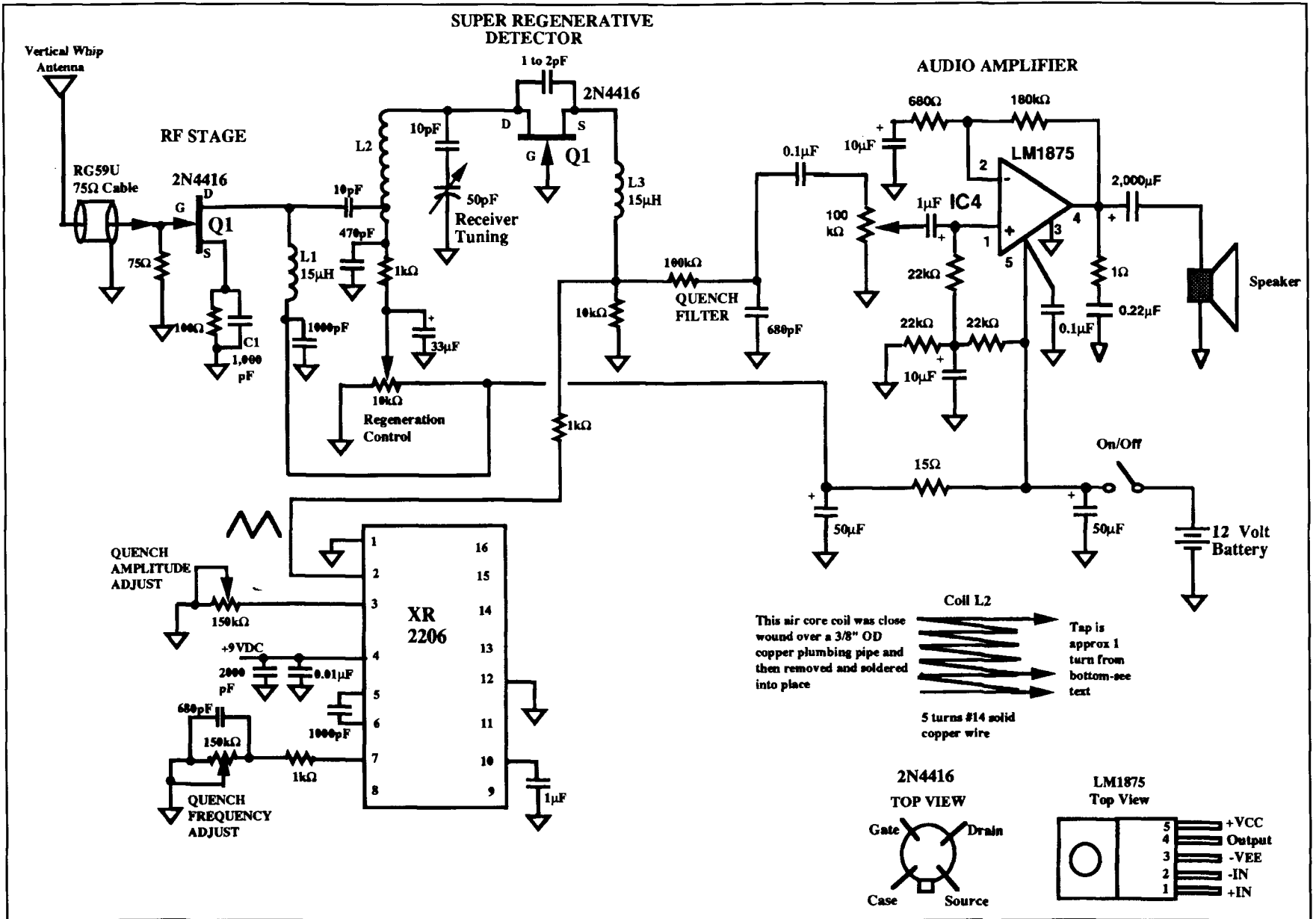
The value of the RF choke connected to the detector's source is another cause of reception holes in the grounded-gate FET-type of super regenerative detectors described in this article. This works together with the feedback capacitor connected between source and drain, to set the amount of positive feedback for the detector. The optimum value for the RF choke can at times be critical. Because individual circuit layouts will vary considerably, the homebrewer of super regenerative detectors should always

experiment with the value of RF choke and feedback capacitor to obtain the best results.

Separately quenched circuits need very good power supply decoupling to prevent the detector's RF signal from leaking into the quench oscillator. Supply bypass capacitors should be located very close to the IC, FET, etc. being decoupled using ceramic or mica capacitors with very short leads.

Regeneration controls should be 5 to 20 k; 10 k is about optimum for 9-volt battery sup-

Figure 9. A separately quenched super regenerative aircraft receiver for automotive use.



plies. Lower values provide smoother control, while higher values use less battery current.

## Parts information

Parts for the receivers described in this article may be purchased from the following sources:

Tuning capacitors, tubes, tube sockets, transformers, knobs, potentiometers, wire resistors, fixed capacitors, and other miscellaneous components (new and surplus) can be purchased from: Fair Radio Sales Co., P.O. Box 1105, 1016 E. Eureka Street, Lima, Ohio 45802, and Antique Electronics Supply, 6221 South Maple Avenue, Tempe, Arizona 85283.

Analog Devices AD745 op amps and Motorola 2N4416 JFETs are available from Newark Electronics.

The National Semiconductor LM1875 power op amps are available from many suppliers, including Digikey Corporation. ■

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3. Frank Jones, *The Radio Handbook*, 1936 edition, Pacific Radio Publishing Company, Inc., Pacific Building, San Francisco, California, pages 238-242.

# PRODUCT INFORMATION

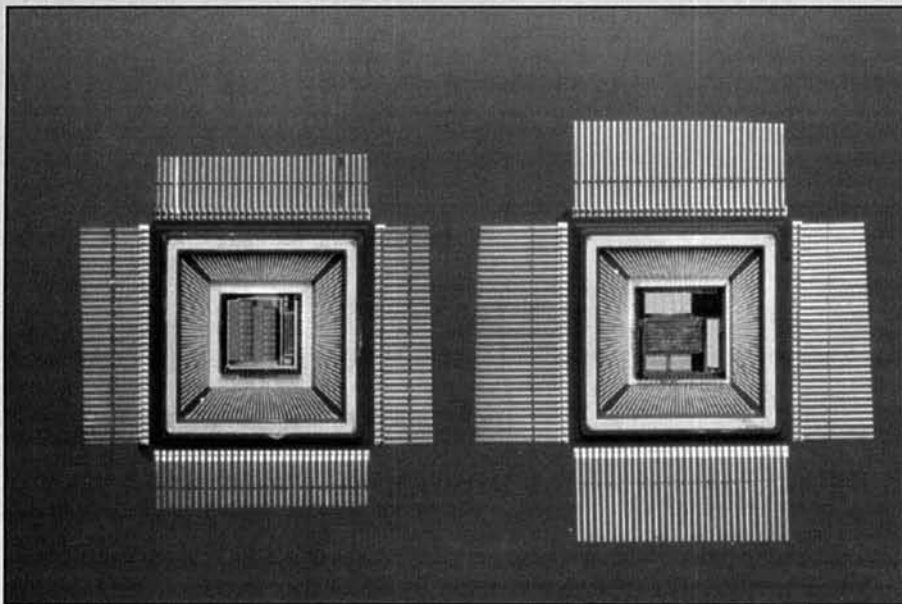
## New Chipset From Kodak Berkeley Research

Kodak Berkeley Research announces their new chipset. The chipset uses a Reed Solomon (255,223) code to provide forward error correction at data rates of 155.52 megabits per second. It can correct a data stream with random error rates of one bit per thousand to 0.4 errors per trillion using 1/8 of channel bandwidth.

Space-qualified CMOS construction allows for high chipset reliability, high radiation tolerance, and low power consumption. The chipset was originally developed for telemetry communications on NASA's Freedom Space Station, and consists of two integrated circuits that implement forward error correction as specified by the Consultative Committee on Space

Data Systems (CCSDS) Blue Book 101.0-B-3. The Encoder-Decoder-Frontend IC encodes byte-wide data at speeds to 155.52 Mbps. Coupled to the Backend Data Processor IC, plus a small standard RAM, the two ICs decode at 30 Mbps.

The chipset is available from Kodak Berkeley Research as the primary part of a custom forward error correction (FEC) subsystem, which also includes data interleaving, code synchronization and system interfaces. For more information, contact Jerry Walker, Manager, Systems Engineering, Kodak Berkeley Research, 2120 Haste Street, Berkeley, CA 94704. Phone: 510-649-2700. FAX: 510-548-2358.



# CD-ROMS FOR THE RADIO AMATEUR

*CD-ROMs put callbooks—and  
more—at your fingertips*

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If you've been teetering on the brink of adding a personal computer to your collection of amateur radio equipment, CD-ROM (Compact Disk/Read-Only Memory) technology now offers you yet another compelling reason to do so.

Today, you can purchase a basic CD-ROM drive for an IBM PC-compatible computer for as little as \$200. More elaborate models supplied as a bundle with external loudspeakers, several CD-ROMs, and an audio-interface card sell for \$700 or less. At least five CD-ROM disks of interest to radio amateurs are available, and all cost less than \$80 each.

In this article, I'll provide an overview of CD-ROM technology and review what's available in radio amateur-specific CD-ROM disks.

## CD-ROM basics

A music compact disk (CD) and a CD-ROM share common technology—each stores digital data in the form of a single spiral path stamped into a reflective metal layer deposited on a plastic substrate. Along the path, microscopic depressions form a series of pits and lands—much like a badly potholed country road on a microscopic scale. A transparent protective layer covers the reflective surface.

A compact-disk drive rotates the CD-ROM, while an infrared (IR) laser beam focused through the disk's protective layer illuminates the spiral path. Pits along the path scatter, and lands reflect, the incident beam. Servo systems within the drive maintain IR beam focus and track the spiral path.

A photodiode converts the reflected beam

into an electrical signal, and additional circuitry translates transitions from pits to lands into logic ones, and the absence of transitions into logic zeros.

Why not use pits as logic zeros and lands as logic ones directly? A transition-sensing scheme works better because the IR laser beam's 1-micron spot diameter exceeds the 0.6 micron diameter of the average pit, making a single pit difficult to distinguish from optical and electronic noise.

A complex modulation scheme helps overcome errors. When the disk is recorded, a run-length encoding modulation protocol adds extra zeros to data, ensuring that at least two zeros separate each logic one from the next. Thus, the one/zero transition length exceeds laser spot diameter ( $2 \times 0.6 \text{ microns} > 1 \text{ micron}$ ).

A self-clocking pattern included in the data stream helps overcome errors introduced by variations in disk rotation speed. Given that manufacturing processes for CD and CD-ROM disks share common technology, drive manufacturers must shoulder the burden of providing drives with acceptably low error rates.

While audio CD drives typically introduce data errors at the rate of 1 in  $10^8$  (10 billion) bits read, CD-ROM drives' average error rates approach 1 in  $10^{15}$ . Although most audiophiles won't notice a few erroneous bits in a musical selection, a similar error will crash a computer program.

To appreciate both the massive storage capacity offered by the CD-ROM and the requirement for low error rates, imagine that a CD-ROM's spiral data track, unwrapped, becomes a 470-meter long wire.

Using a very tiny brush, you could paint



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Turnersville, NJ 08012-2021  
Phone: (609) 875-8897  
List Price: \$19.95

World Of Ham Radio  
Amsoft  
P.O. Box 666  
New Cumberland, PA 17070  
Phone: (717) 938-8249  
List Price: \$40

Ham Radio  
CDRP, Inc.  
P.O. Box 360  
Cambridge, MA 02141-0004  
Phone: (617) 491-5330  
List Price: \$29.95

HamCall  
Buckmaster Publishing  
Rt. 4, Box 1630  
Mineral, VA 23117  
Phone: (703) 894-5777  
List Price: \$50.00

QRZ! Ham Radio  
Walnut Creek CD-ROM  
1547 Palos Verdes Mall, Suite 260  
Walnut Creek, CA 94596  
Phone: (800) 786-9907  
(510) 674-0783  
List Price: \$29.95

**Table 1. Publisher data/price information for disks reviewed in this article.**

1,400 ones and zeros *per millimeter* along the wire's length to form a read-only visible "memory" equivalent to a CD-ROM's 650 MB (megabytes) of data.

How large is 650 MB? Let's suppose that you wish to store copies of your CW QSOs. If you transcribed a typical 5-minute 13 w.p.m. (word-per-minute) CW QSO of 450 characters into a block of text, you could make nonstop QSOs for 13.6 years before you fill the disk. Put another way, 650 MB accommodates approximately 325,000 typewritten pages, or the contents of 450 1.44 MB 3-1/2 inch floppy disks

In practice, CD-ROM publishers can push capacity even further—to one gigabyte or more—by storing data in compressed form. Decompression software expands selected files and restores them to executable condition.

If raw storage capacity alone were the whole story, the CD-ROM would no doubt occupy a significant but minor niche in computer history.

When first introduced a decade ago, high-priced CD-ROMs and disk drives created a chicken-and-egg situation that limited CD-ROM applications to a few specialized databases for mainframe computers.

A decade ago, a typical commercial software package release fitted comfortably on three or four floppy disks. However, in recent years, two powerful forces—competition and widespread acceptance of graphics-intensive operating systems—have forced software vendors to add more features to programs. As a consequence, many product releases now occupy 10 or more floppy disks.

Today, as a lower-cost alternative to distributing software on stacks of floppy disks, many commercial software manufacturers offer versions of popular programs on CD-ROMs. This reduces production costs and shortens installation time.

As a distribution medium, the CD-ROM also offers relative permanence—stray magnetic fields won't erase its contents, and a drive can "see through" minor smudges and scratches in the disk's protective layer. Also, vendors can offer encoded collections of typefonts and clip-art images that unlock when you phone the manufacturer and purchase a password.

Two factors that may affect the long-term future of CD-ROM include longevity and standards. While scratches or heat can disfigure or warp a CD-ROM beyond readability, early-model CD-ROMs sometimes suffered from oxidation of the disk's reflective layer due to poor sealing and manufacturing process problems.

While disk manufacturers have resolved most media problems, you can avoid disk damage by treating CD-ROMs as you would magnetic media—store in a cool, dry place, and keep disks in plastic carriers (called jewel boxes) to avoid scuffs and scratches.

While most CD-ROMs follow data standards established in the early 1980s, innovators regard a typical CD-ROM's 650 MB capacity as inadequate for image-rich applications that store enormous amounts of data.

For example, Kodak's Photo CD technology allows you to transfer images from camera film to specially-formatted CD-ROMs, which differ from conventional CD-ROMs in a key aspect. The Photo CD process—an application of WORM (write-once/read-many) optical disk technology—accepts additional pictures at a later time.

A multisession Photo CD disk includes more than one directory and is incompatible with standard, or single-session, CD-ROM drives that can read only a single file directory. Radio amateurs who enjoy photography as a second hobby should explore Photo CD compatibility before purchasing a CD-ROM drive.

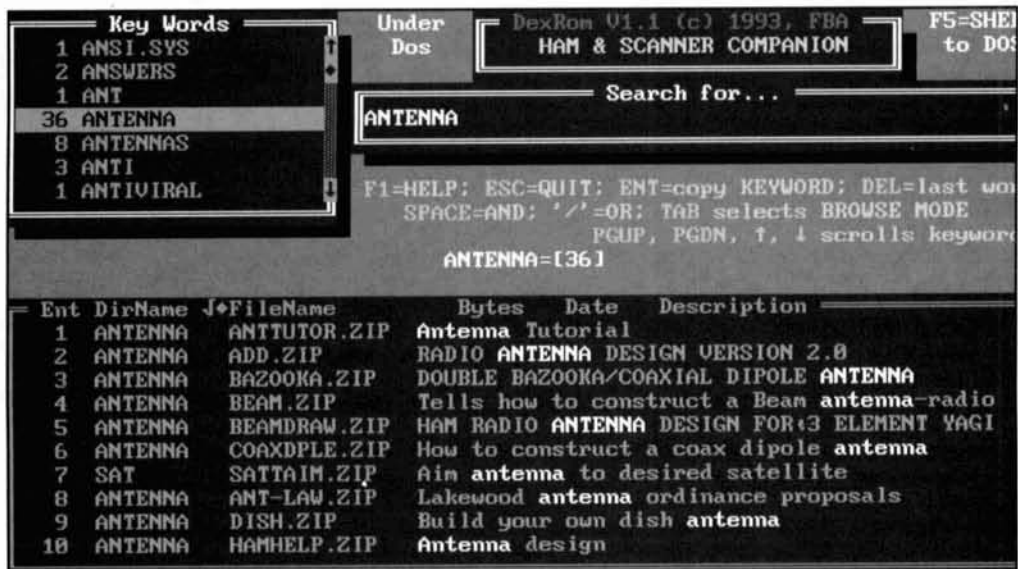


Figure 1. *Ham Radio and Scanner Companion's* versatile search engine provides keyword search, an alphabetical file list, and brief descriptions.

As a minimum standard, make sure that the CD-ROM drive you purchase provides MPC Level 1 compatibility. This standard ensures that the drive can transfer data at sustained average throughput rates of at least 150 kBPS (kilobytes per second), enough for replaying animated image sequences.

Also, newer-model drives spin disks at multiples of the standard speed. These double, triple, and quadruple-speed drives transfer data more quickly than single-speed models.

## Looking for disks

To find amateur radio-related CD-ROMs, look first for advertisers in amateur radio, scan-

ner, and SWL hobbyist magazines. Also, personal-computer magazines include ads for CD-ROM suppliers, many of whom offer disks at discount prices.

If you live near a metropolitan area, visit a computer show or swap meet. Closeout jobbers and wholesalers compete aggressively to sell off noncurrent disk editions at bargain prices—often under \$10 per disk. You can expect to see an increasing selection of used or discounted CD-ROMs at hamfests, too.

Most programs offered on amateur radio CD-ROMs fall into one of three categories—shareware, freeware, and public-domain software. To avoid misusing anyone's work, always check program documentation or help files for a clear statement of the author's intentions.

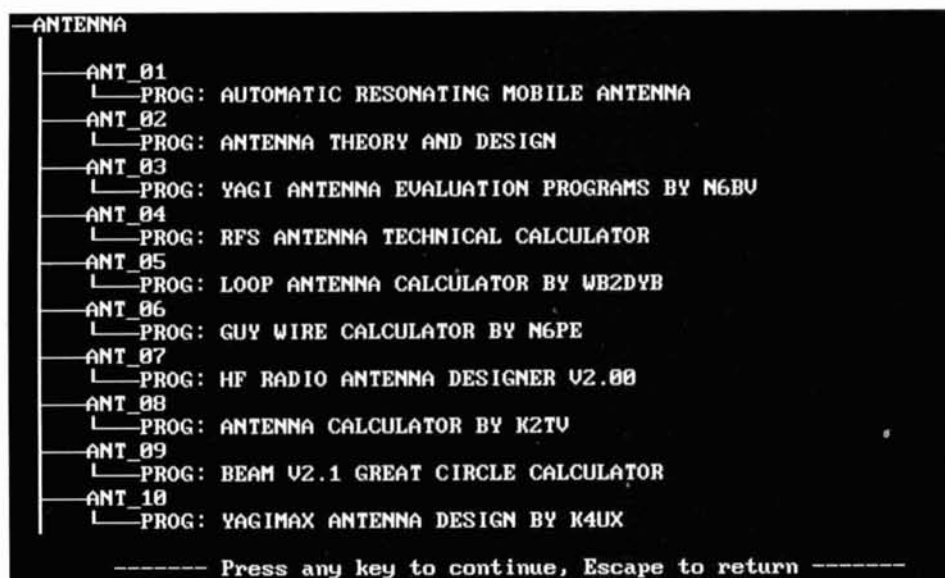


Figure 2. AmSoft's *World of Ham Radio* displays files in tree directory form.

|  |   |
|--|---|
| Antenna Design and Construction                | Miscellaneous Programs  |
| ARRL Bulletins                                 | Modifications, Equipment  |
| Bibliographies                                 | MUF (Maximum Usable Frequency) Software                                   |
| Bulletin Board Systems                         | OSCAR Satellites  |
| Callbooks                                      | Packet Radio (Includes PK232, WORLI, TCP/IP, Equipment-Specific Software) |
| Clubs and Organizations                        | QSL Management Software   |
| Contest Logs and Duplicate Callsign Matchers   | Reviews of Equipment  |
| Control, Software for Equipment                | RTTY (Radio Teletype) Software  |
| CW Practice Programs and Interface Software    | SSTV (Slow-Scan TV) Software  |
| Digests (Text Files and Computer BBS Archives) | SWL (Short Wave Listener) and Scanner Software                            |
| DOS Utilities                                  | TCP/IP  |
| DX Techniques                                  | Unix-Related Amateur Radio Software                                       |
| Exam Aids and Study Programs                   | Utility Programs  |
| FAX, Radio                                     | WAV (Audio) Files   |
| FCC Regulations and Bulletins                  | Weather-Related Software  |
| File Decompression Software                    | Windows-Specific Software   |
| Frequency Databases and Lists                  |   |
| Glossaries and Definitions                     |   |
| Local-Area Network Software                    |   |
| Logging programs                               |   |
| Maps   |   |
| Mathematics For Electronics                    |   |
| Menu Software                                  |   |

**Note:** Not all CD-ROMs cover all topics. Also, depth of coverage varies, and considerable overlap of contents among disks exists. Contact software publishers if you have a specific requirement.

**Table 2.** File categories typically available on CD-ROMs reviewed.

Shareware consists of programs written by individuals who offer the software for sale on the honor system. You can try the software for a limited time to determine its usability and then register the product for a small fee—usually \$50 or less—or sometimes a barter exchange.

In return for registering shareware, you may receive a printed manual or the most-current version of the program. A few authors provide more extensive support, but don't count on obtaining anything in return for registration.

Also, always send an inquiry letter to verify the address given in the registration form. Many amateur radio shareware programs are several years old, and if the author has moved, your registration fee may never arrive.

Freeware includes programs offered for individual use without imposition of a shareware fee. However, authors of freeware retain certain rights to the code—typically, users cannot modify freeware or include it in for-profit applications without permission.

Public-domain software consists of programs written by individuals who provide the programs for anyone to use without paying a registration fee. Software developed under U.S. Government auspices and paid for by taxpayers also may appear in public-domain releases. On occasion, public-domain authors provide source code that you can modify or integrate into your own applications.

In a broad sense, public-domain software

combines the best aspects of personal computing's early days and the spirit of amateur radio—a vision of a community of individuals who share a common interest and a willingness to help others overcome technical problems. Thus, if you incorporate someone's source code into a program you write, please credit the original author's work.

While commercial software typically includes documentation and technical support, shareware and public-domain software may provide neither—you're on your own if you encounter a problem. To troubleshoot the software, check for proper installation, device-driver conflicts, and memory requirements. Contact shareware authors for bug fixes and more up-to-date versions.

Also, don't overlook the possibility that a more recent release of a troublesome program already exists on the same CD-ROM. It's not uncommon for shareware publishers to include several versions of the same program, often under different subdirectory headings.

## Working with CD-ROMs

Once you've purchased an amateur radio CD-ROM, you can gain access to its contents via several methods. If you're an experienced user of PCs and DOS, think of a CD-ROM as a large, read-only disk drive. You can use standard DOS commands you're familiar with to

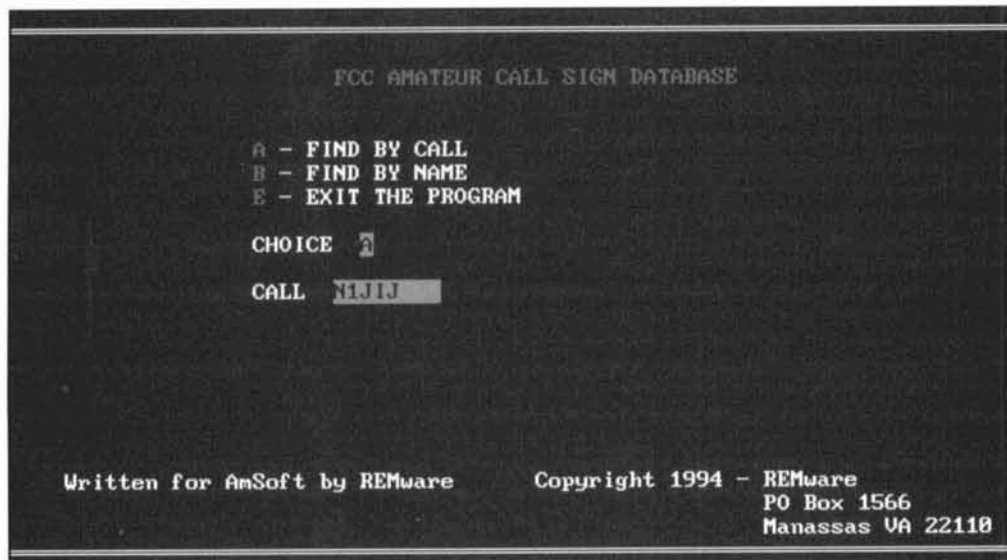


Figure 3. AmSoft's CALLSIGN retrieval program provides name and call search capabilities.

| Filename     | Dir | Subdir   | Description                            | PgDn for more |
|--------------|-----|----------|--|---------------|
| *****        | *** | *****    | *****                                  |               |
| ADD.ZIP      | ANT | ADD      | RADIO ANTENNA DESIGN VERSION 2.0       |               |
| ANT-LAW.ZIP  | ANT | ANT-LAW  | Lakewood antenna ordinance & proposals |               |
| ANTDES.ZIP   | ANT | ANTDES   | Antenna Design Aid                     |               |
| ANTDESIG.ZIP | ANT | ANTDESIG | Antenna design prog                    |               |
| ANTENNA1.ZIP | ANT | ANTENNA1 | Design dipole antennas                 |               |
| ANTENNA2.ZIP | ANT | ANTENNA2 | An assortment of antenna calculators   |               |
| ANTENNAS.1   | ANT | ANTENNAS | Reisert on antennas - Part 1: General  |               |

Figure 4. Chestnut Software's Ham Radio shareware simplifies file transfers.

explore a CD-ROM's directory and transfer files to your PC's hard disk.

If you're a newcomer to DOS and find its command-line user interface somewhat cryptic, you can use one of many commercial disk directory-management programs (e.g., Fifth Generation Systems' XTree Gold, or the directory shell provided with MS-DOS) to explore a CD-ROM. XTree and other utilities typically include viewers that allow you to examine a compressed file's contents, in addition to decompression tools that reduce file transfers to a few keystrokes.

CD-ROM publishers may include custom directory-management programs that vary considerably in ease of use and flexibility, and you may soon outgrow a version or uncover its

shortcomings. Also, no two CD-ROM directory-management programs provide an identical user interface, and you may prefer a single commercial utility that's consistent and easier to learn.

You can often run certain programs directly from the CD-ROM itself, a technique that minimizes demands on hard disk space at the expense of slower program access. However, programs that attempt to create temporary or "scratch pad" files on the read-only CD-ROM will return an error message or else lock up your PC, forcing you to reboot. In general, programs will run much more smoothly from a hard disk.

As previously noted, CD-ROMs contain compressed files identified by file extensions

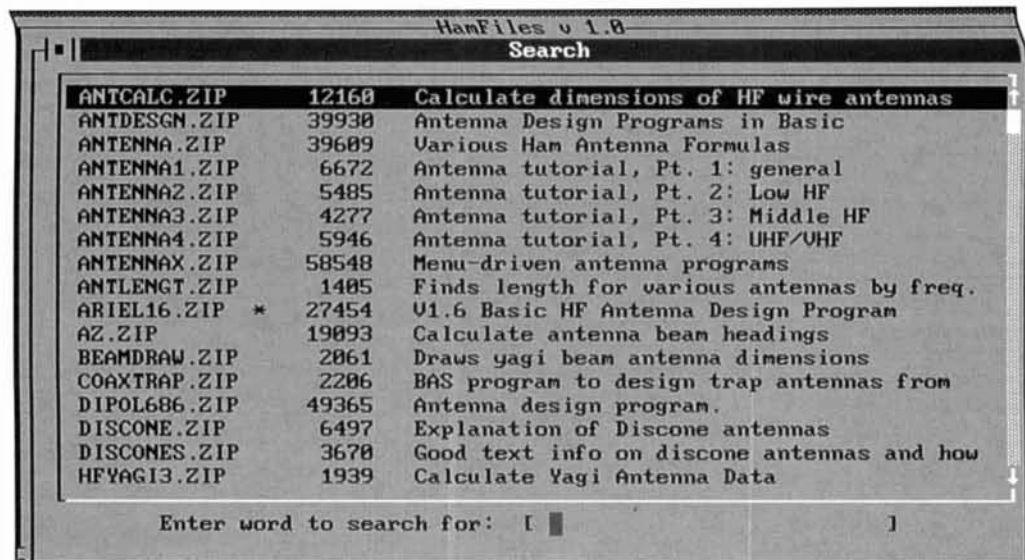


Figure 5. Buckmaster's *HamCall* CD-ROM search screen displays file names, lengths, descriptions and updated versions (marked with asterisks).

such as .ZIP, .ARC, .BQS, and .ZOO. A compressed file may contain dozens or hundreds of files that, when expanded, consume anywhere from twice to ten times the space of the compressed archive file.

You must use a matching utility program to decompress or expand these packed-together files. Most publishers provide on-disk copies of popular decompression programs such as PKUNZIP, UNZIP, SHEZ, and LHARC.

Most directory-management tools offer either a built-in decompression feature or else allow you to invoke a program from a CD-ROM. In the reviews that follow, the term "decompression" applies as a generic descriptor for any archiving method used.

After you select and decompress a program, read all documentation files accompanying the program. Check for special hardware and software requirements, and review the licensing agreement. Your PC's AUTOEXEC.BAT and CONFIG.SYS files may require modifications before you can run a program.

Programs provided as source code require an interpreter or compiler to run. Different versions of common languages such as BASIC abound, and source code may not match the language version you own. Most shareware authors fail to note which version of BASIC they used in writing programs, a problem that a single comment line in the code would remedy.

Potential problems with source code include device-dependent display and printer-driver routines, commands that don't match language syntax, and illegal variable names. While it's possible to translate a program, sometimes it's faster to use the original as a model and rewrite the program.

Although CD-ROM publishers attempt to

provide virus-free software, a virus could escape their screening procedures. Practice normal antivirus precautions, including periodically checking your PC's hard disk drive and memory, and scanning newly uncompressed files BEFORE you attempt to run the programs.

## Reviews

My search for amateur radio-related CD-ROMs uncovered a quintet of disks (see **Table 1** for names, addresses, phone numbers, and pricing information). Others may also exist, but small publishers who distribute their CD-ROMs regionally—for example, in California or only on the east coast—make it difficult for buyers and reviewers to locate their offerings.

Fortunately (or unfortunately), considerable overlap exists among the contents of the CD-ROMs I reviewed. Given several thousand files per disk, it's impossible to provide a detailed list of each disk's contents or duplicated files from disk to disk. **Table 2** lists major categories of software found on the disks reviewed.

Not all vendors classify a given program under the same category—an antenna design program might appear in the "Antennas" directory on one disk and under the "Technical Programs" heading on another. A little time spent browsing will reveal a disk's organization.

Callbook disks use U.S. amateur license data provided by the Federal Communications Commission. Errors in the database will affect accuracy of any of the callbook programs.

If you operate on a tight budget, consider purchasing a discounted older version of any of the CD-ROMs reviewed. While its callbook section may not contain the latest entries, with few

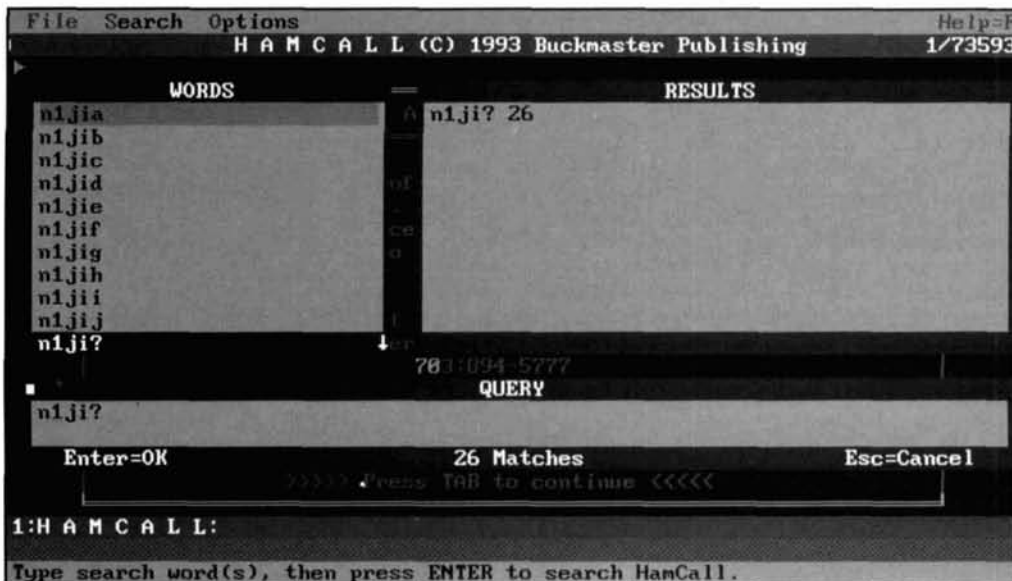


Figure 6. HamCall's Folio Views search screen shows query, number of matches found (26), and total number of records available (735,930) in screen's upper-left corner.

exceptions most of a disk's program contents won't change dramatically in later editions.

## The Ham Radio and Scanner Companion

Consisting of 3,191 files comprising 206 MB, the newly-introduced *Ham Radio and Scanner Companion* from John O'Connor Publishing, Ltd., includes a collection of IBM PC-compatible shareware and freeware programs, but omits a radio amateur callbook. List price for the disk is \$19.95.

Using the CD-ROM's batch program (GO.BAT), you can run programs from disk, decompress and copy files to your PC's hard disk, and view text files. A versatile PRINT function allows you to create a disk file or printed listing containing program descriptions.

Files are arranged in categories and subdirectories, but the disk's DexRom search engine allows you to search via topic (see **Figure 1**). You can use <AND> and <OR> operators to narrow the search range.

After marking files, you can export them in compressed or decompressed form. Pressing your PC's <ESC> key returns you to the main menu and not the category list, a minor annoyance. You can also use your PC's mouse to browse the keyword list shown in the upper-left corner.

Files on disk include decompression and antivirus utilities and entries. Copies of MININEC 1.7 (an antenna-analysis program) and SCAT 2.0 (an RF design tool) are provided, as is GEOCLOCK 4.5 (a graphical world-time clock).

No .WAV files (used with PC audio-inter-

face boards) are included, and a number of typographical errors mar this first-edition disk's file descriptions (e.g., G3ZCZ's software is listed as C3ZCZ\_15.ZIP in the directory). The disk's most recent directory entry bears an October 1993 date.

If you don't require a callbook, the *Ham Radio and Scanner Companion* will provide a modestly priced and useful introduction to CD-ROM's shareware capabilities.

## The World of Ham Radio

Now in its second edition, Amsoft's *World of Ham Radio* CD-ROM provides a U.S. amateur call directory, plus a collection of IBM PC-compatible programs and utilities in 7715 files that total almost 358 MB of disk space. The callbook's files consume approximately 124 MB.

You can access the callbook one of two ways—one program (CALLFIND.EXE) accepts call letters and returns name, address and, license data for a single callsign in approximately 5.5 seconds.

Running a second program called CALLSIGN.EXE (**Figure 2**) allows you to retrieve a single call in approximately 1.5 seconds and search for additional calls without rerunning the program. The program doesn't allow you to print single callsign information (except via your PC's Print Screen mode) or a list of mailing labels, or search for a range of calls.

However, you can enter an amateur's last name and then scroll through a list of all amateurs with identical last names, beginning with AA0 calls and ending in the WZ9s. The program will produce an onscreen list sorted by district (i.e. W0, W1...W9) and suffix (i.e., AAA...ZZZ)



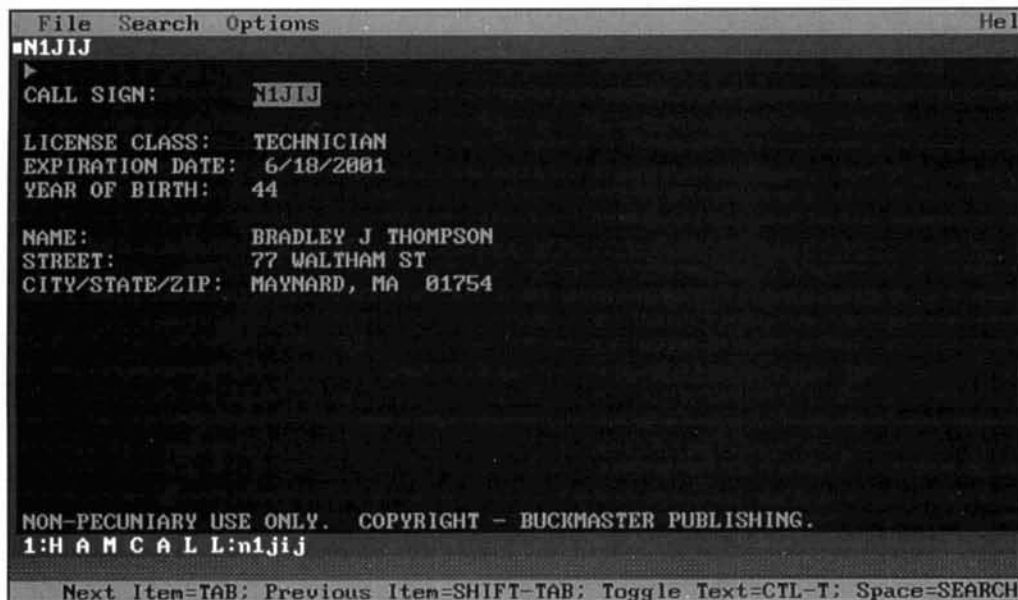


Figure 7. Sample of single call sign record retrieved by *HamCall*.

order. No program help file is available via the user interface, but the program is so easy to use that none is needed.

A shell program provides access to the disk's programs and utilities in compressed and uncompressed formats. You can use Amsoft's shell program to decompress programs and copy them, one at a time, to your PC's hard disk drive, and view (but not print) accompanying text and help files.

In practice, the shell program is somewhat inconvenient to use because you can't view a description of each file alongside its filename. To retrieve an antenna-design file, you go to ANTENNA.DIR, look at file descriptions and locate the file's subdirectory, and then go to the subdirectory (**Figure 3**) to decompress and copy the file.

All file dates in the disk's directories are set to 1/01/94, a major nuisance when you're looking for the latest version of a program. For example, while the disk directory dates the version of MININEC 3 on disk as 1/01/94, an accompanying documentation file is internally dated May 24, 1990.

Most radio-related file categories are represented on disk, including MININEC and SCAT20, which appears under the \MISC\SMTHCHRT subdirectory instead of \ENGINEER—a more logical place to find design programs. HAM\_RAGS, a potentially useful bibliography for amateurs whose libraries include back issues of amateur radio magazines, lacks a useful help file. News files, equipment reviews, DOS-related utilities and TCP/IP-specific files are absent.

Amsoft's disk organization scheme assigns the same names to different files and creates many duplicates. Copies of documentation files

for programs are renamed AMSOFT.III and placed in compressed and uncompressed file directories. All compressed files are renamed COMPRESS.ZIP. While the files reside in separate subdirectories, a first-time user exploring the disk with a file-manager program might become confused.

Given its somewhat primitive callbook, confusing shareware organization and \$79.95 list price, the *World of Ham Radio* CD-ROM doesn't offer the value of its lower-priced competitors, but it's a serviceable disk nonetheless. While possibly still available via closeout channels, the *World of Ham Radio* has been superseded by Amsoft's recently announced \$40 call sign directory CD-ROM.

## Ham Radio

A no-callbook shareware collection for IBM-compatible PCs, the *Ham Radio* CD-ROM is offered by Cambridge, Massachusetts-based CDRP, Inc.—the suppliers of Chestnut brand CD-ROMs.

There's probably at least one program of interest to everyone somewhere in the disk's 188 MB of 9606 files. To gain access, you run a batch program (GO.BAT) that allows you to view and print text files (**Figure 4**), decompress and download programs, and run directly executable programs from the CD-ROM. You use function keys to navigate through decompression and viewing options.

*Ham Radio* includes files grouped into categories and further divided into named subdirectories, each of which contains all the executable files associated with a given program. Compressed versions of the files reside in a separate

subdirectory (ZIPFILES) under each category.

If you use a DOS shell or directory manager, *Ham Radio*'s organization lends itself reasonably well to casual browsing. A shareware program called Browsemaster provided on the disk offers a convenient means of exploring contents of this, and other, CD-ROMs.

The disk includes multiple copies of a number of files. For example, you can find a program called COILS.BAS in the \HAM&EL#1, \TECHRF\_ENGR, and \HAMUTIL2 subdirectories. The \HAMMISC1 and \HAMUTIL1 subdirectories also include many duplicates.

The disk doesn't include Windows-specific programs, .WAV audio files, or bibliographies. Also, almost all files including "news" entries predate January, 1993—a few carry dates as early as 1986.

In addition to assorted spelling and syntax errors found in directories' program descriptions, a few oddities appeared. In subdirectory MISC\ROC, a program called ROC.BAS (for Receiver Operating Characteristics) includes a documentation file (ROC.DOC) that discusses disease models but also refers to the receiver program. In program PH.EXE (which generates phonetics for callsigns), the phonetic for the letter N is listed as MOVEMBER (sic).

At a list price of \$29.95, Chestnut's *Ham Radio* CD-ROM represents an easy-to-use disk whose contents deserve an update and a thorough proofreading. Chestnut CD-ROMs frequently sell at discounted prices, making *Ham Radio* a more attractive purchase than it would be otherwise.

## HamCall

Long a provider of amateur radio magazine collections on microfilm and microfiche,

Buckmaster Publishing offers a semiannually updated \$50 amateur radio callbook and shareware collection.

Containing software and U.S. and foreign callbooks for IBM PC compatibles and the Apple Macintosh, *HamCall* weighs in at a hefty 663 MB of data, 326 MB of which comprise the callbook and 25 MB of which consist of files for the Apple Macintosh (not reviewed).

Buckmaster organizes its CD-ROM's PC-compatible program files into alphabetical subdirectories (A through C, etc.). While subdirectories containing Macintosh software (e.g., [SAVANT\_1]) appear in the disk's root directory, you can't explore their contents—Mac and PC file structures aren't compatible.

According to *HamCall*'s publisher, Jack Speer, N1BIC, future releases of *HamCall* will revert to Buckmaster's earlier practice of providing Mac and PC files in separate directories to minimize confusion.

*HamCall*'s retrieval program for PC-compatible software features a simple user interface (HAMFILES.EXE) which allows you to select part one or part two of a keyword menu and then search for a specific filename.

You select a file, and HAMFILES decompresses and transfers the file's contents to the directory of your choice. As **Figure 5** shows, files marked with an asterisk (\*) indicate updated versions from the previous disk edition.

However, 1,051 out of *HamCall*'s 1,398 files are dated 9/15/92, a significant annoyance if you're looking for an up-to-date version of a program. You can determine a file's original date by examining the decompressed version.

Buckmaster provides four callbook directory tools. HCALL, a U.S.-only directory, is provided for compatibility with earlier disk versions.

ICALL searches for a single U.S. or foreign

```
Date: Wed, 11 Aug 93 04:38:16 PDT
From: Ham-Ant Mailing List and Newsgroup <ham-ant@ucsd.edu>
Errors-To: Ham-Ant-Errors@UCSD.Edu
Reply-To: Ham-Ant@UCSD.Edu
Precedence: Bulk
Subject: Ham-Ant Digest U93 #9
To: Ham-Ant

Ham-Ant Digest           Wed, 11 Aug 93           Volume 93 : Issue   9

Today's Topics:
  2-meter mobile (car) antenna question (3 msgs)
    Computer Rotator Control?
    Dipole on side of tower?
    Help needed for 2 metre HB9CV...
  IS there an R5---R7 Cushcraft upgrade??? (2 msgs)
    My Experiences Tuning the R7 Vertical
    Polarization

Send Replies or notes for publication to: <Ham-Ant@UCSD.Edu>
Send subscription requests to: <Ham-Ant-REQUEST@UCSD.Edu>
Problems you can't solve otherwise to brian@ucsd.edu.
<S>-Search  <R>-Rev. Search  <ESC>-Exit  PgUp  PgDn  <?>-Help
```

Figure 8. Walnut Creek's *QRZ!* CD-ROM includes digests of Internet News Group transactions. This sample deals with antenna-related topics.

callsign. An assortment of command-line switches allows you to configure the program for various purposes. For example, ICALL /L /M alters the call information display from color to monochrome and searches for additional calls until you press your keyboard's return key.

Another of ICALL's switches produces station latitude, longitude, altitude, time zone, and area code based on the licensee's ZIP code. A call to Buckmaster's technical support department revealed that latitude and longitude are expressed in decimal degrees (e.g., 42.4326 and 71.454, respectively, for AA1IP's former Maynard, Massachusetts QTH), and altitude in feet (40 for AA1IP).

Users unfamiliar with command-line switches may find ICALL's single help screen somewhat terse. Also, some users may find ICALL's choice of colors for onscreen text difficult to read on some displays, and the program offers only limited printing capabilities.

A third program, LOOKUP, installs itself as a terminate-and-stay-resident (TSR) routine in your PC's memory. When you press your keyboard's <CTRL> <ALT> and <C> keys, the program becomes active and allows you to search for single U.S. and international calls, retrieving most in less than seven seconds.

However, LOOKUP occupies almost 50 kB of memory, and the program's printing capabilities are limited to a single callsign at a time. Also, LOOKUP's database doesn't include amateur callsigns for Israel, Japan, England, Germany and several other countries. LOOKUP couldn't find callsign data for a pair of Italian hams who appeared in QST's December, 1993 DXCC list, but ICALL could.

Buckmaster provides a fourth U.S. callsign program, HAM, which uses a commercial data-

base engine, Folio Views, manufactured by Folio Corp. of Provo, Utah. In search mode (Figure 6), Folio Views winnows out callsigns one character at a time and as quickly as you can type. Figure 7 is an example of a sample callsign record.

Folio Views searches equally well for first and last names, cities, states, and ZIP codes. You can specify logical operators—for example, the sequence, Greenfield <AND> MA <NOT> Technician, will retrieve the names, addresses and callsigns of 21 radio amateurs residing in Greenfield, Massachusetts who do not hold Technician-class licenses.

Folio Views lends itself to casual browsing—you can search for a name from Aab to Zywo by entering a character at a time. While you watch, the search engine whittles away the "matches found" counter.

Searches for whimsical callsigns are fun—you'll find a K9DOG, but no K9CAT—and you can use a wild card character, the question mark, (e.g., N1J1?) to locate other members of your amateur "class" (i.e., amateurs who took a license exam at the same time as you did). However, multiple wildcard searches (e.g., for ??ICAT) slow the search considerably, and a Thompson <AND> ?1??? sequence left the computer churning for over two hours before I lost patience and interrupted the search.

Folio Views can direct a single callsign record (called a folio) or a group of records (called a view) to either a disk file or your PC's printer. However, printer setup requires considerable experimentation, and if you're generating mailing labels, you may find it easier to print to a disk file, and then use a conventional word processor to edit the file and produce the list.

Within the HAM program's introductory screen, pressing the <F1> help key returns an

```

\simtel\hamradio
aaaread.me      Information about the files in this directory
autocw.zip     Morse code practice, random/keyboard/file
autoexam.zip   Novice/Tech/General/Adv./Extra Ham Radio exams
autofax.zip    WEFAX program for Kantronics TNC's EGA/CGA
autolog4.zip   HAMS: Control ICOM radio, automate log book
bestbeam.bqs  Select best beam antenna design
comb6.zip      Hams: HF radio propagation prediction program
contest.zip    Ham radio contest database by G3ZCZ
contest.zip    Hams: Real contest logging/ARRL SS simulation
ct626.zip     CT 6.26 Ham Radio contest logger by K1EA
cw.zip        Morse code practice
cw104.zip     Hams: Send and receive CW via RS-232 port
dove3w13.zip  DOVE satellite telemetry decoder,files or HAPN
dxb20dmo.zip  Hams: Scientific Sol's DXBASE logging SW DEMO
dxcc104.zip   Hams: DXCC Award logger & lister w/statistics
dxlog185.zip  Hams: PAYL DXLog 1.85 Ham Radio logger DEMO
elmer100.zip  ELMER, the ham's Expert System or smart server
fax40.zip     DKBJV's FAX software for weather charts/photos
fftmorse.zip  Hams: Sound-Blaster FFT Morse code decoder
filter11.zip  Electrical filter designs, esp. Butterworth
gc103.zip     Hams: Great circle distances & bearings, w/src
geosat.zip    Find Azimuth and Elevation for sync. satellite
geosat.bqs    Find Azimuth and Elevation for sync. satellite
Search: antenna
F10, ^s agai

```

Figure 9. A keyword search feature helps locate antenna-related files in QRZ's alphabetical file list.

error message—"unable to find RTMANUAL.NFO". However, pressing <F1> within the search screen brings up a single help screen.

You can get additional help by executing a separate program, MANUAL.EXE, which includes additional information about Folio Views' features. What's missing is a list of basic definitions and printer setup hints, and help pertaining to the amateur callsign database.

In general, though, Buckmaster's *HamCall* CD-ROM will meet most users' expectations, although its user interface needs additional polishing. For Macintosh users, *HamCall* enjoys no competition.

## QRZ! Ham Radio

Walnut Creek CD-ROM, a pioneering publisher of shareware disks, offers *QRZ! Ham Radio*, a \$29.95 collection of 5,087 PC-compatible files comprising 494 MB of interest to the amateur radio community. Currently, Walnut Creek has plans to update the CD-ROM's contents each calendar quarter and invites subscription inquiries.

*QRZ!*'s shareware and freeware collection includes 48 MB of amateur radio-related files taken from Internet News articles. Topics covered include packet radio, space applications, digital signal processing, antennas (see **Figure 8**), homebrewed equipment, and regulations and policies.

Within each topic, you can use a text editor or file-viewer utility program to browse through chronologically arranged collections of newsletters. Although the newsletters lack the immediacy of tapping into the Internet, you avoid paying connect-time charges and will probably find browsing an educational and entertaining diversion when the bands are dead.

*QRZ!* includes a user-interface program for file viewing and decompression. Unfortunately, the decompression program evokes an error message—the \BIN\ subdirectory and UNZIP.EXE file are missing from the CD-ROM. As an alternative, you can find the file in the disk's \DOS\ subdirectory and decompress the files manually. *QRZ!*'s file-directory utility presents a hard-to-use alphabetical list of mixed-topic files, but a search routine highlights a specified keyword.

Decompression difficulties aside, you'll find a wealth of amateur radio-related shareware and freeware dispersed among several subdirectories, most of whose contents are derived from various BBSs and networks. File dates extend to late 1993, making this disk's contents the most current among CD-ROMs reviewed. However, as found in other collections, many of the files are earlier versions.

Walnut Creek provides two callbooks on

*QRZ!*—*QRZ.EXE*, a DOS program, features an extensive range of command-line switches that control *QRZ!*'s search, display, and printing functions. With no switches invoked, *QRZ!* allows you to enter one call at a time, or a call suffix, and returns name, address, date of birth, and license class data.

While *QRZ!* works well for U.S. calls, the program unfortunately garbles Canadian licensees' birthdates and date-of-license issue data, and omits street addresses. However, Walnut Creek's programmers have fixed a bug appearing in earlier versions of *QRZ!* that added one day to everyone's birthdate.

A second program shown in **Figure 9**, *QRZWIN.EXE*, works only under Windows but runs more smoothly. Using *QRZWIN*, you can search for partial calls, locate the 128 licensed amateurs named John Smith, identify all 34 amateurs in Princeton, Texas, and direct search results to a logging file. I encountered no errors in retrieving Canadian callsign data.

You can also print call data and mailing labels from the logging file—although I encountered difficulties with my test system's Hewlett-Packard LaserJet III, which attempted to print labels one line per sheet. As a workaround, I successfully used a text editor to print labels from the logging file.

Its printing difficulties aside, *QRZWIN* is easy to use and beginner-friendly. Overall, the *QRZ!* CD-ROM represents an above-average value for the purchase price. If you enjoy browsing through Internet notes files, check computer shows and discount CD-ROM brokers for a copy of the March, 1993 edition of *QRZ!*—this disk includes Internet notefiles dating back to 1989.

## Future directions

In addition to amateur radio-related disks, you can choose from among thousands of other shareware and commercial software titles. For example, Walnut Creek and CDRP both publish general-purpose and programmer-specific shareware collections.

On the commercial side, amateurs will find CD-ROM software atlas disks of interest. For example, DeLorme Mapping of Freeport, Maine, offers a Windows-compatible street atlas of the United States for under \$100.

Using atlas software, you can generate custom maps showing the way to your QTH, or plan a visit to a friend or a hamfest in a distant city. Also, mapping software that includes topographical details may prove useful when you're planning a new antenna installation.

Thanks to increased use and technological innovation, CD-ROM publishing costs have fallen considerably during the past five years. You



can purchase a Philips CD-ROM recorder/reader subsystem for under \$7,000, and writable blank CDs cost approximately \$20 each. Thus, making your own one-of-a-kind CD-ROM collection of DX records, logs, and computer data files is no longer an impossibility.

If you wish, you can become a CD-ROM publisher for under \$5,000. Commercially produced disks cost \$3 or less per copy in moderate quantities, and most publishers will accept raw data on one-off CD-ROMs, hard disk drives, magnetic tapes, and even stacks of floppy disks.

Where can the amateur radio community go with CD-ROM technology? For starters, we can already obtain audio (.WAV) files useful for checking packet and RTTY demodulators. Beginning amateurs and SWLs would no doubt find a collection of .WAV files identifying RTTY and FAX signals equally useful.

Multimedia and animation offer interesting

educational possibilities—imagine a collection of three-dimensional antenna radiation signatures that include movies to show how directional patterns and sidelobes vary over a frequency range.

Finally, don't overlook the possibility of writing and contributing software of your own. While the financial rewards of shareware publishing are uncertain, many of the programs currently available to the amateur radio community would benefit from competition.

## Notes

Test system used: Ares 486DX/25 PC equipped with 8 MB of RAM, 210 MB of hard disk storage, Always IN-2000 SCSI controller and CD Technology/Toshiba T-3201 Porta-Drive CD-ROM drive, and Hewlett-Packard LaserJet III printer. ■

## PRODUCT INFORMATION

### One-Stop Shopping Technical Training BBS

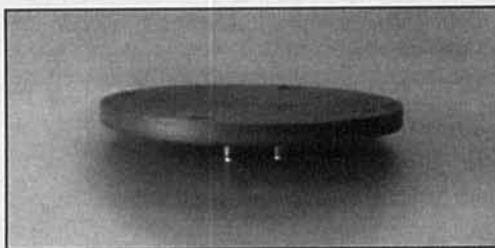
East Coast Network Training Services, Inc. has implemented the first one-stop shopping multi-line bulletin board system (BBS) for technical training products available at 401-726-6830 (up to 14.4Kbps, 8, 1, N, Ansi).

This BBS is open and available to all corporate training managers, MIS management, LAN/WAN specialists, programmers, telecommunication specialists, and end users needing access to a selection of nationwide classroom seats, computer-based training, video training programs, and self study kits. Novell, UNIX (SCO, Solaris, USL, Univel, Ultrix, AIX,...), Banyan, MS Lan Manager, MS Windows NT, Proteon, Pathworks, Lantastic, and Windows for Workgroups training product information and certification updates are available for download. Open Systems, Client Server, Application Software, Databases, CBT Authoring Tools, Lan Diagnostic Services, and Network Management Tools are also filing areas available with hundreds of training product descriptions features.

For more information and to speak to a training specialist, call 800-475-3130.

### A New Microstrip Patch Antenna

Antenna Research Associates introduces their new microstrip patch antenna for the GPS marketplace. Model PAS-1575/DL is a dual linearly polarized antenna designed for 1575.4 MHz with less than 1.5:1 VSWR. Two separate outputs are provided with either SMA or pigtail connections. Typical gain is 5 dBi and typical half power beamwidth is  $>80^\circ$ . The



antenna is 3.5 inches in diameter and .25 inches in size and weighs less than 3 oz.

For more information, contact Antenna Research Associates, Inc., 11317 Frederick Avenue, Beltsville, MD 20705 (301-937-8888; FAX: 301-937-2796).

### Wideband High Gain Microstrip Patch Antenna

Antenna Research Associates has introduced a wideband high gain microstrip patch antenna for applications from 3.0 to 3.5 GHz. The antenna is designed for 16% bandwidth with a 2.0:1 VSWR and offers gain of 8.0 dB over the band. Typical half power beamwidth for this antenna is  $60^\circ \times 40^\circ$ . The hermetically sealed assembly can be used as a feed for reflector antennas. It can also be used as an element in wideband high gain microstrip flat arrays for both satellite and ground mapping applications. The antenna is 3.5" dia.  $\times$  0.3" in size and weighs less than 3 oz.

For more information, contact Antenna Research Associates, Inc., 11317 Frederick Avenue, Beltsville, MD 20705 (301-937-8888; FAX: 301-937-2796).

# THE SOLAR SPECTRUM

*New organization helps amateurs obtain eclipse data*

On May 10th, 1994, a new research organization brought a team of scientists to Baja, California to make detailed environmental measurements during the annular eclipse of the Sun (**Figure 1**). The team took continuous data on the total column ozone density and made the most extensive measurements of the background radiation that have ever been made during an eclipse. We asked Dr. Shawn Carlson, a physicist at Lawrence

Berkeley Laboratory for over ten years and now full-time executive director of this organization, to tell us about its purpose and the Baja experiment. Shawn:

Perhaps the most remarkable thing about this team was not the data it acquired, but the group itself; it was composed almost entirely of amateur scientists. An amateur scientist designed the equipment to monitor the ozone layer, and an amateur devised a system to record the data.

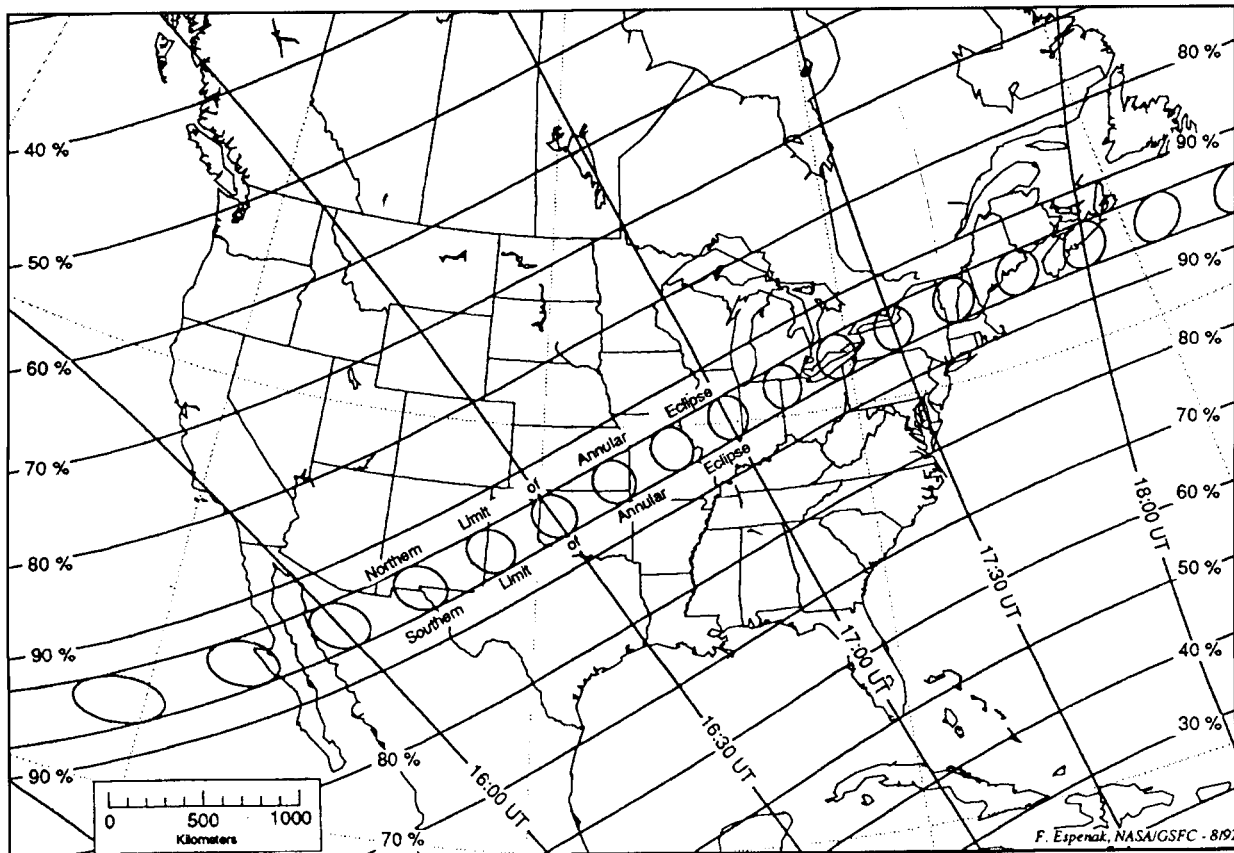


Figure 1. The path of the May 10, 1994, annular eclipse across North America. The SAS team was stationed within the band of central eclipse as it crossed the Baja peninsula. Diagram courtesy of F. Espenak, *NASA Reference Publications 1301*.

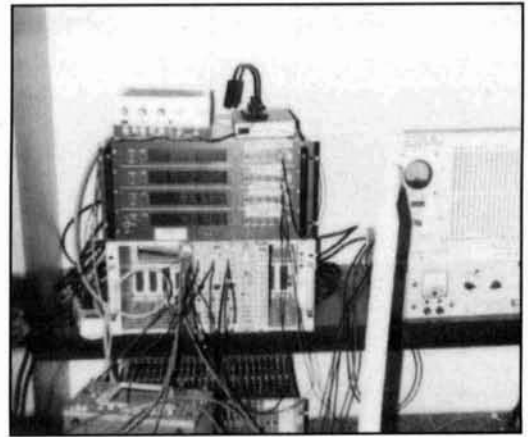




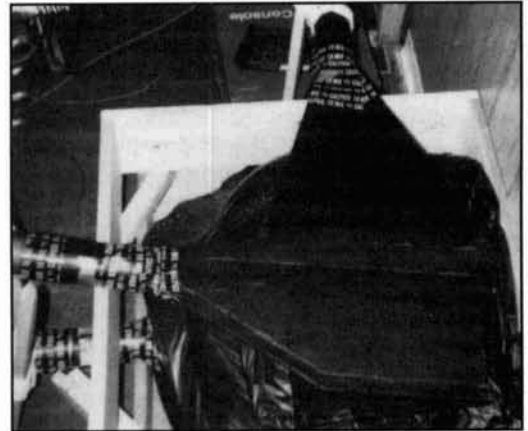
**Photo A.** The annular eclipse of January 4, 1992, in a ring of setting sunlight over the Pacific Ocean off the San Diego coast at Crystal Pier, California. During an annular eclipse the moon is too far away from the Earth to entirely obscure the Sun, and instead produces a spectacular "ring of fire." Photograph by Dr. William Livingston of the National Solar Observatory—Kitt Peak; supplied by the National Optical Astronomy Observatories.

Amateurs built and calibrated the equipment and amateurs took most of the data. Certainly of equal importance, amateurs are currently analyzing the data and drafting two papers for publication in professional scientific journals.

The organization that made this happen is the Society for Amateur Scientists (SAS). SAS is a unique collaboration between world-class professional scientists, including two Nobel Prize winners, and nonprofessionals with diverse backgrounds. Its purpose is to empower avocational scientists to make real contributions to knowledge, and to participate in the great sci-



**Photo B.** Cosmic ray counter electronics.



**Photo C.** Cosmic ray detector. Two sets of two crossed scintillating panels separated by an absorber made of plastic trash bags filled with sand. Photomultiplier tubes, hidden inside the metal cylinders, collect the light generated in the panels when a cosmic ray passes through.

entific debates of our time as full members of the scientific community. SAS is founded on the premise that the ability to do good science does not reside exclusively among people who have earned a doctorate, and maintains that the world would be a much better place if we could convince more of these people to use their talents to help unlock Nature's mysteries. As director, it was my pleasure to oversee this expedition.

The data taken on May 10th is illustrative of one method SAS uses to help its members do real science—by providing the oversight to involve amateurs quickly in professional-quality projects designed by leading researchers. The ozone measurements were made using the MicroTOPS instrument created by Forrest Mims. Mims, an avid amateur scientist, is one of the world's leading ozone experts.

The MicroTOPS is a hand-held device that measures the intensity of sunlight in a number of narrow ultra-violet (UV) bands. By using the relative intensities, one can determine the col-

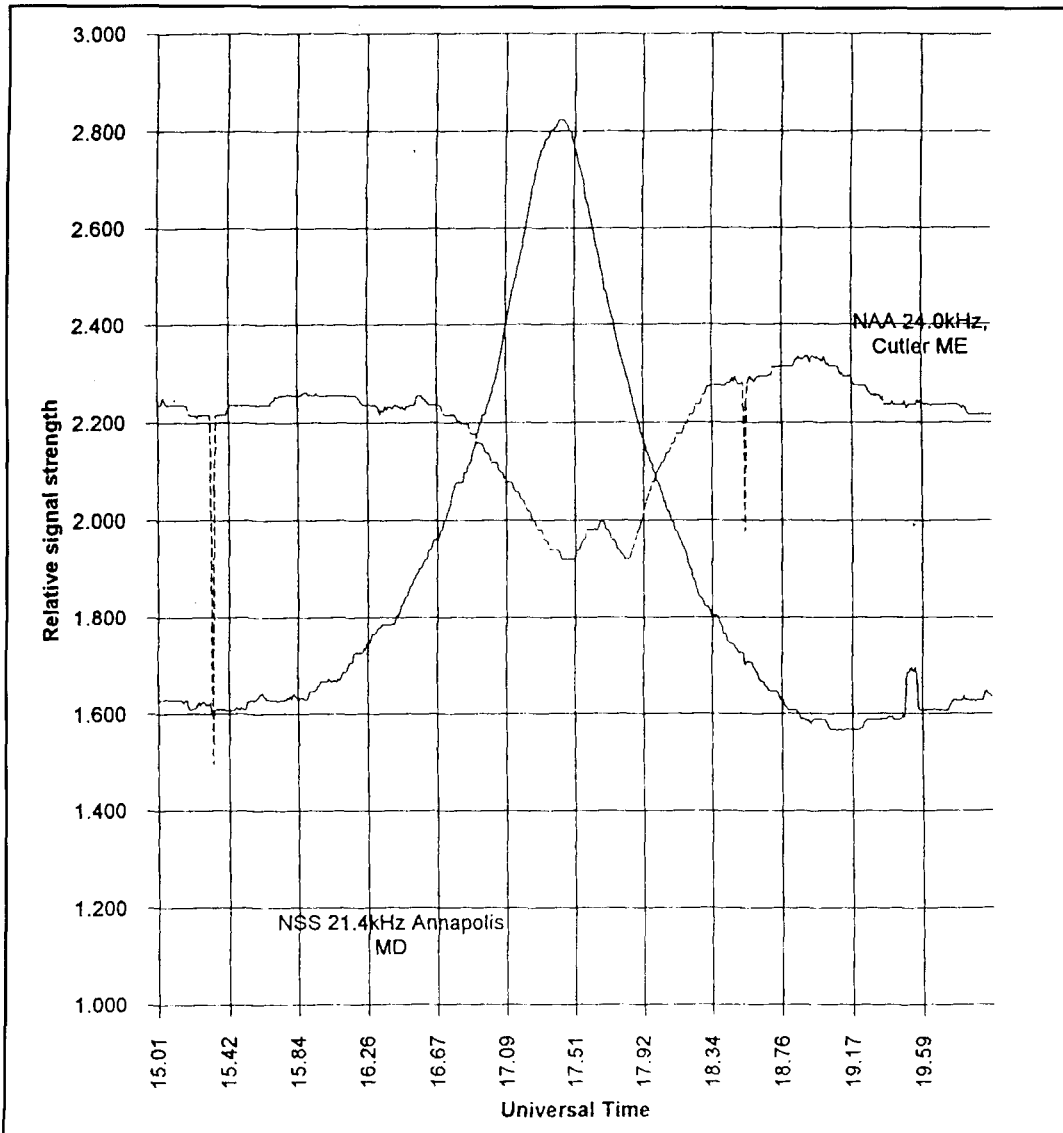


Figure 2. As the eclipse path moved eastward across North America, the atmospheric D-layer that propagates VLF radio signals was significantly affected. Diane Lucas, Wellington, Ohio, was monitoring solar flare associated ionospheric anomalies when she recorded this dramatic effect on stations NSS and NAA.

umn density of ozone as well as atmospheric aerosols and water vapor. The data are easily read into a personal computer via a RS-232 serial port. The equipment was loaned to SAS by Forrest Mims as part of Project Halo—a collaboration organized by Mims of 21 teams (some professional and some amateur) to take UV measurements at the annular eclipse.

When we measure the column ozone density during an eclipse, we can obtain vital information about two different kinds of phenomena—the ways ozone concentration can be affected by atmospheric chemistry, and the dynamics of the stratosphere during an eclipse. The equilibrium concentration of ozone is a balance between the processes that make it and that destroy it. The Sun is the sole creator of the stratospheric ozone and is also its principle destroyer. Ozone breaks up when it absorbs

UV. However, atmospheric chemistry also takes its toll.

In order to untangle the effects of the Sun from the chemistry, one would like to isolate the effects of the chemistry by shutting the Sun off. An eclipse does this very nicely (**Photo A**). Also, the stratosphere is a very dynamic place. An eclipse creates a moving cold spot in the atmosphere, which some researchers have suggested creates all sorts of density fluctuations and other effects high in the atmosphere. If the stratospheric density changes, then the ozone density should change accordingly; consequently, observers stationed in various places along the eclipse path could track these variations.

However, such fluctuations may also be observable using cosmic rays. Cosmic rays are subatomic particles, mostly muons, created in the upper atmosphere when high-energy parti-



**Photo D.** A portion of the intrepid SAS eclipse team. From left to right: Bill Bowlen, Mark Derzon, Joseph Aguilar, Vincent Sanchez, Nancy Aguilar. Below center: Michael Kaspen. Not shown: Shawn Carlson and Brent Beckett.

cles smash in from outer space. Muons are unstable and decay in flight. If the upper atmosphere becomes denser, these collisions take place at a higher altitude. The muons then have farther to travel, and fewer muons make it to ground. Thus, by measuring both ozone and cosmic rays, we are able to separate the effects of the density fluctuations from stratospheric chemistry in our ozone measurements.

The SAS team continuously monitored the cosmic ray rate with the help of four large scintillating paddles, an absorber, CAMAC electronics, and a four-channel visual scalar—all generously loaned to us by Lawrence Berkeley Laboratory (**Photos B and C**). The paddles were divided into two sets of two, each criss-crossed and separated by about 10 centimeters of “absorber” made from trash sacks partially filled with sand. A particle from a radioactive decay in the sand or air would not be able to travel through the absorber, but cosmic rays are penetrating, and can easily pass all the way through. We required that at least three of the four paddles fire simultaneously before an event was identified as a cosmic ray.

During three hours of data gathering, the group collected over 200,000 cosmic ray events. To measure the rate of cosmic rays, the number of counts were continuously displayed on a visual scalar. The team constructed a timer by connecting a second scalar to a signal generator. Both displays were recorded on video tape using an ordinary Camcorder.

SAS put together a very diverse team (**Photo D**). Brent Beckett is a sound engineer in the film industry. He developed a system to feed a continuous track of WWV time signals mixed with voice annotations into the video cameras that recorded the readings on all our instruments. Brent handled all the sound and video

equipment that was used to collect our data. Nancy Aguilar, a stock trader in Los Angeles, did a great job “plateauing” (finding the correct operating voltage) for the photomultiplier tubes and assisted in setting up the electronics.

Veteran eclipse trackers Michael Kaspen (a painting contractor) and Mark Derzon (a Bakersfield attorney) built absorbers for our cosmic ray experiment and helped set up and test the equipment. Mike undertook an extensive analysis to predict the time of first contact and duration of annularity at Bahia de Los Angeles. He was correct to within a few seconds. Bill Bowlen, another painting contractor and eclipse watcher, teamed with Brent to build the scintillator paddles which detected the cosmic rays and assisted with the data collection. Vincent Sanchez and Joseph Aguilar assisted with the building, setup, and calibration of the cosmic ray detector, and helped in the data collection of the MicroTOPS. Bill, Brent, and Nancy also took time off from their eclipse watching to help record the UV data from the MicroTOPS. This project could not have been undertaken without the help of these outstanding amateur scientists.

Weather conditions during the eclipse were perfect; bright clear skies predominated. Annularity at our location lasted 4 minutes and 10 seconds. The SAS team compiled nearly two hours of continuous UV data from MicroTOPS, and nearly four hours of continuous data from the cosmic ray detector. The data are still being analyzed and so final results are not yet available. However, the data show gross consistency over the entire eclipse and so there is no reason to expect that major undetected problems occurred during the data collection. Based on preliminary results, the team is certain they will have some very interesting conclusions that will be published in the near future.

In addition to its solar eclipse studies, the Society for Amateur Scientists is developing additional projects in biology, seismology, geology, and many other areas of science. If you would like to learn more about the organization, please drop me a note on the Internet or call (800) 873-8767 and ask for your free copy of the SAS newsletter, *The Amateur Scientists' Bulletin*.

**Shawn Carlson**

**Internet: [scarlson@SAS.org](mailto:scarlson@SAS.org)**

As the eclipse traveled across North America, the North Atlantic, and into Morocco, a number of contributors to the AAVSO program of recording ionospheric anomalies caused by solar flares (sudden ionospheric disturbances) reported systematic variations in the VLF radio signal they were recording. **Figure 2** is a typical representation of the eclipse's affect on such stations. ■

# A 1.8 TO 30-MHz 100-WATT SSB TRANSMITTER

*This handy transmitter is the companion piece to a receiver built several years ago*

This transmitter was built to complement my communications receiver described in the November 1977 issue of *Ham Radio* magazine.<sup>1</sup> When transmitter and receiver are used together, transceiver operation is possible over all amateur bands between 1.8 to 30 MHz with 100 watts PEP output power. The transmitter may also be used as a stand-alone unit. No tuning, other than the setting of the operating frequency and mode, is necessary. The transmitter selects the appropriate harmonic filter and mode automatically, as determined by the frequency of operation. This is done by decoding the BCD information that drives the digital frequency display. The unit also features automatic selection of one of eight antennas. A block diagram is shown in **Figure 1**.

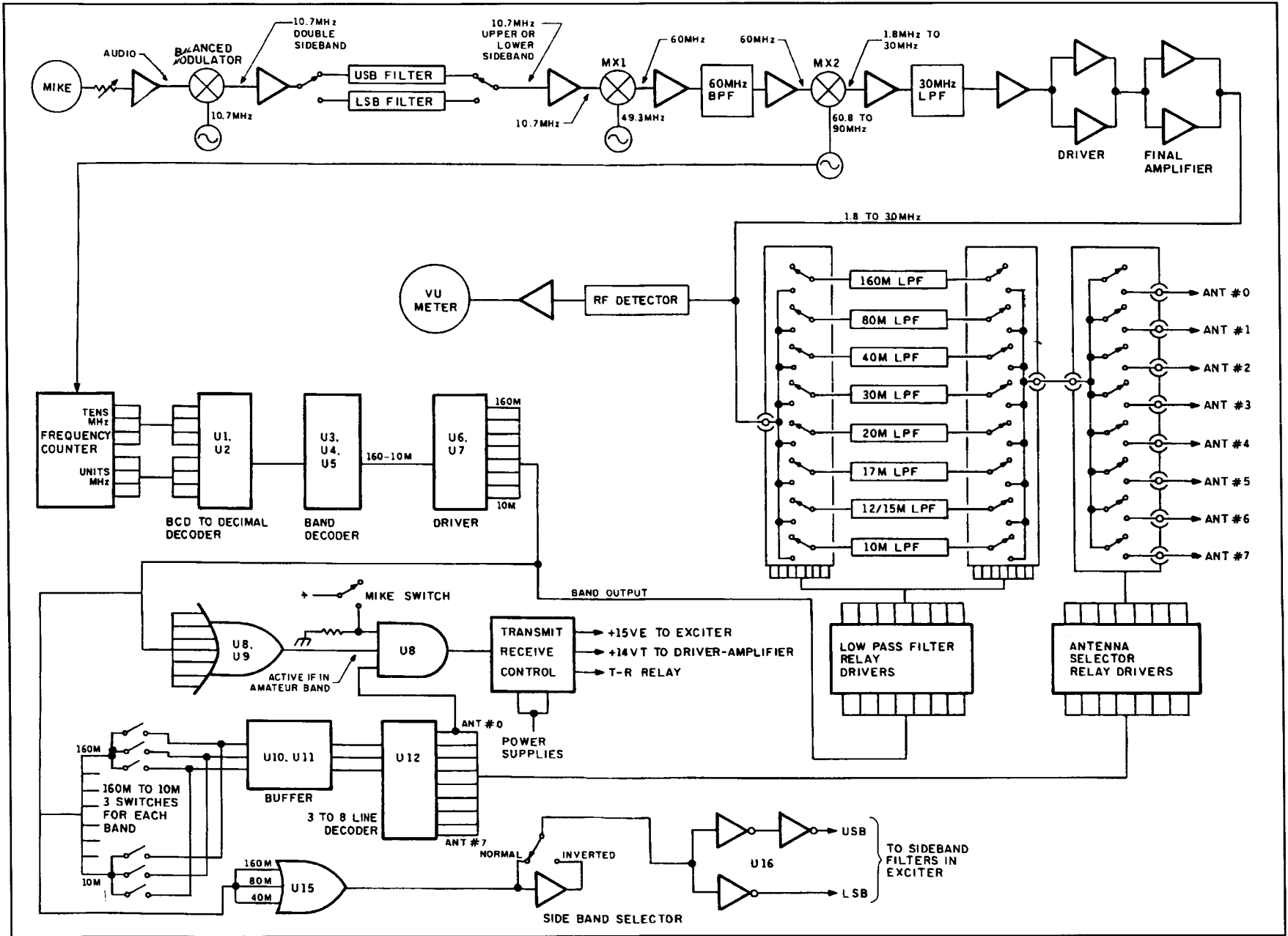
## Theory of operation

Mike audio is amplified by one half of an LF347 operational amplifier (IC1a in **Figure 2**), and is then combined with a 10.7-MHz signal in the UPC1037H IC to produce a 10.7-MHz DSB signal. Audio gain may be set by changing the value of the 1-meg resistor. The 10.7-MHz signal is produced by a 2N4416 JFET oscillator. The upper and lower sideband filters, USB and LSB, remove the unwanted sideband resulting in a single-sideband suppressed carrier signal. The sideband filters are diode switched.

The 10.7-MHz single-sideband signal is buffered and then mixed to provide an IF frequency of 60 MHz. The 49.3-MHz is produced by an overtone oscillator using a 2N5179 transistor (Q4 in **Figure 2**). A double-balanced diode ring mixer, which uses a Minicircuits Lab 7-DBM LO mixer (MX-1 in **Figure 2**), combines the 10.7-mixer sideband signal and 49.3-MHz mixer output to the desired 60-MHz IF. A Minicircuits Lab MAR-4 amplifies and buffers the 49.3-MHz oscillator signal and provides the +7-dBm LO signal level needed at the DBM LO port.

If you have difficulty obtaining the 10.7-MHz sideband filters, try using the more commonly available 9-MHz crystal filter units. This substitution requires some simple modifications, including: changing the 10.7-MHz oscillator to 9.0 MHz and changing the 49.3-MHz oscillator to 51.0 MHz. You may also use a single symmetrical SSB filter in lieu of the matched USB and LSB asymmetrical sideband filters. This eliminates the need to diode switch the filters, but involves designating one of the two 9-MHz crystals for selecting the appropriate sideband. The exact frequencies needed are determined by the filter used and are normally set at the 300 Hz points on the filter slopes. I chose the 10.7-MHz filters because they were available. Also, because they were used in the companion receiver, I included an identical mixer scheme in the transmitter to permit transceiver operation. A 2N3904 transistor emitter

Figure 1. Block diagram.





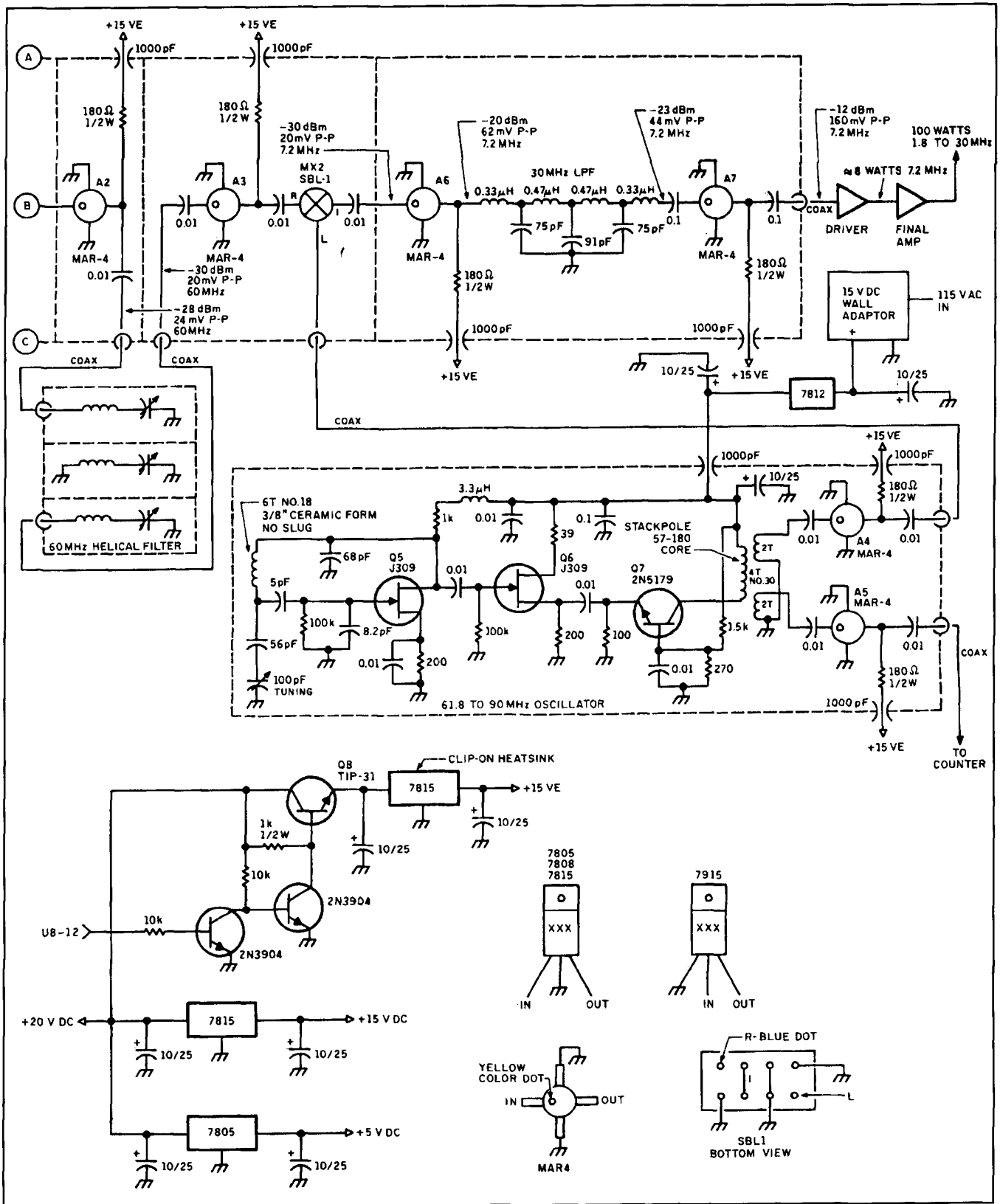


Figure 2B.

er (device A2 in Figure 2). The MAR-4 input impedance does vary somewhat, as mismatches to various spurious frequencies are reflected back from the 60-MHz helical filter that fol-

lows; however, it does provide a suitable termination for the IF mixer port. The MAR-4 amplifier also provides gain to make up signal levels in the mixer and helical filters, which are



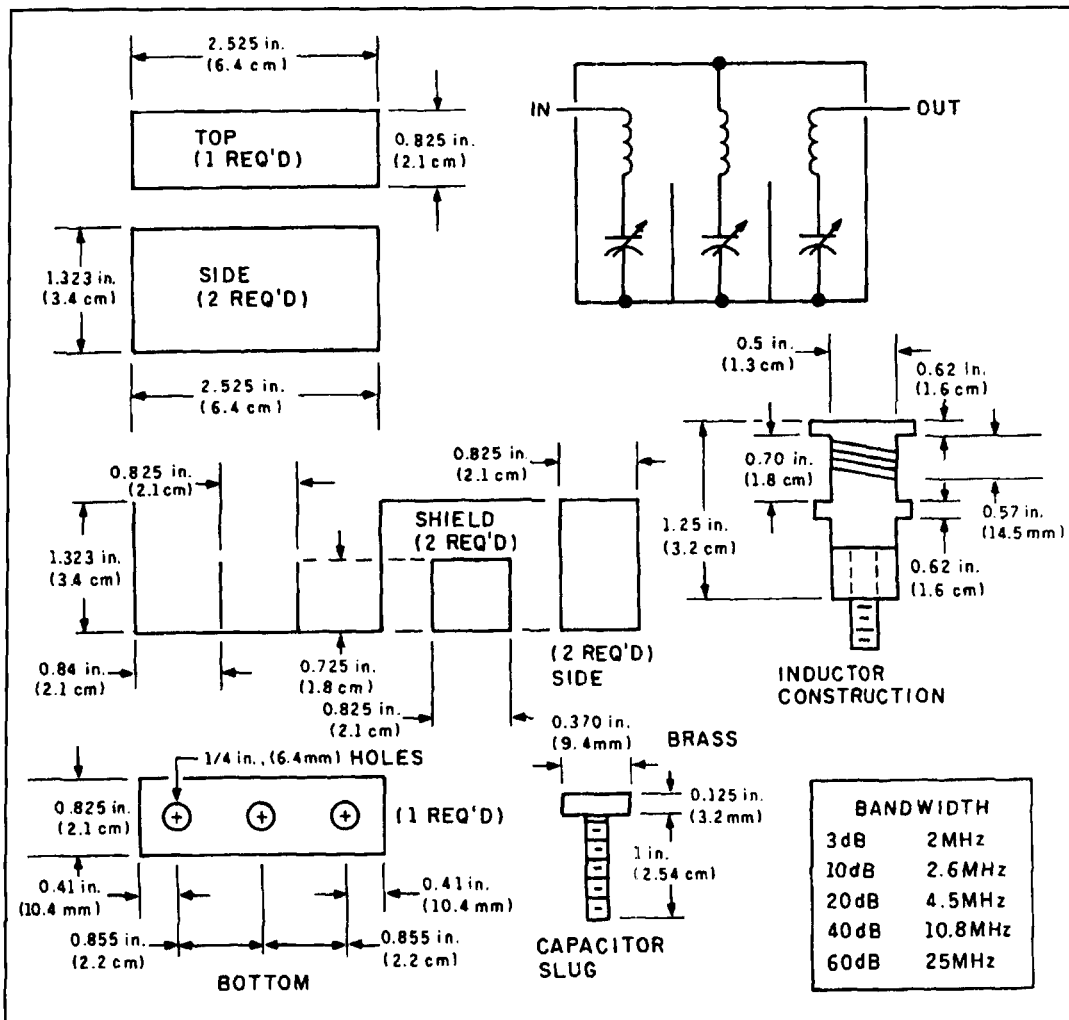


Figure 3. Layout of the 60-MHz bandpass filter. The helical filter circuit appears in the upper right-hand corner.

passive devices with insertion losses. The 60-MHz helical filter is a homemade device and is shown in **Figure 2** and **Figure 3**. This filter serves the same function as a roofing filter used in an upconverting receiver. Most modern receivers would use a VHF monolithic crystal filter for this application, but the helical filter is ample and more cost efficient for a transmitter design. Another MAR-4 amplifier follows the 60-MHz bandpass filter.

A second MCL DBM (MX-2 in **Figure 2**) mixes the 60-MHz IF signal from amplifier A2 back down to the 1.8 to 30-MHz operating range. A VFO operating from 61.8 to 90 MHz provides the needed LO signal (more on this later). Another MAR-4 device, A6, a simple LC 30-MHz lowpass filter, and amplifier A7 (MAR-4 stage) follow the IF port of mixer MX-2. The MAR-4 amplifiers provide the buffering and set the terminating impedances, while providing gain to overcome the losses of MX-2 and the 30-MHz LPF. The LPF eliminates the high-side mixer product that would fall in the 122 to 155-MHz range.

Note that the last mixer stage uses subtractive mixing and, in doing so, "inverts" the signal. Thus, if an upper sideband signal is produced at the 10.7-MHz first mixer IF, it will become a lower sideband signal after the final mixer stage. The RF levels shown in the schematic were taken at 7.2 MHz.

### Transmitter power chain

Refer to **Figure 4** the first stage of in-line gain at the operating frequency is provided by a MAR-4 amplifier stage (A7). The driver uses a Motorola MHW591 hybrid gain block driving a pair of Motorola MRF433 transistors. The MHW591 has approximately 35 dB of gain. Components C1, R1, and R2 yield a more uniform gain across the operating range, while the negative feedback from components R3, L1, C4, R4, L2, and C3 improve driver linearity. The driver is capable of producing up to 10 watts output. The bias point for the MRF433 transistors is set by the 1000-ohm pot on the

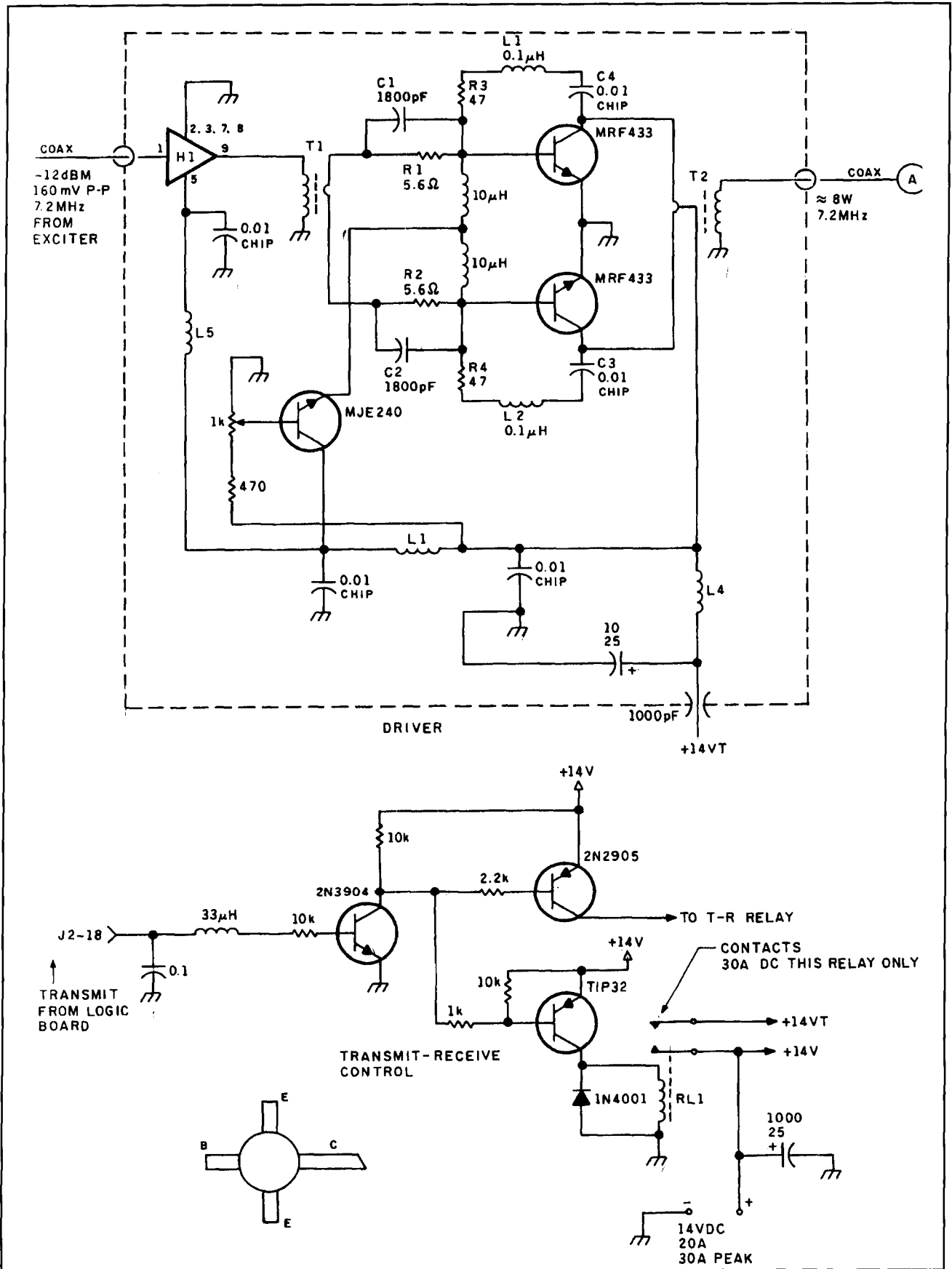
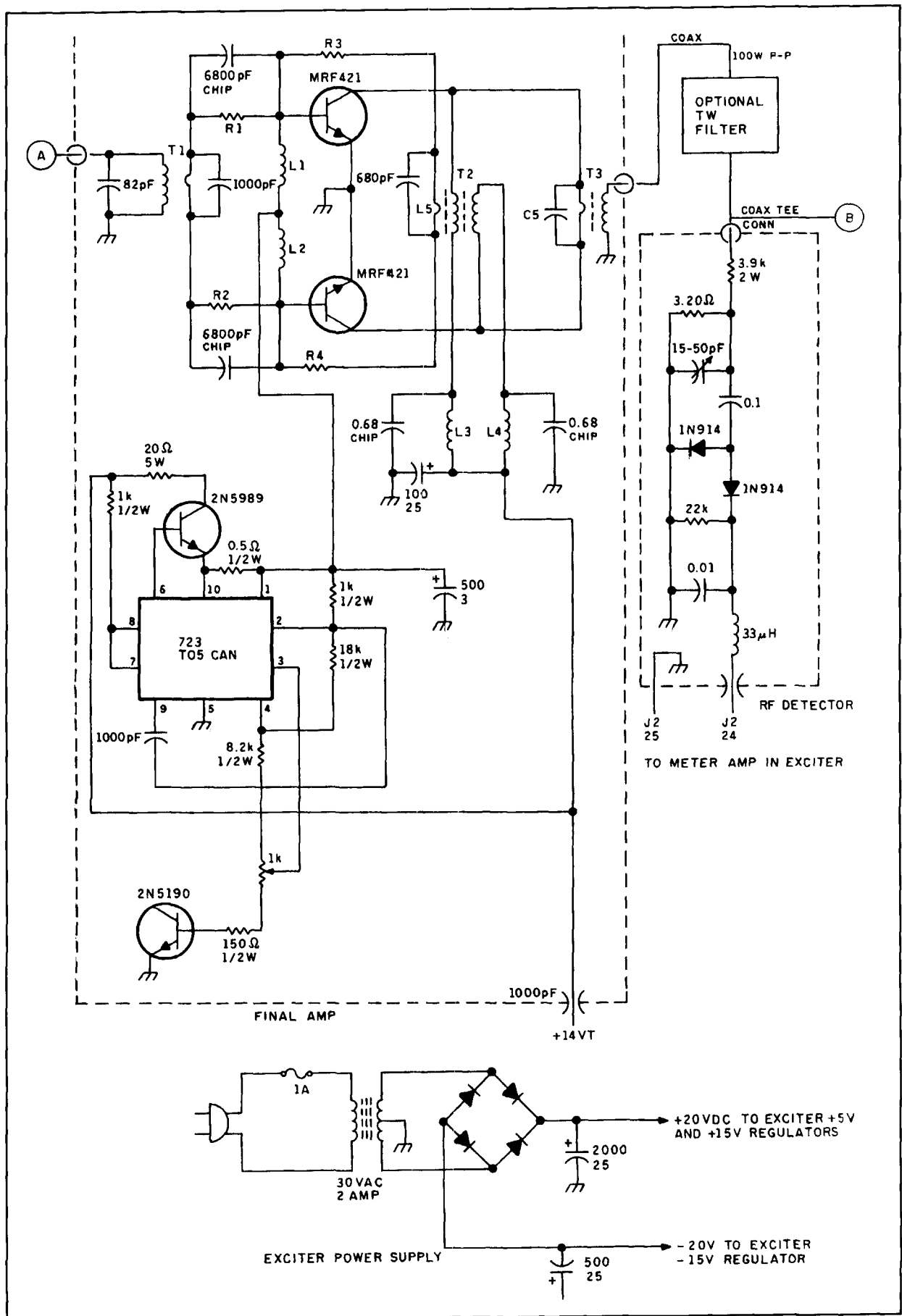
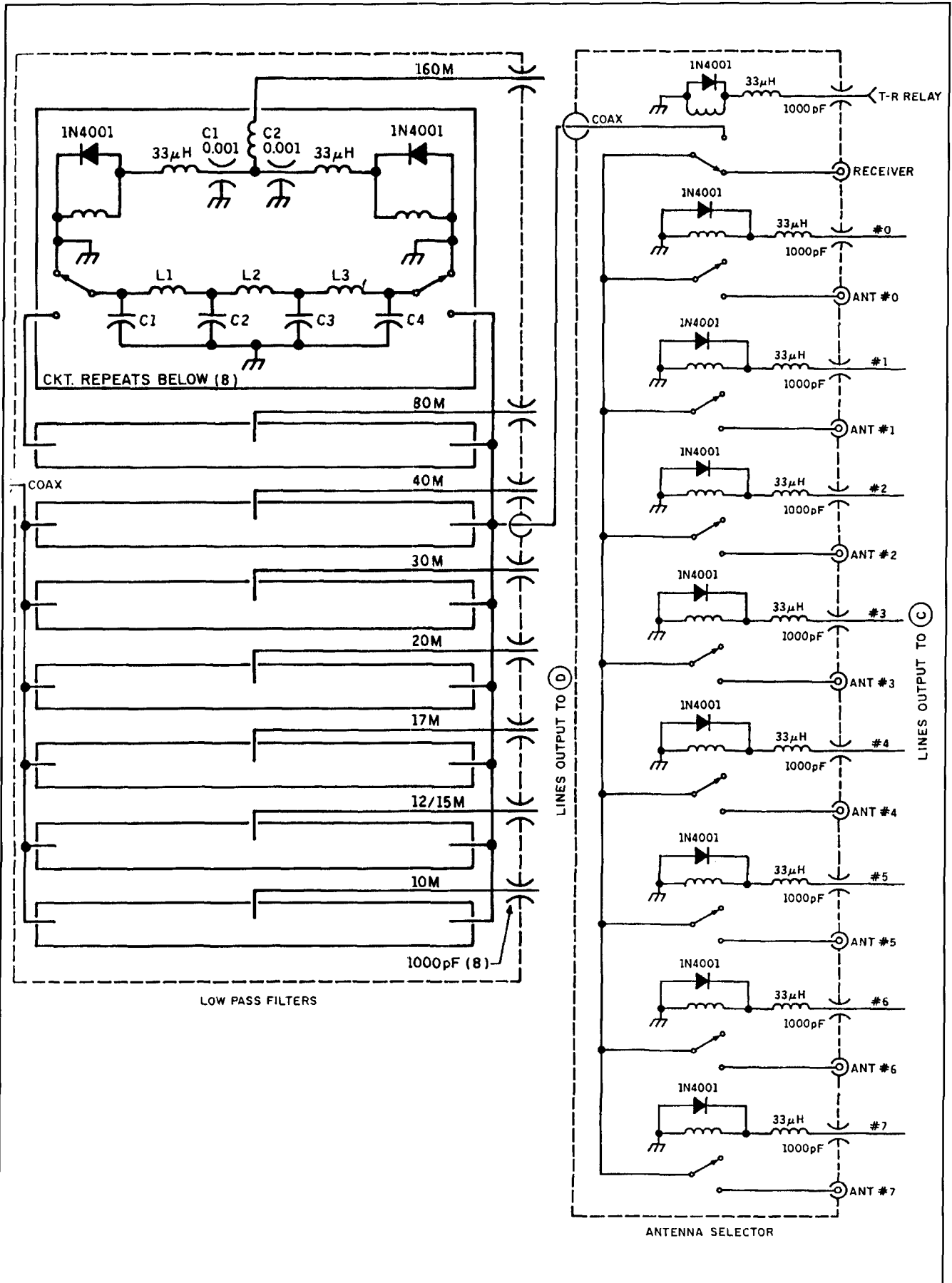
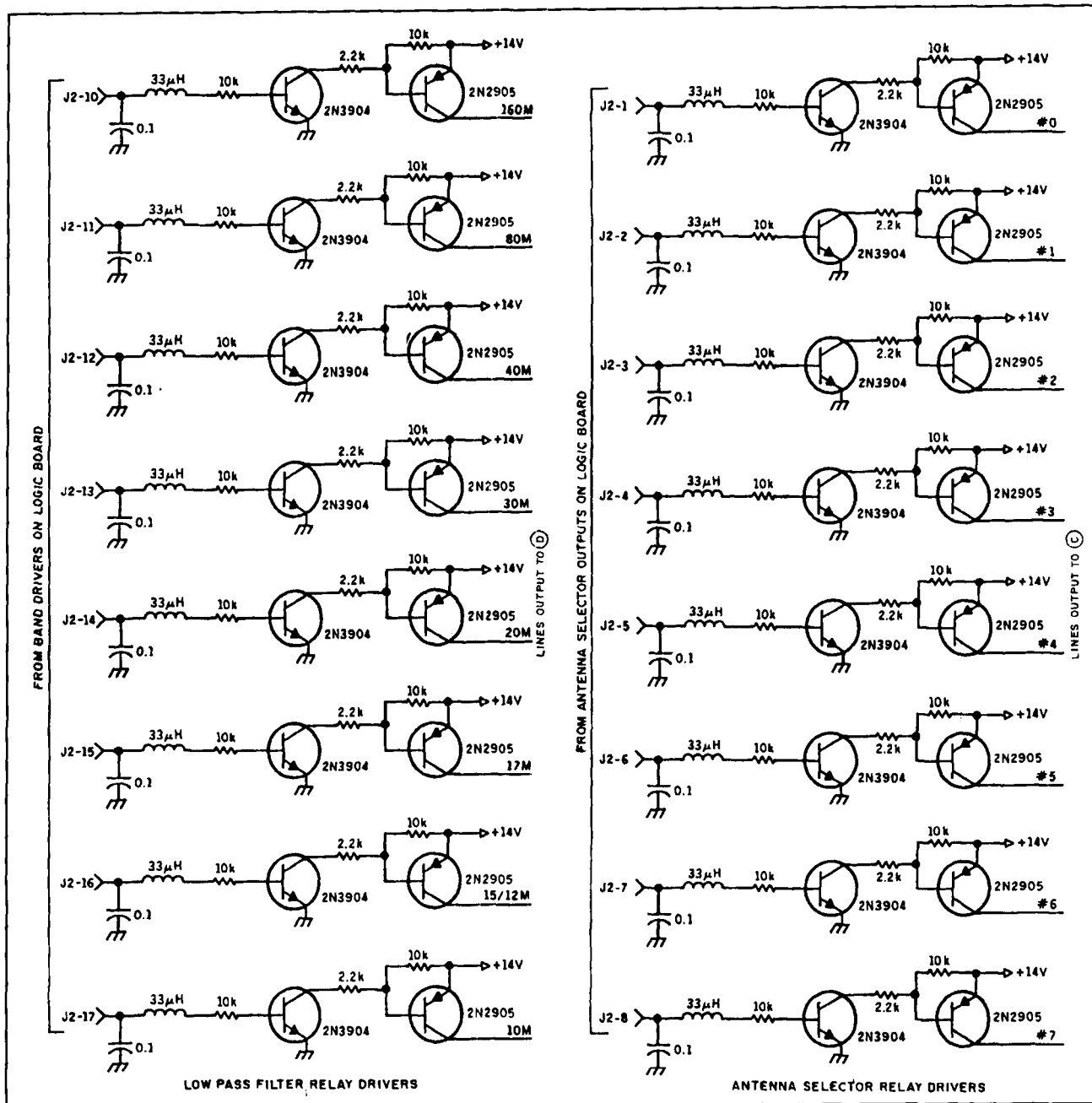


Figure 4. Amplifier assembly.







base of the MJE240 transistor. This amplifier is taken from Motorola application note AN779H and can be found in most Motorola RF power transistor volumes. Total in-line gain is about 50 dB. (See Figure 4 for details.)

With 10 watts of drive, the final amplifier will produce 100 watts PEP output. Negative feedback is also used in this stage. A LM723 and pass-transistor provide base bias for the MRF421 final transistors. Eight to 15 watts, increasing with frequency, are needed to drive this stage to the 100-watt output level. Appropriate harmonic filters are automatically relay switched for each amateur band. Without them, the harmonic content would be about 30 dB

below the carrier and would not meet FCC specifications. The amplifier draws upwards of 20 amps on voice peaks. The 14 volts DC power leads must be as large as practical to reduce losses, as even a small voltage drop will affect the power level. This amplifier is based on Motorola application note AN762-180. The SBL-1 mixers, MAR-4s, Motorola application notes, and both the boards and components for the driver and PA stage, can be obtained from CCI.\* Ferrite cores are available from Amidon Associates.\*\*

\*CCI, 508 Millstone Drive, Xenia, Ohio 45385.

\*\*Amidon Associates, 12033 Oisego Street, North Hollywood, California 91607

## Parts List: Amplifier Assembly

### Driver

T1,T2            2:1 and 1:2 turns ratio, respectively on FairRite 2643006301. Windings: 1 turn of shield from RG-174 coax and 2 turns of #22.  
 L1,L4,L5        FairRite 2343000101 on a wire.  
 H1                Motorola MHW591

### Final Amplifier

R1,R2            2 x 3.33 ohms, 1/2 watt in parallel.  
 R3,R4            2 x 3.9 ohms, 1/2 watt in parallel.  
 C6                1940 pF (2 x 470 pF chips and 1000 pF in parallel).  
 T1                4:1 turns ratio Fair-Rite 2873000201. Primary: 4 turns of #20. Secondary: 1 turn. Shield from RG-174.  
 T2                6 turns #18 bifilar wound on Stackpole 57-9322  
 T3                5:1 turns ratio on 2 Stackpole 57-9238 ferrite sleeves. Primary: 1 turn RG-58 shield. Secondary: 5 turns #18.  
 L1,L2            Ferroxcube VK200 19/4B ferrite chokes.  
 L3,L4            Two FairRite ferrite beads 2673021801 on #16 wire.  
 L5                1 separate turn of #18 on T2.

### Low-pass Filters

| Band  | C1,C4   | C2,C3   | L1,L3    | L2       | Core   |
|-------|---------|---------|----------|----------|--------|
| 160m  | 1000 pF | 2400 pF | 27 turns | 32 turns | T80-2  |
| 80    | 500 pF  | 1300 pF | 17       | 21       | T80-2  |
| 40    | 300 pF  | 680 pF  | 10       | 11       | T130-7 |
| 30    | 180 pF  | 470 pF  | 11       | 12       | T80-6  |
| 20    | 160 pF  | 360 pF  | 9        | 10       | T80-6  |
| 17    | 110 pF  | 270 pF  | 12       | 13       | T68-10 |
| 15/12 | 100 pF  | 220 pF  | 10       | 11       | T68-10 |
| 10    | 2x43 pF | 2x91 pF | 11       | 12       | T130-0 |

Cores are Micrometals with #20 wire.

Capacitors are 5 percent silver mica.

All relays, except RL1, are Magnecraft W76UR CPXC16 type with 12-volts DC coil, 10-amp AC contacts, or equivalent.

The driver heatsink is cut from a 1/2 length section of single-side finned heatsink—CCI's model 99 will do. You'll need a full section of this heatsink material (12 inches) for the PA assembly. The PA and driver are enclosed in perforated aluminum shields to prevent stray RF radiation; this aids in providing stability and preventing local TVI.

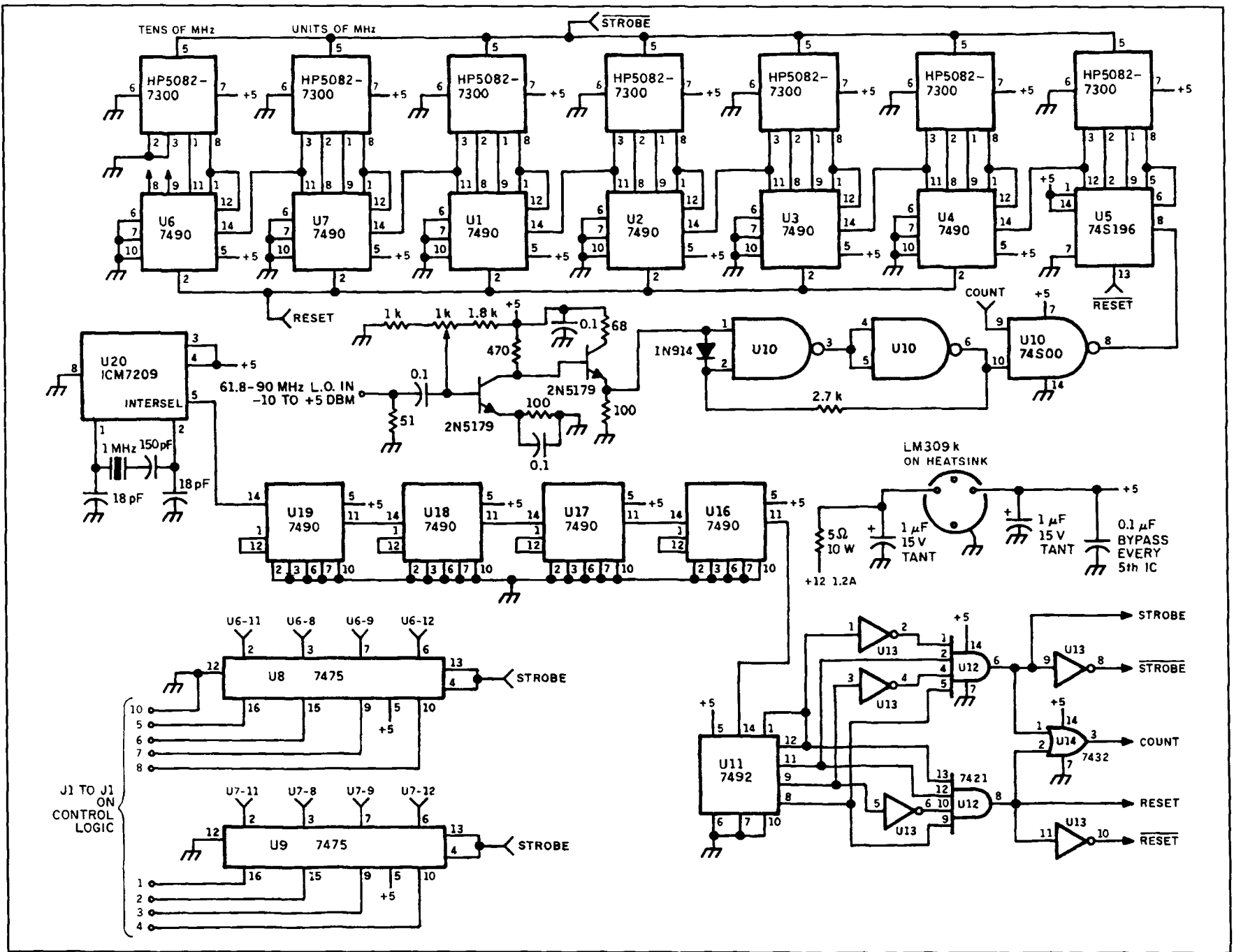
The appropriate low-pass filter for each amateur band is chosen by relay switching, and is automatically selected by circuitry decoding the frequency counter display information. This is followed by an automatic antenna selector that chooses one of eight available antennas. Any antenna can be selected on each of the bands. If you have one all-band antenna, a single antenna output can be chosen for all bands. As config-

ured, the transmitter is locked out when antenna #0 is selected.

A frequency range of 60.8 to 90-MHz from the VFO drives the 100-MHz frequency counter. The BCD outputs from the tens of MHz and ones of MHz counters also drive ICs U1 and U2—BCD to decimal decoders. U3 and U4 decode this information into one of eight decimal outputs. In turn, these buffered outputs are used to make the appropriate low-pass filter relay drivers and antenna selection. The transmitter automatically locks out when a non-amateur band is selected, reverting to antenna "0."

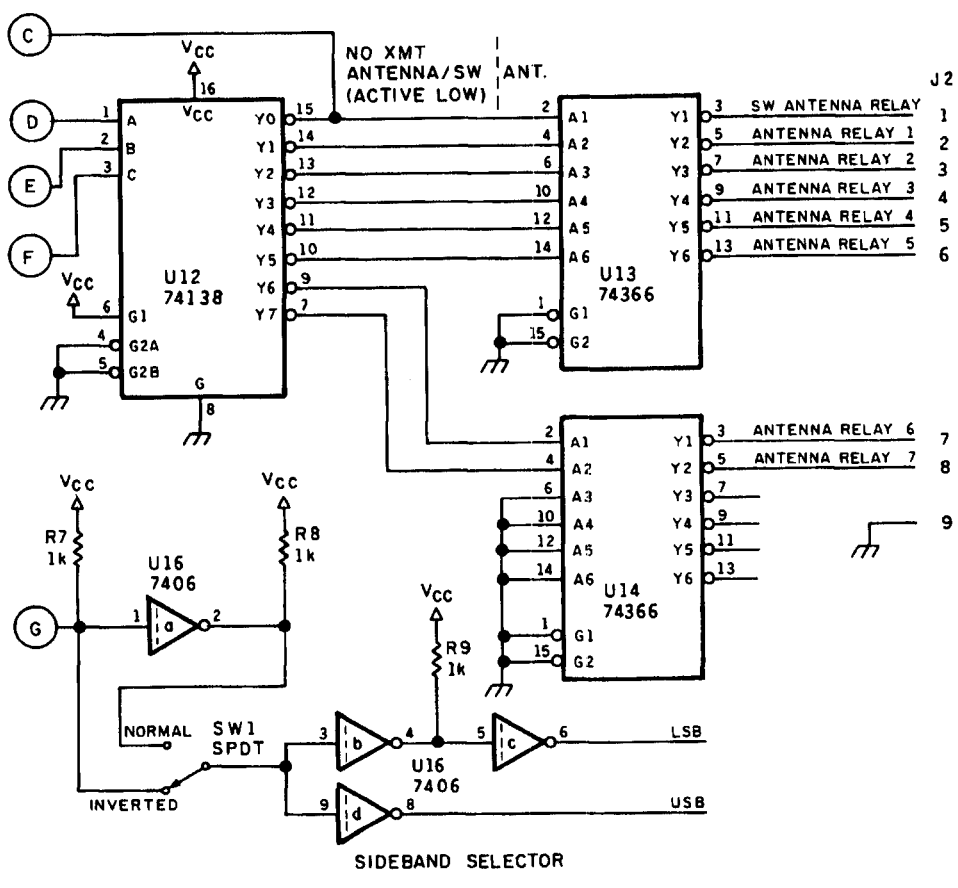
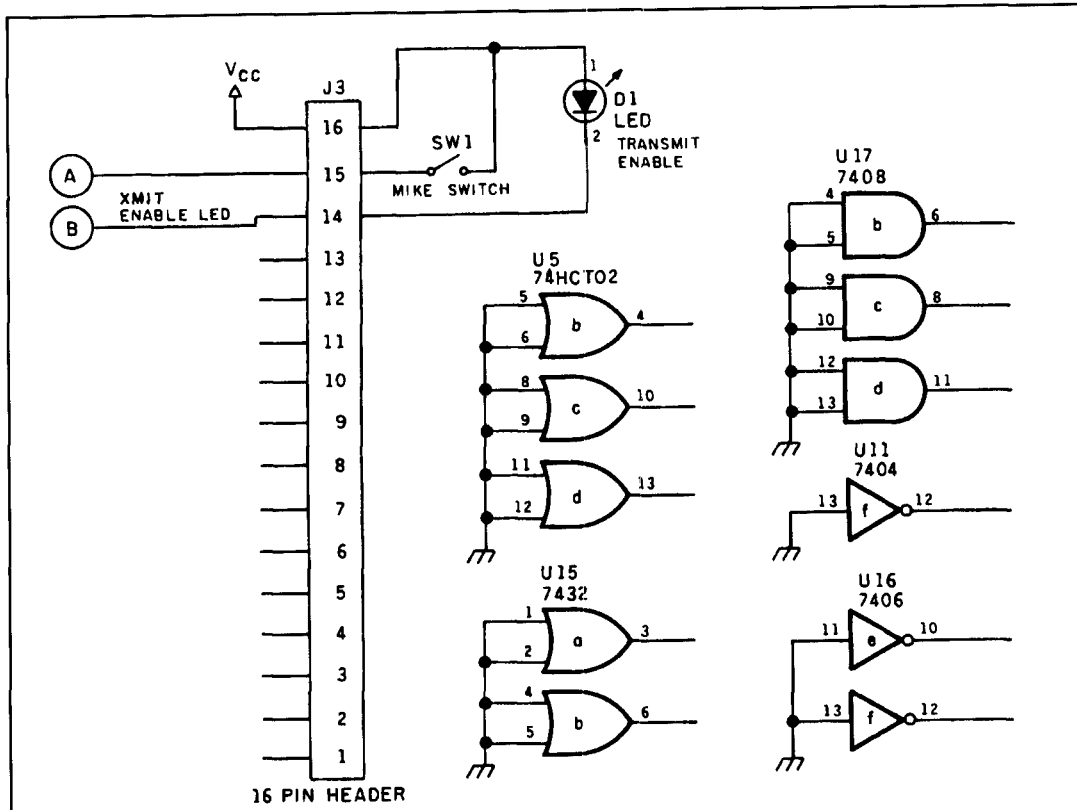
A frequency counter suitable for use in a stand-alone, non-transceiver, version of this transmitter is presented in **Figure 5**. Note that the counter must be the non-multiplexing type,

Figure 5. Frequency counter for use in stand-alone, nontransceiver version of the Transmitter.









| Switch 3 | Switch 2 | Switch 1<br>Selected | Antenna |
|----------|----------|----------------------|---------|
| Off      | Off      | Off                  | 0       |
| Off      | Off      | On                   | 1       |
| Off      | On       | Off                  | 2       |
| On       | Off      | Off                  | 4       |
| On       | Off      | On                   | 5       |
| On       | On       | Off                  | 6       |
| On       | On       | On                   | 7       |

**Table 1.** Switch settings for antenna selection.

so the BCD counter information may be used for antenna relay, sideband selection, and transmitter low-pass filter selection (See **Figure 6**).

Because 160, 80, and 40 meters are normally lower sideband, these band signals, decoded by U15, activate the lower sideband filter. On the other bands, the upper sideband is selected. A normal-inverted switch is provided to change sidebands, if desired. It's important to note that conversion in the mixer reverses sidebands; that is, the lower sideband becomes the upper sideband at the output and the upper sideband becomes the lower sideband.

## The VFO

The heart of the VFO (**Figure 2**) is a Vacker oscillator converting from 60.8 to 90 MHz. This class A oscillator is relatively stable and has minimal phase noise. It is buffered by Q6 and Q7. The VFO provides the drive to the LO port of the last mixer stage, MX-2. A 7812 voltage regulator IC, powered continuously by a wall-type plug-in power supply, powers the VFO. This ensures long-term stability and minimal drift. The VFO assembly should be mounted away from heat sources like the PA assembly.

## RF power meter

The RF detector (see amplifier assembly diagram, **Figure 4**) samples the RF out and provides a DC voltage, which is buffered by IC1b in the exciter and fed to the power meter. The trimmer capacitor is set for flat frequency response from 1.8 to 30 MHz.

The antenna selector (shown in the control logic circuit of **Figure 6**) is programmed to select one of eight antennas. An antenna can be used on one or more bands. Antenna #0 inhibits transmit. I suggest you select antenna #0 if no transmit antenna is available for a particular band. There are three BCD switches for each band. These switches select the desired antenna. Again, if you have an all-band antenna, it

can be selected for all bands by setting the dip switches in each band for that antenna. If you wish, these dip switches can be front-panel toggle switches. **Table 1** lists the switch settings. RF for the 60.8 to 90-MHz oscillator is connected to the display frequency counter. BCD output from the tens-of-MHz display is connected to U1 (**Figure 6**), and the ones-of-MHz display is connected to U2. To reiterate what was covered earlier, this information in turn selects the appropriate low-pass filter, antenna, and proper sideband (**Figure 4**). The tens-of-MHz and units-of-MHz BCD codes from the counter are converted from BCD to decimal by U1 and U2.

This decimal-based band information also drives U9 and U8c, a 9-input OR gate. The purpose is to provide an active input to U8a only when the transmitter is in an amateur band. U8a provides a transmit output if the transmitter is in an amateur band (as described), antenna #0 is not selected, and the mike button is pushed. Output is buffered by U7 and activates relays from the transmit-relay control located in the amplifier assembly.

Each "band" output drives three dip switches for each amateur band to select the appropriate antenna using **Table 1**. The three activated outputs pass through U10 and U11 to U12—a 3 to 8 line decoder. Outputs are buffered by U13 and U14 and are routed to the antenna selector relay drivers in the amplifier assembly (See **Figure 5**). One-sixty, 80, and 40 meters from each band are decoded by U15a and U15b, a three-input OR gate. This arrangement selects lower sideband for those bands and upper sideband for all other bands. SW1 reverses sideband, if desired. U16c and U16d drive Q1 and Q2 in the exciter.

The 14-volt DC power supply shown in **Figure 7** is built in a separate box so it can be used for other projects. T1 and CR1-4 provide unregulated 19 volts DC. The 723 voltage regulator drives the 2N6290 that drives four 2N3371s. The 10-k pot sets output voltage; the 50-k pot sets current limit.

## Exciter

The exciter assembly (see **Figure 2**) comprises the audio, RF generator, and logic board. This all fits in a chassis 10 by 12 by 3 inches (part no. LMB C10123).

The audio board is built breadboard style on a piece of copper-clad pc board. The logic circuits are wire-wrapped. The RF generator is built in chambers using cut pieces of pc board. This ensures that RF doesn't leak around stages. There appears to be no radiated interference, so no covers are used. However, leave the cover on the LNB box to keep RF from the

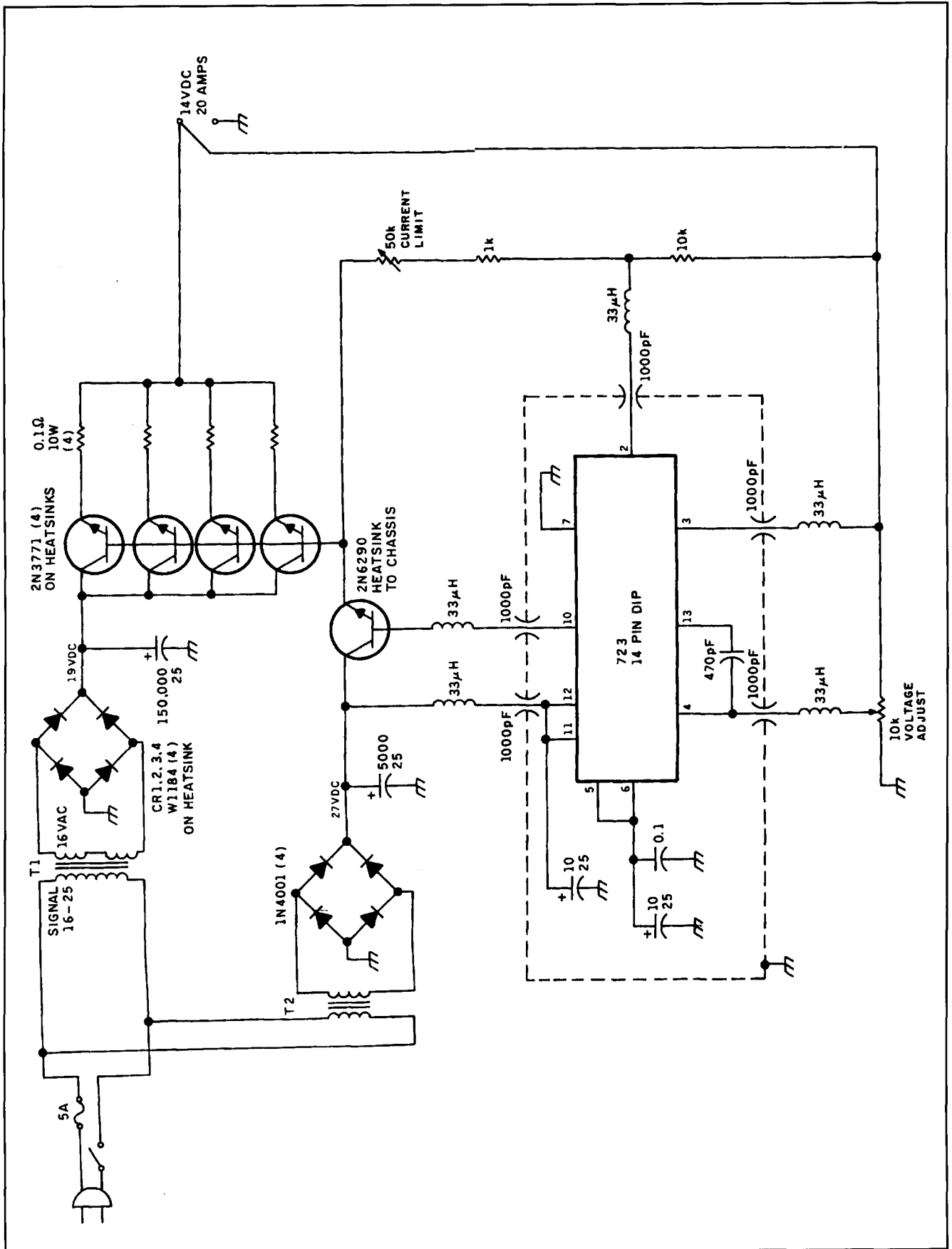


Figure 7. Power supply.

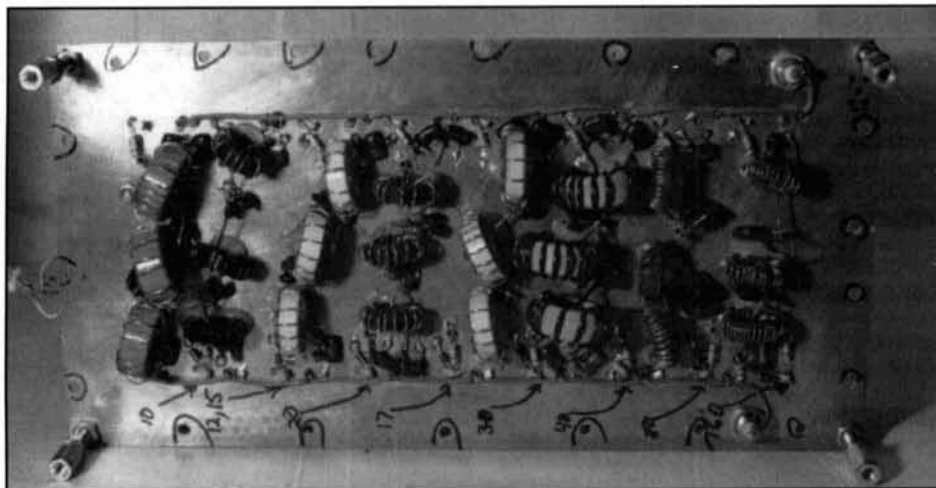


Photo A. Toroids are secured in an upright position using RTV.

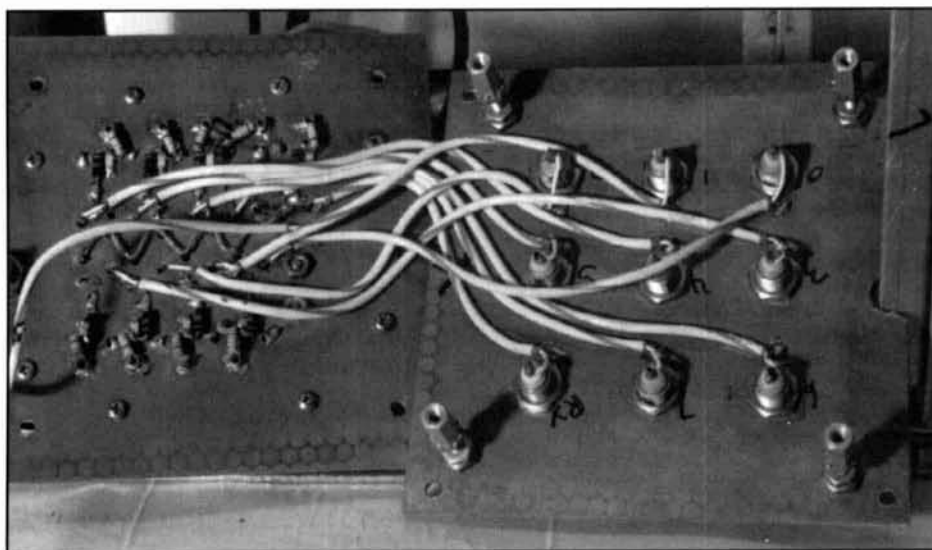


Photo B. Antenna selector construction.

antenna out of the exciter. Two DB 25 connectors, J2, connect the exciter to the amplifier assembly and two DB 15, J1 connectors are used between the exciter and counter. A 16-pin IC socket and header, J3, connects logic to the mike switch and transmit LED. The VU meter, transmit LED, mike connector, and sideband selector switch are located on the front panel.

### Oscillator assembly

The 49.3-MHz oscillator and the 61.8 to 90-MHz oscillator are built in 3 by 4 by 3-inch high cast aluminum boxes. C1 should be a double-bearing brass capacitor, with about a 200 to 1 or 36/216 to 1 reduction to the tuning knob. Power is obtained from a 15-volts DC wall adapter, so it can run continuously. This assem-

bly should be well shielded to avoid TVI. Capacitors less than 100-pF are silver micas.

### 60-MHz bandpass filter

This assembly is built on a copper-clad pc board box as shown in **Figure 3**. Use half-inch coil forms. Remove the slugs and replace them with brass disks that act as tuning capacitors. For each coil, wind 24 turns of no. 30 AWG (0.25 mm) spaced one wire diameter. To provide one wire diameter spacing, wind two wires at the same time and remove one winding.

### Low-pass filter assembly

The low-pass filter assembly is built on single-sided solid copper pc board about 6 by 12

inches. Relays are mounted on the component side of the board; most of the other parts are mounted on the foil side. Chokes and feedthrough capacitors are placed near each relay. More chokes and feedthroughs are located on a bracket on one end of the board. Secure the toroids in an upright position using RTV (see **Photo A**), but do not glue them before each filter is tested. I chose perforated aluminum for all shielding because it's easy to bend in a vice.

## Antenna selector construction

Construction of the antenna selector (**Photo B**) is similar to the filter assembly. Use two 6 by 6 inches of pc board; the extra piece is for mounting 8 BNC connectors. It would appear that assemblies in the amplifier section are overshielded. This may be true, but it's easier to overshield than to determine the location of RF leakage from one assembly to another, or the cause of TVI.

## Power supply construction

This box construction is similar to that of the amplifier box; however, its dimensions are 12 by 12 by 6 inches high. Components are mounted on the sides as shown in **Photo C**. The power transistors are mounted in pairs on approximate 6-inch length sections of heatsink. The four 1N1184s are mounted on a 6-inch long section of heatsink material.

## Setup and alignment

The test equipment required for this project is listed below:

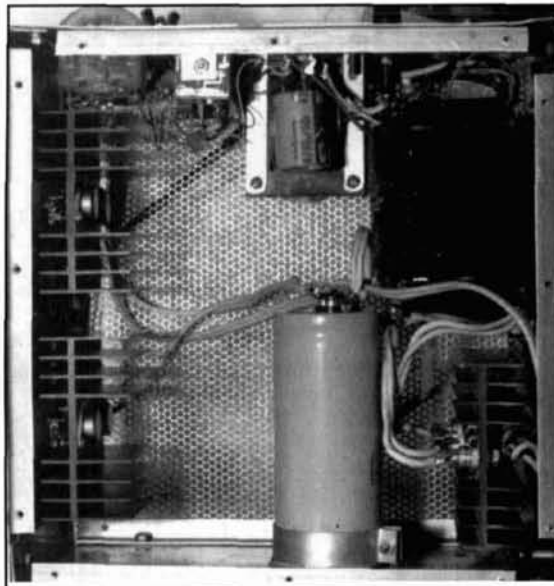
1. digital voltmeter
2. 100-MHz frequency counter
3. 100-MHz spectrum analyzer, 100-MHz scope, or 50-MHz scope
4. 100-watt HF wattmeter and dummy load
5. 2 to 30 MHz RF signal generator
6. 1-kHz audio generator

## Power supply

Set the output to 14 volts DC and the current limit pot to midrange. With a 1 to 2-ohm 100-watt resistor across the output, adjust the current control and verify that it works. Adjust the current limit for 30 amps max into a short circuit.

## Exciter

Using a DC scope or meter, check outputs U6 and U7 for the bands from 160 through 10



**Photo C.** Power supply top view. Power transistors are located on the heatsinks (left); transformer and 1N1184s are on the right.

meters. Verify outputs when selecting antennas 0 through 7. Next, connect the low-pass filter assembly and make sure the proper relays are being activated in the appropriate bands. Connect the antenna selector and verify operation of all antenna relays in all bands.

Verify LSB-USB. With the switch in norm, LSB should be active on 160 through 40 meters and USB on 30 through 10 meters. Sidebands are reversed by the exciter.

Connect a 1-kHz tone to the mike input. Adjust the 10.7-MHz oscillator trimmer for 10.7 MHz  $\pm$  10 Hz. Connect the VFO (60 to 90 MHz) and the 49.3 MHz oscillator. Verify RF levels up to FL3. Tune FL3 for maximum output. Verification levels through to the output of the exciter are as shown on the schematic. Levels will be close to what is shown, but may vary from band to band.

Note: Before applying DC voltages to the driver and PA stages, you *must* set all bias pots for minimum bias.

## Driver

Perform initial driver testing with a power supply set to limit at 1 amp. Also, to protect the MRF433s from damage, I suggest a separate 5-amp regulator for this board. You might consider using a power pass transistor controlled by a 723 or a LM338, or one of the new 4-amp IC regulators.

Connect 14 volts DC and set the MRF433 resting current for 200 mA. If a spectrum analyzer and two-tone generator are available, you can tweak the bias for the MRF433s for best

3rd order IMD. If the MHW591 is in place, it draws about 300 mA.

## Output stage

Set the resting current for about 0.5 amps—or adjust for the best IMD performance, as suggested in the driver alignment section. Forty watts, as shown on an average reading wattmeter, corresponds to 100 watts p-p.

## RF detector

On 160 meters, with a 1-kHz tone to the mike input, set the output level control for 100 watts output measured into a load with 1.1 to 1 or less SWR. Check the DC voltage from the detector with your DVM. Go to 10 meters, and the 100-watt level, adjust the variable capacitor so the DC voltage is the same as 160 meters. Check all bands to ensure the DC voltage is within 10 percent.

## Output filters

Before use, sweep the filters manually and measure the output response using a scope or a detector probe on a DVM.

For the test setup, drive the filters from a 50-ohm generator followed by a 10-dB pad to ensure proper source termination. Make sure the filters are also followed by a 10-dB pad terminated into 50 ohms. The output should be down no more than 0.3 dB (2 percent) at the band edges and 40 dB down at the second har-

monic. Fine tuning can be accomplished by spreading or compressing turns on the toroids. In some cases, you may need to add or remove a turn due to core material tolerance. After tuning, you may use silicon rubber cement to glue the toroids in place standing on end.

## Parts information

You can obtain the SBL-1 mixers, and the boards and parts for the driver and output stages, from CCI, 508 Millstone Drive, Xenia, Ohio 45385. Send for a catalog. When ordering Motorola boards, be sure to request application notes. The driver is model AN779H; the final is AN762-180. Toroidal cores are available from Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607.

Heatsink material is also available from CCI. I suggest one full section for the final amp, 1/2 section for the driver, 1/2 section for the 1N1184 diodes, and 1/2 section for the 2N3771 power supply pass transistors. You might consider scouting around flea markets or surplus stores for heatsinks to reduce the cost. Driver and final heatsinks should have fins on one side only.

## Acknowledgments

I would like to thank my friend, Marc Batten, who designed the control logic and assisted with this project. ■

### REFERENCES

1. Wayne Ryder, W6URH, "High-performance, General Coverage Communications Receiver," *Ham Radio*, November 1977, pages 10-24.

# PRODUCT INFORMATION

## New Desoldering Pumps From Tool Resource

Two new desoldering pumps from Hexacon are now available from The Tool Resource. These new desoldering pumps allow for the safe, quick removal of solder during rework. The S501AS is an anti-static desoldering pump which provides instant vacuum for safe desoldering with high impact. The heat-resistant plastic body and self-cleaning black conductive Teflon™ tip are included. The S601CD model is a conductive pump for use on static sensitive materials. A black conductive Teflon™ tip is also included.

For more information, contact The Tool Resource, P.O. Box 1106, W. Dundee, IL 60118. Phone/FAX: 708-468-0849.

## RF Vision For Windows 3.1

Pioneer Hill Software introduces RF Vision for Windows 3.1 which provides the ability to

display the RF spectrum in real-time on a computer screen.

The program works in conjunction with Science Workshop's RF Spectrum Analyzer hardware package and any Windows compatible stereo sound card. The program allows users to see if a band is "open" at a glance, or find a quiet spot on the band; sweep an area for illegal "bugs," identify modulation modes or investigate "secret" signals on the cable.

RF Vision provides a full screen spectrum display with the ability to freeze the measurement, pick off the frequencies with the mouse and print out a hard copy. In addition to the spectrum display, the program includes a 3-D surface plot and a color spectrogram of the RF spectrum over time.

For more information, contact Pioneer Hill Software, 24460 Mason Road, Poulsbo, WA 98370. Phone/FAX: 206-697-3472.



# QUARTERLY DEVICES

## *New receiver chips from Analog Devices*

Analog Devices, a corporate name long synonymous with exotic ICs for high-tech military and industrial applications, has recently announced a new line of high-performance receiver chips for cellular and other low-voltage consumer RF products. These devices feature the latest in Gilbert Cell technology from the hand of Barrie Gilbert himself, and offer many unusual features that broaden their usefulness well beyond the scope of simple handheld telephones. Analog Devices also manufactures a new high-intercept active mixer of special interest to receiver designers. In this

edition of "Quarterly Devices," I'll cover three new AD offerings; the AD607 Monoceiver, AD608 Receiver IF Sub-system, and the AD831 Low Distortion Mixer. Some technical details may be omitted in order to treat all three devices in one sitting, but complete data sheets are available directly from your AD distributor.

### AD607 Monoceiver™

The AD607 "Monceiver" is a single-conversion superhet in a single IC package, minus fre-

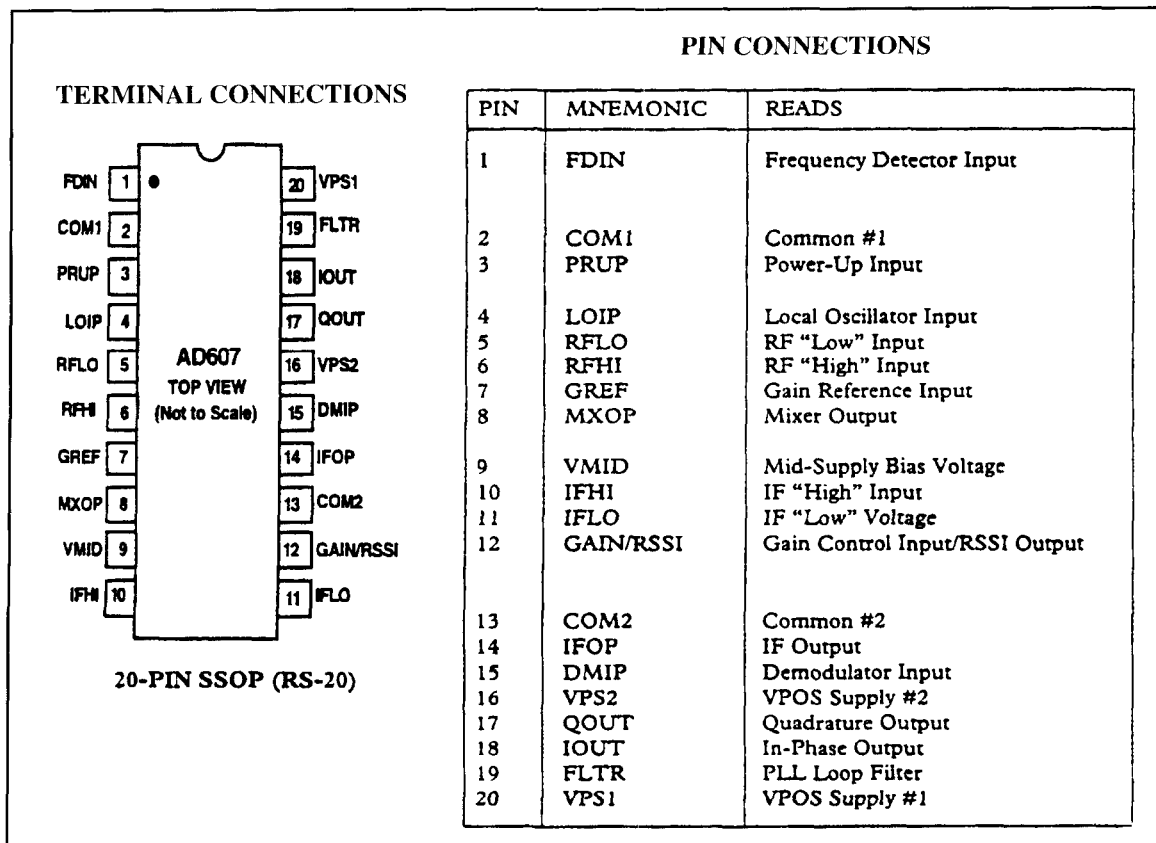


Figure 1. AD607 pinout and specs.

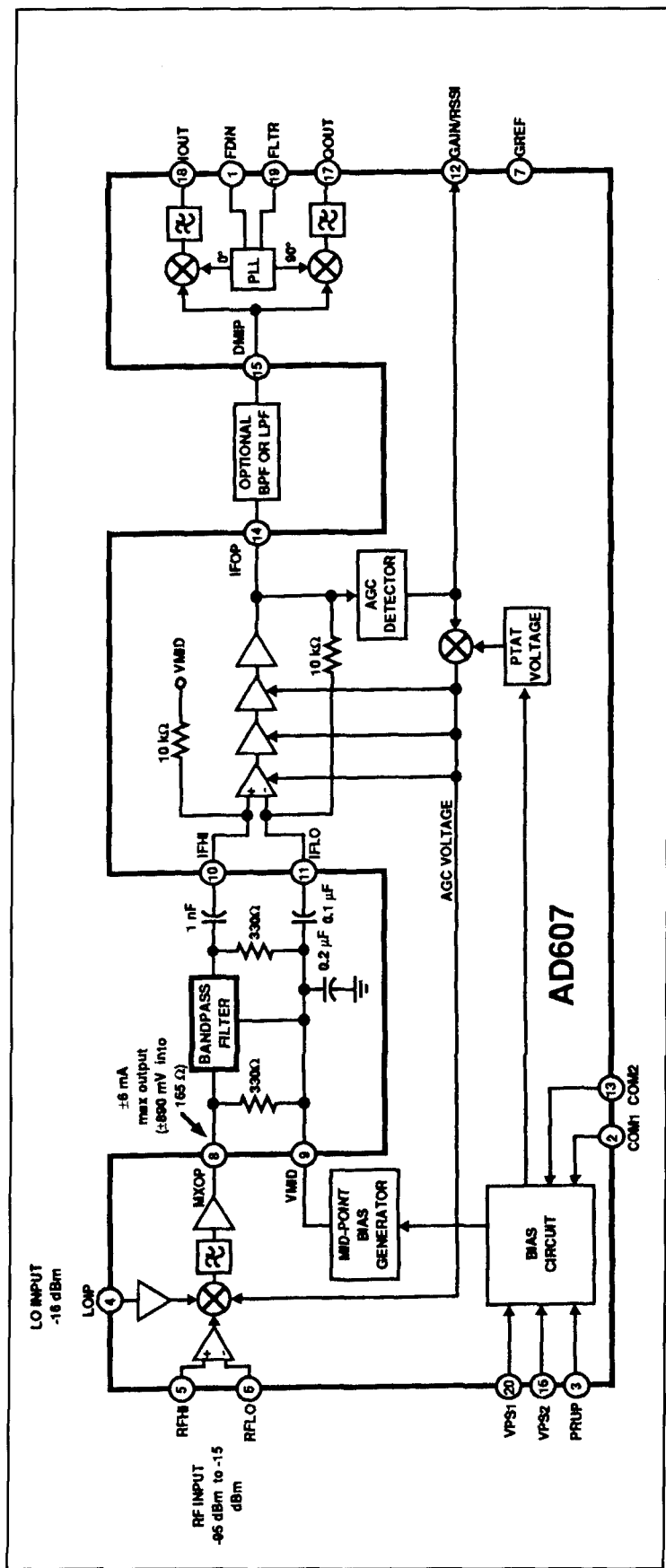


Figure 2. AD607 functional block diagram.

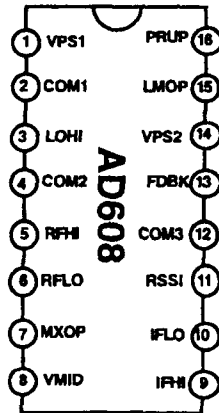
quency-control and AF power amplifier. However, this is not your typical FM-only chip! The AD607 works up into the UHF region, comes with internal I and Q demodulators and an associated carrier-recovery PLL for multi-mode detection, and features a very wide-range internal AGC system. Indeed, the AD607 is virtually in a class by itself (some AM-stereo chips have I/Q demodulation, but not the versatility and high-frequency performance of the AD607). Please refer to **Figure 1** for a run-down of the AD607's specifications and **Figure 2** for a functional block diagram.

Starting at the beginning, the AD607's Gilbert Cell DBM front-end has a frequency range extending up to 500 MHz. Amplitude response is essentially linear from -95 dBm to -15 dBm, the mixer's 1-dB compression point. Input-referenced third-order intercept (IP3) is specified at -5 dBm—several dB better than most popular active DBM's and receiver chips currently on the market. Maximum mixer gain is 23 dB.

The mixer's RF, LO, and IF ports are configured to be "user-friendly." An internal LO pre-amp reduces the external LO drive requirement to -16 dBm. This, in turn, reduces buffer and shielding requirements for the LO itself. Differential RF input permits direct interface with SAW filters (common practice when the chip is used in conjunction with a down-converter). Single-ended input may also be used with conventional bandpass filters. The mixer's single-ended IF output port can drive virtually any external IF-bandpass filter. Mixer gain is a function of transconductance ( $gmR_L$ ), and is proportional to the filter's load impedance.

Designers may select any IF frequency between 400 KHz and 22 MHz; the primary limiting factor is the range of the I/Q detector circuits. Much of the AD607's overall gain is focused in its 4 IF stages (approximately 72 dB). The chip's internal AGC system, which also provides MGC (manual gain) with external analog input, controls both mixer and IF-amplifier gain over a 100-dB range. IF amplifier output is broken out ahead of the I/Q demodulator section to permit inserting a post-IF filter. The carrier envelope of incoming AM and FM signals may also be sampled at this point for the purpose of phase-locking the detector VCO for synchronous detection. In-phase (I) demodulation is used for AM, SSB, and CW, and Quadrature (Q) demodulation is used for FM and PM. When receiving CW and SSB, the detector VCO must be locked onto an external BFO rather than to the carrier envelope of the incoming signal. For reception of more exotic digital modes like GSM, TDMA, and TETRA, the In-phase and Quadrature outputs may be routed directly to the AD70XX family of baseband converters.

## TERMINAL DIAGRAM



## ORDERING GUIDE

| MODEL                  | TEMPERATURE RANGE | PACKAGE           |
|------------------------|-------------------|-------------------|
| AD608AR<br>SOIC (R-16) | -25° to +85° C    | 16-Pin Narrowbody |

## PIN DESCRIPTIONS

| PIN | MNEMONIC | DESCRIPTION                               |
|-----|----------|---|
| 1   | VPS1     | POSITIVE SUPPLY INPUT                     |
| 2   | COM1     | COMMON                                    |
| 3   | LOHI     | LOCAL OSCILLATOR INPUT CONNECTION         |
| 4   | COM2     | COMMON                                    |
| 5   | RFHI     | RF INPUT, NONINVERTING                    |
| 6   | RFLO     | RF INPUT, INVERTING                       |
| 7   | MXOP     | MIXER OUTPUT                              |
| 8   | VMID     | MID-POINT SUPPLY BIAS OUTPUT              |
| 9   | IFHI     | IF INPUT, NONINVERTING                    |
| 10  | IFLO     | IF INPUT, INVERTING                       |
| 11  | RSSI     | RECEIVED SIGNAL STRENGTH INDICATOR OUTPUT |
| 12  | COM3     | OUTPUT COMMON                             |
| 13  | FDBK     | FEEDBACK LOOP OUTPUT                      |
| 14  | VPS3     | LIMITER POSITIVE SUPPLY INPUT             |
| 15  | LMOP     | LIMITER OUTPUT                            |
| 16  | PRUP     | POWER-UP                                  |

Figure 3. AD608 pinout and specs.

The AD607 runs on a wide range of supply voltages—from 2.7 to 6.0 volts—and has a “kill pin” for switching the device into low-current standby. The only available packaging is 20-pin SSOP (surface mount). You must use two-sided pc construction with appropriate

grounding and bypassing with any device packing this much high-frequency gain. The surface mount limitation may restrict the chip’s application to more serious manufactured products. In other words, the AD607 is probably not suitable for beginner kits or dead-bug bench pro-



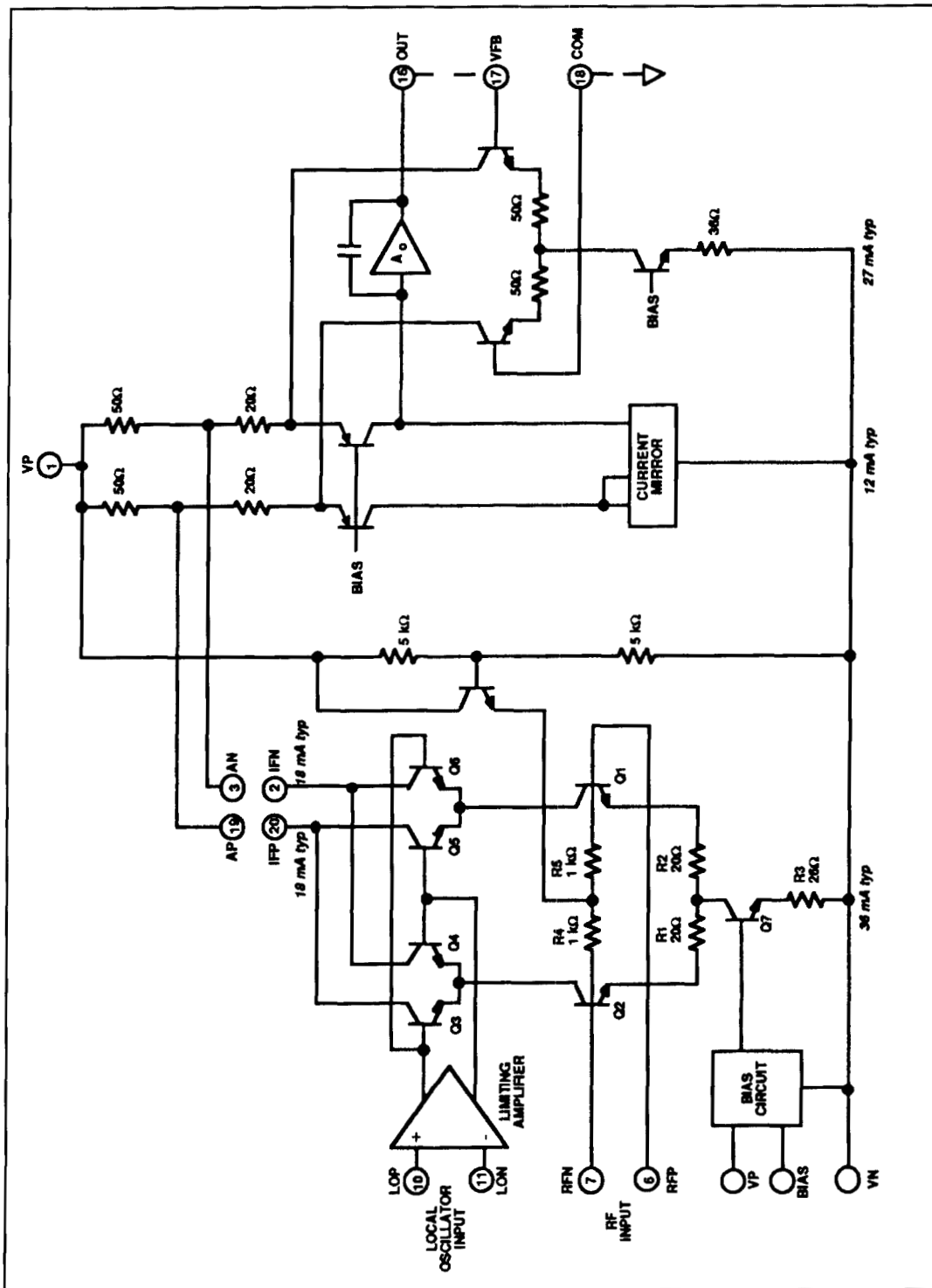


Figure 6. AD831 simplified schematic.

output drives virtually any industry-standard 10.7-MHz or 455-kHz filter (including the Murata narrowband harmonic-mode ceramics covered in the Summer 1994 "Quarterly Devices"). Any IF frequency up to 30-MHz may be used.

Once past the mixer section, the AD608 takes on an identity of its own. The 5-stage IF ampli-

er and limiter sections provide more than 100-dB of gain with a hard-limited output swing of 400-mV p-p. Phase error over an 80-dB dynamic range is stable to  $\pm 3$  degrees. Detectors for digital and analog modes are connected externally to the limiter output and RSSI as needed. For example, FM recovery requires the addition of an emitter follower and ceramic discriminator

circuit (see **Figure 4**). RSSI output is faithfully logarithmic over a 90-dB range.

Like the AD607, the AD608 runs on 2.7 to 6.0 volts and has a power-down (kill) pin to switch the device into low-current standby. The AD608 is available in 16-pin plastic SOIC only, and demands the same careful layout and construction practices as the AD607.

Applications include single and dual-conversion FM receivers, low-cost spectrum analyzers, cordless and cellular phones, data transceivers, and a host of other related applications.

## Low-distortion mixer

There's a myth among some receiver designers that passive DBMs offer the only practical approach to truly bullet-proof IMD performance. Not so! The AD831 is a low-distortion active mixer with a +10 dBm 1-dB compression point and an output-referred third-order intercept point of +24 dBm (see **Figures 5** and **6**). With that kind of headroom, it would take some pretty big guns to shoot down the AD831!

In addition to wide dynamic range, the AD831 has a very modest LO drive requirement (-10 dBm). This eliminates a lot of the shielding, buffering, and isolation normally associated with more power-hungry passive mixer designs. Being an active device, the AD831 doesn't require signal-robbing terminations and won't introduce insertion loss into your signal path (it is normally configured for unity gain). Frequency coverage is good up to 500 MHz, with a maximum IF-output bandwidth of 250 MHz.

Given the AD831's wide dynamic range, high port isolation, and raw output capability (+10 dBm undistorted output = 10 mW of drive into 50 ohms), Analog Devices recommends it for a number of other mixing applications beyond receiver front ends. For example, they suggest using it as a second mixer in DMR base stations, direct-to-baseband conversions, doppler shift detection in ultra-sound imaging, and I/Q modulators and demodulators.

The AD831 can run from a +5/-5 volt split supply or from a 9 to 10 volt single supply. When a split voltage source is used, RF, IF, and LO signals may be DC-coupled or AC-coupled. When a single source is used, signals must be

AC coupled. RF input may be either single-ended (50-ohm terminated) or differential (SAW filter interface). The IF output port is a differential open-collector configuration that permits connection of a 1:1 center-tapped IF transformer for AC coupling. Alternatively, single-ended voltage-output coupling may be used.

When it comes to powering wide-range mixers, you can't fool Mother Nature! Any active mixing device that delivers +10 dBm undistorted output into a load is going to need some juice! The AD831 is no exception, drawing around 100 mA at 10 volts. However, you can program this down to around 45 mA via an external bias pin with some reduction in IP3.

The AD831 comes in a square 20-pin PLCC package for socket or surface mount (direct surface mount is suggested for VHF layouts). Careful attention to layout, decoupling, and shielding must be observed in order to keep broadcast interference out of the mixer. Also, you must avoid introducing stray capacitance or parasitic lead inductance that could cause unwanted circuit peaking or oscillation.

## To obtain more information

For complete Application Notes, specific pricing, and sample policy on the AD831, contact your nearest Analog Devices distributor. To identify your local distributor, write: Analog Devices at One Technology Way, P.O. Box 9106, Norwood, MA 02062—or call them at (617)329-4700.

The AD607 and AD608 are both sampling, but not yet in full production. Qualified experimenters may obtain Data Sheets and samples by writing Bob Clarke at Analog Devices, One Technology Way, P.O. Box 9106, Norwood, MA 02062 (*no phone calls, please*).

## The bottom line

As usual, we welcome and encourage readers to share their ideas and designs in *Communications Quarterly*. Rumor has it that at least one AD607 receiver project is already under way and will appear in these pages in the near future. If you have designs or suggestions for using any of these devices, we'd like to hear from you as well. ■



## On the receiving end

Whether we just read about them—or actively build them—receivers and receiver circuits are one of the most popular features in *Communications Quarterly*. We have considered publishing an annual receiver-focused “Tech Notes” column for some time, but, unfortunately, most of the circuits we’ve run across have simply evolved around the now classic NE602 mixer—ladder filter—NE602 product detector “cookbook” layout.

With this issue of *Communications Quarterly*, we are pleased to offer what will hopefully become a yearly “Tech Notes” feature—the latest in receiver design trends.

Highlighting this installment of “Tech Notes” is work done by Colin Horrabin, G3SBI, who has made substantial improvements over previous work using the SD5000 DMOS quad-FET mixer with his new “H-mode” design.

Peter Bertini, K1ZJH  
Senior Technical Editor

## G3SBI's H-Mode Receiver Design

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“Technical Topics”  
Pat Hawker, G3VA, Editor  
*Radio Communications*  
September and October 1993,  
January 1994

**Notes in the** February “Technical Topics,” drawing on the long article “Recent Advances in Shortwave Receiver Design,” by Dr. Ulrich L. Rohde, KA2WEU/DL2JR (*QST*, November 1992) and the IEE’s book *Radio Receivers*, edited by Dr. W. Gosling, drew attention to current thinking on advanced, high-performance, HF receiver front-ends. It referred, in particular, to mixers and associated circuitry capable of providing excellent dynamic range. This was followed in the April “Technical Topics” by information on “An Ultra Low Distortion HF Switched FET Mixer” designed by Eric Kushnik (*RF Design*) that required significantly less oscillator power than is generally needed for mixers having a very high-order intercept point.

The subject also crops up in “A High-Dynamic Range MF/HF Receiver Front End,” by Jacob Makhinson, N6NWP (*QST*, February

1993, pages 23 to 28, with correction note *QST*, June 1993, page 73).<sup>\*</sup> In this article, N6NWP shows that “By properly applying known design principles, radio amateurs can construct a high-performance front-end which combines a very high intercept point with excellent sensitivity. Used with a low-noise LO, the front-end described in this article achieves a wide dynamic range even with its preamplifier stage in-line. A receiver incorporating such a front-end can provide strong-signal performance that rivals or exceeds that of most commercial equipment available to the amateur.”

**Figure 1** shows the essentials of the N6NWP, 14-MHz mixer (with 9-MHz IF) based on a Siliconix Si8901/SD8901 DMOS FET quad device together with a 74HC74 dual flip-flop to provide square wave LO injection from a VFO operating at about 10.5 MHz. The mixer is followed by a simple diplexer network; N6NWP also provides details of suitable high-performance pre and post-mixer amplifiers. The mixer can be used either with or without the input preamplifier which, like the post-mixer amplifier, uses two MRF586 transistors in push-pull.

Colin Horrabin, G3SBI, has been investigating in depth the N6NWP mixer (with some modifications) and finds that it is possible to achieve extremely high third-order intercept points. In fact, other parts of the circuitry, such as the diplexer or crystal filter rather than the mixer itself, tend to be the limiting factor. The following is a short summary of G3SBI’s interim report on the measured performance of his implementation of the N6NWP mixer.

“The excellent Siliconix Si8901 device (which has been replaced by the identical SD8901 available from Calogic Corporation) contains four DMOS FETs already configured for use as a commutation (switching) mixer. N6NWP utilizes this device with square wave drive to the gates of the FETs from a high-speed CMOS D-type bistable device operating somewhat unusually from a 9-volt supply. Although the intercept point as usually defined would be about 2 dB less than the +41 dBm claimed (this is acknowledged in the correction note), this is still an excellent performance.

“It was decided to construct a mixer (**Figure 2**) based on the ideas of N6NWP, but utilizing the more widely available Siliconix SD5000

<sup>\*</sup>For more on N6NWP’s work with high-dynamic range receivers see: Jacob Makhinson, N6NWP, “High Dynamic Range Receiver,” *Communications Quarterly*, Premier Issue, November 1990, pages 69-87.



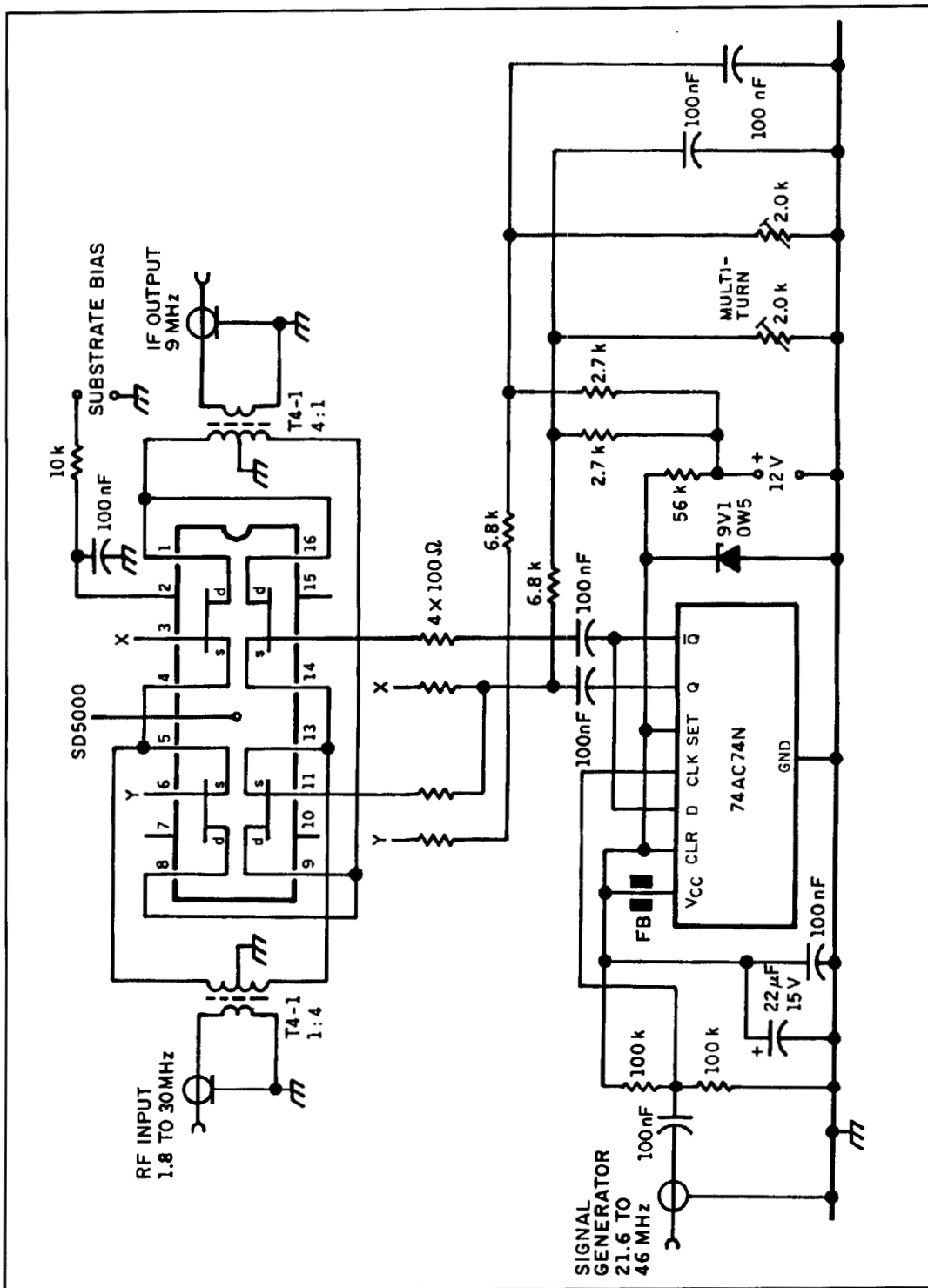


Figure 2. G3SBI's modified N6NWP-type mixer test assembly using the SD5000 FET array and 74AC74N to provide square-wave injection from a high-quality signal generator source with output at twice the required frequency.

and a gate bias of about +4.5 volts were used. Conversion loss was 7 dB. These are extremely good results.

"However (now the bad news), the intercept point degrades sharply as soon as the input signal exceeds +7 dBm (0.5 volt) which is still a big signal. It is thought that the reason for this is that the FETs that should be "off" in the

commutation ring see a negative drain-to-source signal voltage greater than -1.7 volts and start to conduct. The situation can be recovered by dropping the gate bias voltage, but it is then no longer possible to achieve the super intercepts of greater than +45 dBm. An alternative arrangement is being assembled that should make it possible to handle very large

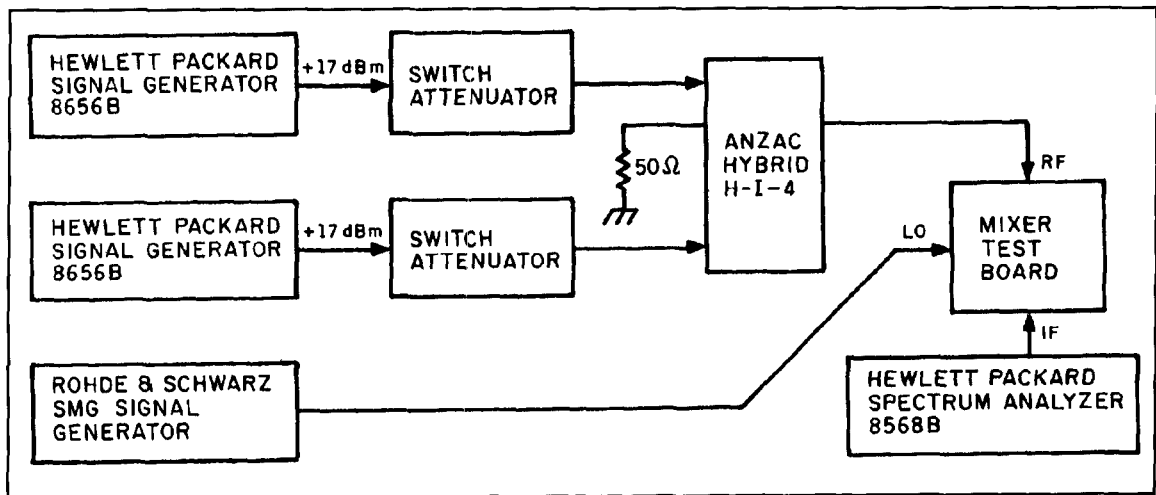


Figure 3. The test instrumentation setup used by G3SBI for intermodulation tests on the mixer.

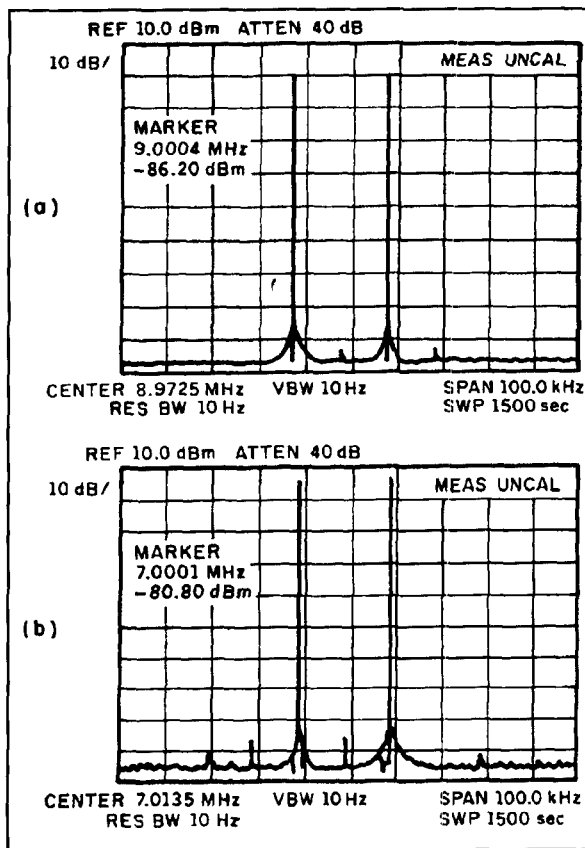


Figure 4. Spectrum analysis of the mixer performance. (A) Mixer spectrum output at 9 MHz. (B) Input to mixer at 7 MHz +7 dBm/line. Note that one of the signal generators had some low-level 10-kHz modulation to cause the larger spurious signal in (B), and this appears after up-conversion to 9 MHz in (A). The third-order distortion is on the baseline at the output of the mixer indicating a mixer input intercept point of +50 dBm.

input signal voltages without degrading the intercept points."

For the post-mixer amplifier, G3SBI uses basically the same circuit as N6NWP, but with some subtle changes (Figure 5) that have

improved performance in terms of gain and output intercept point, and has a noise figure of 0.5 dB. "An important change was the use of the MRF580A transistor instead of the MRF586 since this should give a lower noise figure at a collector current of 60 mA." Measured performance of the amplifier gave gain as 8.8 dB, output intercept +56 dBm, noise figure 0.5 dB. G3SBI points out that with intercepts of this magnitude it is important to remember that the measuring equipment is being pushed to the limit, and transformers must be looked upon as possible sources of limitations in overall linearity. Also that, unfortunately, the measurements are for operation into a resistive load. In practice, the crystal filter driven by the post-mixer amplifier would present a complex impedance to the amplifier. Particularly on the slope and near the stopband, this would seriously degrade the amplifier performance.

G3SBI has also investigated the performance of quadrature hybrid 9-MHz crystal-filter combinations and finds that the performance of budget-priced crystal filters is a serious limitation. He found that this can be reduced by eliminating the post-mixer amplifier, with the mixer going immediately to a quadrature hybrid network 2.4 kHz-bandwidth filter, followed by a low-noise amplifier. In this case, the 2.4-kHz filter is, in effect, used as a roofing filter. With such an arrangement, assuming the effective noise figure to be 5 dB due to the filter and amplifier, another 7 dB from mixer loss, and a further 1.5 dB loss due to the antenna input bandpass filter, this gives an overall noise figure of about 13.5 dB [sufficient sensitivity up to at least 14 MHz—G3VA] The intercept point on 7 MHz would then be about +51.5 dBm. Nevertheless, G3SBI comments that "This is not the ideal solution since slightly better intercepts could have been obtained by the conventional (post-mixer amplifier) arrangement with

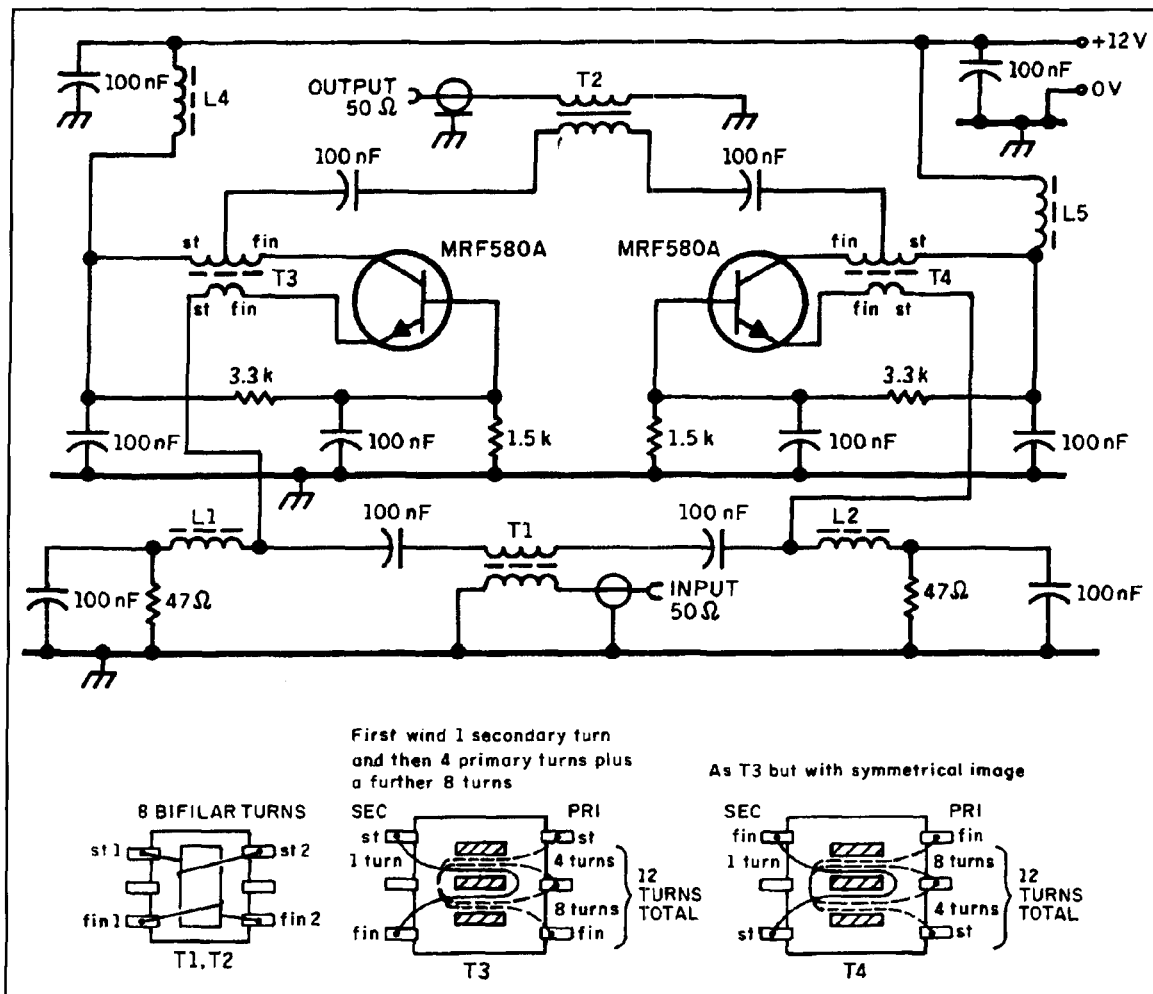


Figure 5. G3SBI's modified post-mixer test amplifier adapted from the N6NWP design but using MRF580A devices. All resistors are 0.25 watt metal-film RS Components. All 0.1  $\mu\text{F}$  capacitors are monolithic ceramic RS Components. L4, L5: 4 turns of 0.315 mm diameter Bicflux wire on RS Components ferrite bead. L1, L2, T1, T2, T3, T4 on balun core Fairite 28-43002402 (Circuit components). L1, L2: 6 turns 0.315 mm diameter Bicflux wire RS Components. T1 to T4, use 40SWG Bicflux wire. Take two glass fiber Cambion 14-pin DIP component headers, cut each in two parts and bend the tags 90 degrees outward. Stick a piece of double-sided tape onto the header and mount the balun cores on this. Wind the transformers as shown above. The amplifier is constructed with earth-plane layout.

a filter having an intercept figure of +55 dBm."

In conclusion, G3SBI writes: "One might ask the question does one need input intercepts of +50 dBm? For amateur purposes the answer has to be the higher the better. [But note that the April "Technical Topics" quotes G3RZP as believing that 'a +20 dBm third order intercept appears adequate, even on 7 MHz at night'—G3VA]. The name of the game is to be able to copy a submicrovolt signal in the presence of a heavy hitter a few kHz away from the desired signal. In addition, on 7 MHz the proximity of the broadcast band is a problem with antenna signals greater than -10 dBm present at times. Extreme linearity is thus desirable if a submicrovolt signal to be copied in these circumstances.

"The fact that the intermodulation performance of the crystal filter can be a serious problem at these intercept levels was no com-

pletely unexpected. The effects of this can be minimized as described by omitting the post-mixer amplifier, but filters with +55 dBm intercepts would enable the construction of a high-performance front end with a post-mixer amplifier. It may be worth considering the use of homemade crystal ladder filters as part of a quadrature hybrid arrangement since no transformers are used, suggesting that the intercept figure could be high, although this has not yet been checked. In addition, the low insertion loss of some ladder filters (about -2 dB) would permit higher IF-stage noise figures.

"The mixer remains the most critical device if input intercepts of +50 dBm are to be obtained on 7 MHz. This performance has been achieved with all SD5000 chips of batch 9042 that were available; one from batch 9024 did not meet this figure on 7 MHz, achieving +44 dBm.

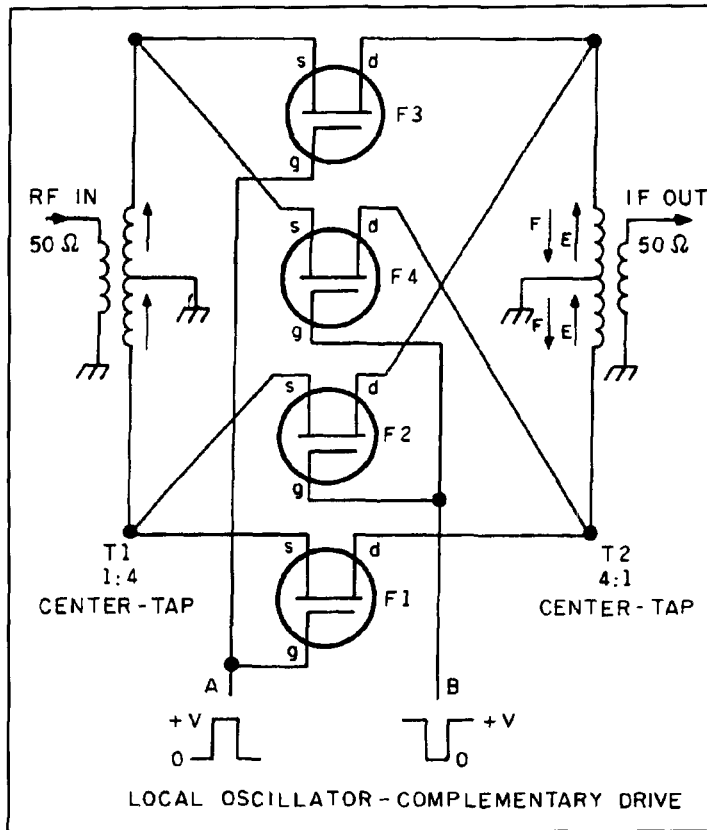


Figure 6. Conventional commutation mixer arrangement based on quad-FET array.

"To summarize, Jacob Makhinson, N6NWP, has pointed the way ahead for home construction of very high-performance HF receivers using a 9-MHz IF. Given that, at a price, high-intercept filters are obtainable, the linearity of the mixer itself is still the limiting factor."

G3SBI next draws attention to published information on quadrature hybrids, including an article "Twisted-Wire Quadrature Hybrid Directional Couplers," by Reed Fisher, W2CQH, that appeared in *QST*, January 1978, pages 21-23 with the subheading: "That title scare you off? Well, don't let it. Just read this and we'll make believers out of you." In the article, W2CQH points out that 3-dB directional couplers or quadrature hybrids for paralleling UHF amplifiers or for achieving circular polarization are commonly implemented in stripline but that "unfortunately, the UHF strip-line models cannot be scaled down to the HF bands since their dimensions become prohibitively large." His article shows how compact, low-cost, lumped-element, quadrature hybrids can be easily constructed for use in the HF amateur bands.

G3SBI then considers N6NWP's method of controlling the impedance seen by the post-mixer amplifier. A 6-dB attenuator between amplifier and mixer has a significant effect on the system noise figure as seen at the input to

the post-mixer amplifier. This is especially so with the 5 dB or 10 dB insertion loss of a narrowband CW crystal filter. He believes that a better solution (if the additional expense is acceptable) is to use two identical filters, in addition quadrature hybrids. His experimental work shows that satisfactory results can be obtained in this way with 9-MHz narrowband filters. But the use of two commercial crystal filters would represent a significant additional cost although this approach, using home-built ladder filters, might be feasible for someone determined to achieve +50 dBm intercept points range on all bands. It must be stressed that performance of the standard being investigated by G3SBI calls for high-quality (although not necessarily high-cost) components and diode-ring mixers. Development work also involves measurements close to, or beyond the limits of, professional-standard test equipment.

### G3SBI's High-Performance Mixer

In presenting information on this new mixer configuration, it should be made clear that Colin Horrabin, G3SBI, is a professional scientist/electronic engineer at the Science and Engineering Research Council's Daresbury Laboratory, which has supported his investigative work on the H-mode switched FET mixer and consequently holds intellectual title to the new mixer. This does not, of course, prevent readers from taking the development further or using the information presented here.

G3SBI writes: "The previous information covered an investigation of all the component parts of a high-performance front end, including a note on the limitations of the crystal filter intercept point. Although the intercept point of the filters readily available on the UK amateur market appeared to limit the performance of a front end to some degree, this could be made compatible with high-performance mixers if no post-mixer amplifier was used in front of the filter and a quadrature hybrid network with two low-loss SSB filters immediately followed the mixer. The SD5000 DMOS FET mixer described earlier followed basically accepted practice in commutation (switching) mixers and achieved a +50 dBm input intercept point on 7 MHz with the use of square-wave drive.

"However, as noted, it was not possible to achieve this performance on all amateur HF bands, including bands lower and higher in frequency than 7 MHz. The results were improved on the lower frequency bands by altering the capacitive balance of the RF input transformer, but this had no significant effect on 14 MHz and above. It was felt that a configuration for the mixer where the RF input signal was not in the gate source switch-on path would prevent

modulation of the true gate-to-source local oscillator voltage by the RF input signal.

"The performance of the new mixer is as follows: With an RF test level of +11 dBm (0.8 volts rms two tones spaced at 2 kHz or 20 kHz); conversion loss 8 dB; RF to IF isolation -68 dB; LO to IF isolation -66 dB. Input intercept points: 1.8 to 18 MHz +53 dBm; 21 to 28 MHz +47 dBm or better; 50 MHz +41 dB. These results were achieved with a gate-to-source DC bias of 1.95 volts and -8 volt substrate bias, a square-wave oscillator amplitude of 9 volts and an IF at 9 MHz.

"Figure 6 shows a conventional commutation ring mixer: if A is 'on', FETs F1 and F2 are 'on' and the direction of the RF signal across transformer T2 is given by the 'F' arrows. The main deficiency of this classic circuit is that as the RF input signal level increases, it has a significant effect on true gate-to-source voltage needed to switch the FET 'on' or keep it switched 'off'. Larger local oscillator amplitudes are then required, but linearity problems may still exist because of the difference between negative and positive RF signal states.

"The alternative arrangement is shown in Figure 7. The shape of this diagram illustrates why the new mixer has been named 'H-mode'. Inputs A and B are complementary square wave inputs derived from the sine-wave local oscillator at twice the required frequency. If A is 'on' then FETs F1 and F3 are 'on' and the direction of the RF signal across T1 is given by the 'E' arrows. When B is 'on', FETs F2 and F4 are 'on' and the direction of the RF signal across T1 reverses (arrows 'F'). This is still the action of a commutation mixer, but now the source of each FET switch is grounded, so that the RF signal switched by the FET cannot modulate the gate source voltage.

"In this configuration the transformers are important: T1 is a Mini-Circuits type T4-1; T2 is two Mini-Circuits T4-1 transformers with their primaries connected in parallel. It is possible that a special five-windings transformer might give even better results, but so far the intercept points achieved with a homemade transformer have been unsatisfactory; it is probably a question of having the right ferrite material. However, the parallel-connected transformers give good balance and perform well.

"The practical test circuit is shown in Figure 8. It is constructed on an earthplane board and all transformers and ICs are mounted in tuned pin DIL sockets. The printed circuit tracks connecting T1 to T2 and from T2 to the SD5000 are kept short and of 0.015-inch width to minimize capacitance to ground. Operation is as follows: The local oscillator is divided by two in frequency and squared by a 74AC74 advanced CMOS bistable similar to the SD5000 mixer

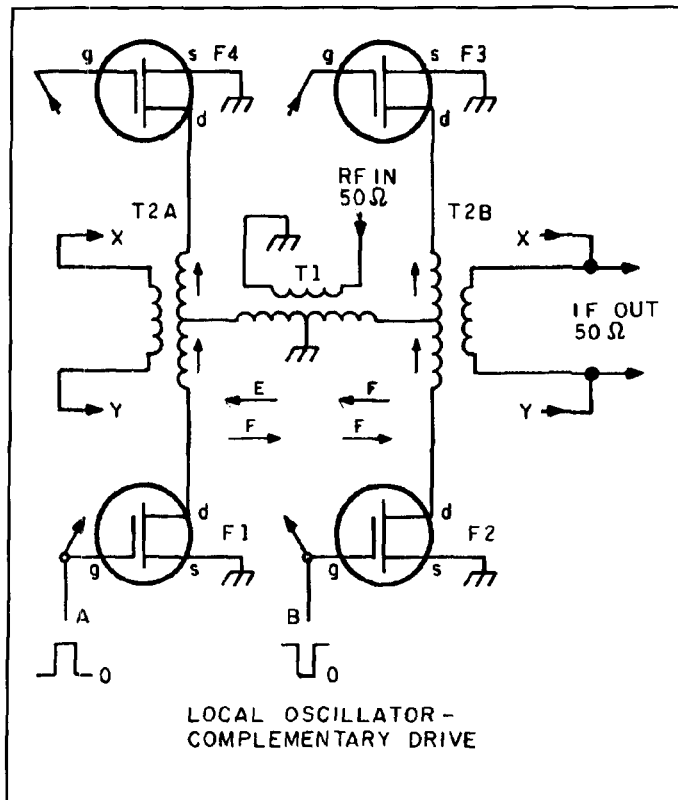


Figure 7. The new "H-mode" commutation mixer.

describer earlier. However, the bistable is run from +10 volts instead of +9 volts and a cut-down RS Components ferrite bead is inserted over the ground pin of the 74AC74 to clean up the square wave.

"The professional test equipment setup used to determine the H-mode mixer intercept points was the same as that noted for the N6NWP-type mixers, including two Hewlett-Packard signal generators and a spectrum analyzer, and a Rohde & Schwarz SMG signal to provide the LO sine wave input.

"The best method of setting the gate bias potentiometers proved to be as follows: One is set to the desired bias voltage for a specific test run, the other is then set by looking at the RF-to-IF path feedthrough on the spectrum analyzer at 14 MHz, and adjusting the potentiometer for minimum IF feedthrough. The setting is quite sharp and ensures good mixer balance.

"An RF test signal of 11 dBm (0.8 volts rms) was used for each test signal for the two-tone IMD tests. The results obtained were the same with 2 kHz and 20 kHz tone spacing [an indication of the purity of the LO source]. All the major HF amateur bands were used as RF sources in these tests and the spectrum analyzer results recorded. The gate bias level chosen enabled an input level of +12 dBm to be reached before the IMD increased sharply, breaking



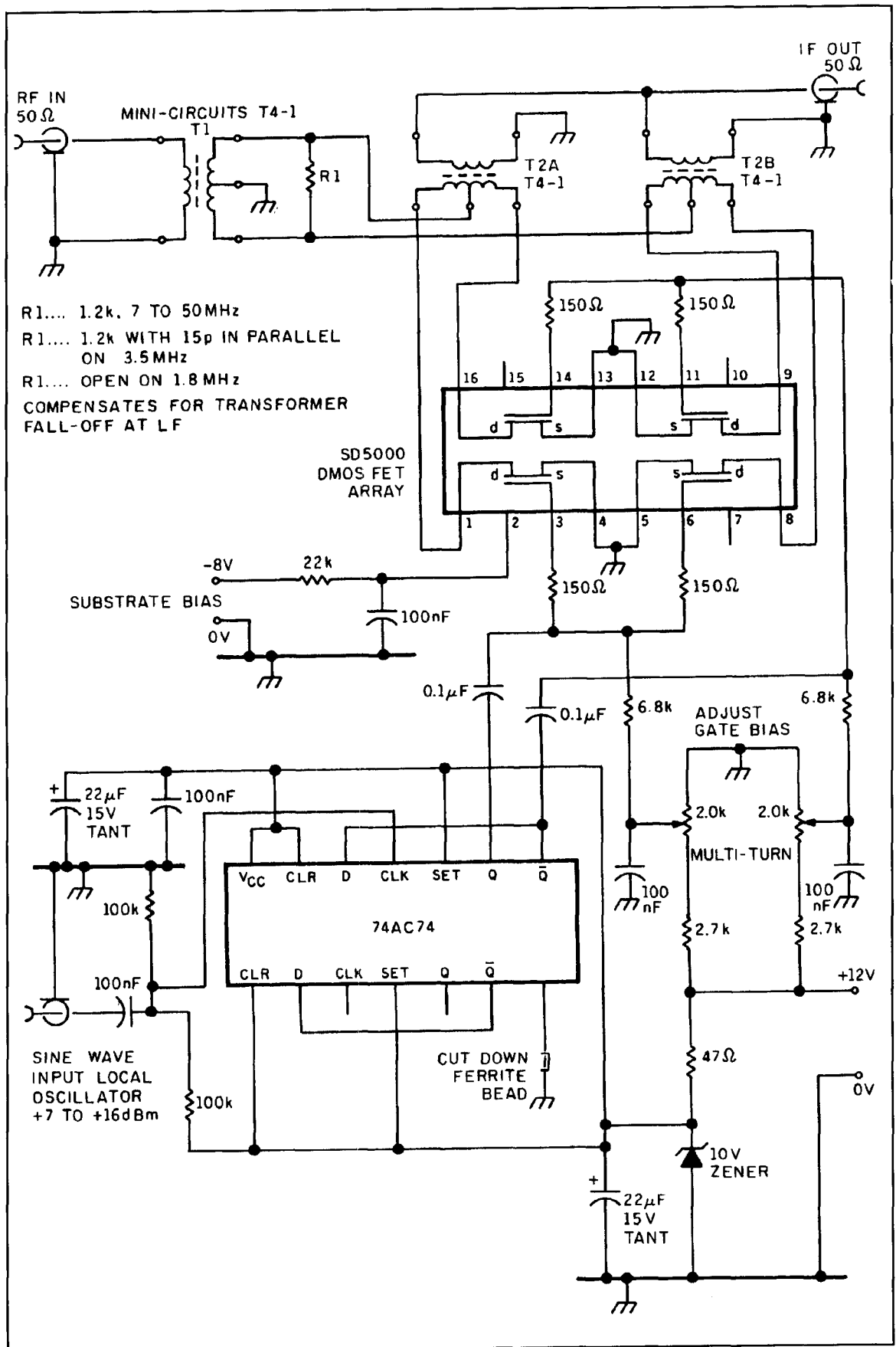


Figure 8. Test assembly for "H-mode" mixer as investigated by G3SBI.

away from the normal 3:1 slope on a log plot.

“Spectrum plots for 14 MHz and 50 MHz are shown in **Figure 9**, indicating input intercept points on these bands of +53 dBm and +41 dBm, respectively. These are excellent results, but is it probable that even larger RF input signals might be handled with a lower gate voltage bias and a larger amplitude square wave injection. The use of the 74AC74 bistable as a square-wave generator is convenient, but the characteristic curves of the SD5000 suggest that a high gate-to-source ‘on’ voltage would give a superior FET ‘on’ resistance for positive and negative drain-to-source signal voltages, possibly giving even better linearity, particularly on 50 MHz.”

G3SBI also concludes that an H-mode mixer does not have to be driven from a square-wave drive and suggests that it is likely that good results could be obtained with transformer-driven sine waves provided the injection was via capacitors so that the bias pots could still be used. Similarly he believes there is no reason why such a mixer should not be used in an upconversion arrangement (rather than the 9 MHz IF used with both his N6NWP-type and H-mode test mixers) as employed today in most factory-built receivers. The same approach could probably be applied at VHF/UHF with resonant-lines and GaAsFETs as switches. He is convinced that his work proves that the H-mode FET switching mixer is capable of extremely good intermodulation performance at HF with a 9-MHz IF and merits further investigation for other applications. Development of the H-mode mixer has been a sideline to his professional work at SERC and it is unlikely that he will take its development further. However, he feels he has enough information to design a complete high-performance HF receiver, after first building and testing the necessary antenna input bandpass filters to ensure that they have intercept points in the +60 dBm region.

Some initial tests by G3SBI with a simple two-crystal 9-MHz ladder filter suggest that this approach is likely to overcome completely the intercept limitations of most available lattice-type crystal filters.

## Crystal Filters for High-performance Mixers

Earlier in this article, G3SBI referred briefly to the problem that as the intercept point of the mixer is raised, a limitation to overall performance of the receiver is likely to be set by the linearity of the crystal filters available on the amateur market.

This was also mentioned in connection with the N6NWP mixer; as a result of which Peter Chadwick, G3RZP, wrote: “IMD in filters

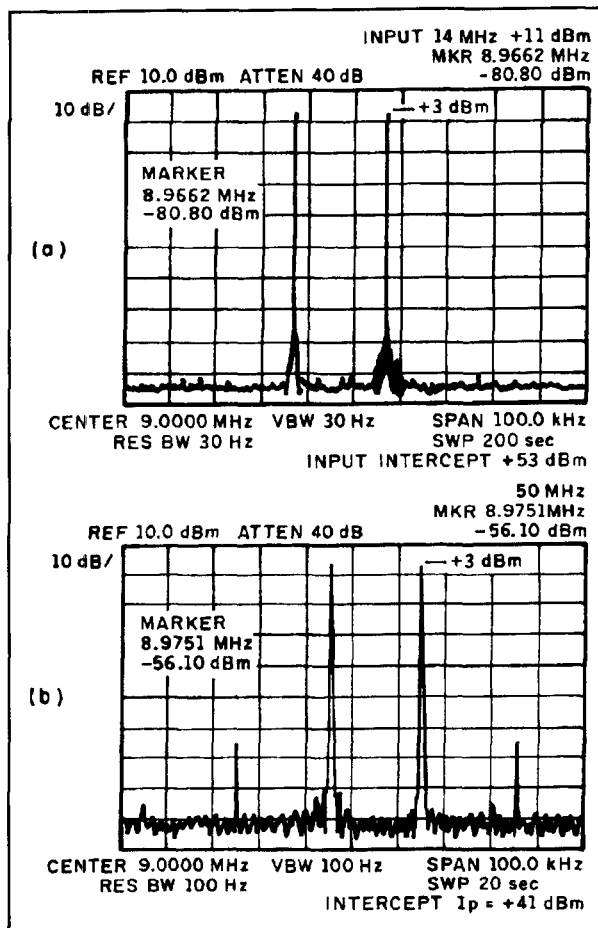


Figure 9. (A) 14-MHz input intermodulation spectrum for output at 9 MHz of the “H-mode” mixer showing an input intercept of +53 dBm. (B) 50-MHz input spectrum showing an input intercept of +41 dBm.

should not come as a surprise. It was first mentioned in a paper by Malinowski and Smythe of Motorola in a paper at the 1973 Frequency Control Symposium; the next known mention was in “Technical Topics” in July 1977, page 53 in a letter I wrote which appeared under the heading ‘Receiver IMD and crystal filters’ and which began ‘We all like to think that quartz crystal filters are passive, linear, reciprocal, two-port networks. In practice they are two-port and passive; but they are far from linear or reciprocal! Typically an HF SSB crystal filter will have an intercept point of +15 to +18 dBm. Turning it round will often alter the intercept point. The IMD products in the passband are more of a problem than those removed by 10 or 20 kHz...’

“Since then, the problem has become ‘recognized’ professionally. Incidentally SAW filters are very good because they don’t stress the quartz, while transformers have no effect unless they are badly designed. The main cause of IMD appears to be the electric field stressing the crystals beyond the point where Hooke’s Law holds, and this explains why higher fre-

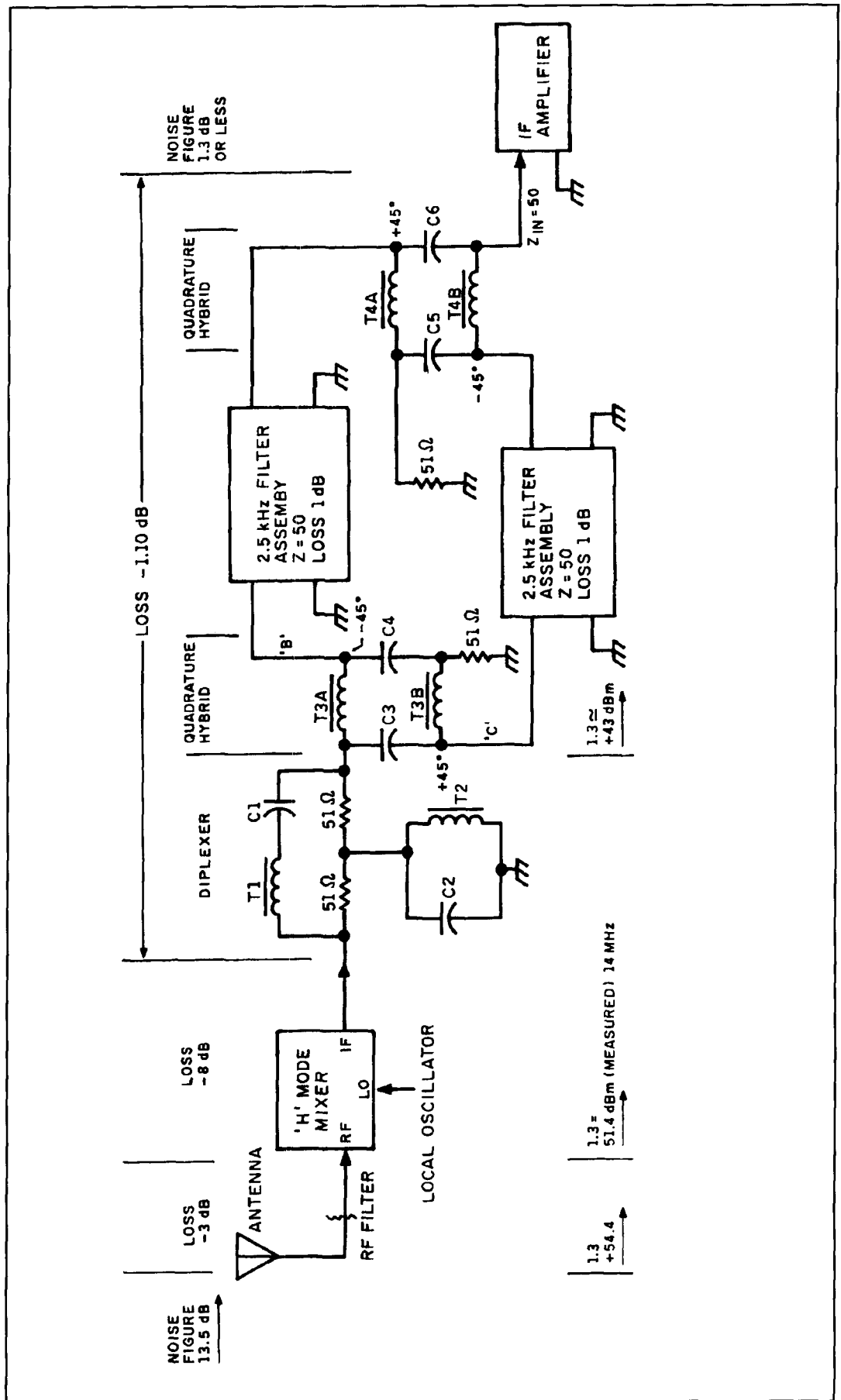


Figure 10. High-performance front end based on the G3SBI, H-mode mixer and low-loss 9-MHz crystal-filter system without a post-mixer amplifier. 13.5 dB noise figure. Component details: C1, C2 330 pF + 18 pF Suflex. C3, C4, C5, C6 150 pF + 15 pF Suflex. T1, T2 (0.88  $\mu$ H) 16 turns of 0.5 mm (Bicelflux RS Components) wire on Fairite T50-10 toroid (Cirkit components). T3A, T3B, T4A, T4B (0.88  $\mu$ H 16 bifilar turns of 0.31 mm Bicelflux enameled copper (RS Components) on T50-10 toroid (twist wires together using hand drill to a twist of about 1 turn on 0.1 inch). The 2.5-kHz filter assembly is shown in Figure 11.

quency filters are worse than low-frequency filters; the crystal is thinner, so the volts/mm exceeds the point where Hooke's Law applies at a lower voltage.

"A more pertinent point in connection with the latest high-performance mixers is whether their good intermod performance can be used in practice. In a well-designed receiver, the IF selectivity, the phase noise, and the IMD-limited instantaneous dynamic ranges should be the same. Thus in a receiver with a 10-dB noise figure, a 2-kHz wide IF has a noise floor of -131 dBm. If the intercept figure is +40 dBm, two signals at -17 dBm will produce an IMD product at the noise floor. For the phase noise from a 17 dBm signal to equal the noise floor, the phase noise must be 147 dBc/Hz (this is derived from the intermod ratio, 114 dB), plus the bandwidth ratio—in this case 33 dB). Getting -147 dBc/Hz from an HF/VHF oscillator (especially a synthesizer) is not easy, particularly close in, such as at 20 kHz spacing, even if you spend 10,000 pounds on a good signal generator! So extremely good mixer performance is not in practice usable: the designer is up against the classic problem of improving one thing and then needing to improve another."

Colin Horrabin, G3SBI, accepts that if the performance of his H-mode mixer is to be

translated into a practical super-linear receiver, then new thinking must be applied to both the IMD performance of crystal filters and to reducing the phase-noise of synthesized oscillators (with the more ready availability of direct-digital-synthesis, DDS, chips). As a start, he has been investigating the performance of 9-MHz post-mixer low-loss crystal ladder filters. The following notes are based on his report of this work carried out at the SERC Laboratory:

The H-mode FET switching-mode mixer has been shown to be capable of a +53 dBm input intercept. However, experimental measurements have also shown that the input intercept of budget-priced half-lattice-type crystal filters available in the UK were not up to this performance, but that the ladder-type filter might give better performance, although at that time no detailed measurements had been made:

"A number of stock 9-MHz crystals (ref A164A) were purchased from IQD Ltd. (Crewkerne, Somerset). This crystal is specified as 9 MHz with 30 pF parallel capacitance and is in an HC49 holder. Measurements have shown that series resonance is about 8.9975 MHz, so that ladder filter designs need a series capacitor for each crystal to move the passband center frequency to exactly 9 MHz. An important measurement showing the high quality of these crystals is that the series resistance is typically under 9 ohms, enabling very low-loss ladder filters to be constructed: less than 1 dB insertion loss for 2.5 kHz bandwidth, -60 dB 15 kHz, ultimate attenuation -80 dB, Rt 450 ohms.

"Measurements made on a number of ladder filters of different bandwidth using these crystals have enabled a typical input intercept for the filter of +40 dBm to be achieved with input signals of 0 and +10 dBm (still showing a 3:1 slope on a log plot). This is about the same as good commercial 9-MHz SSB filters made for the amateur market by IQD Ltd. If such a filter

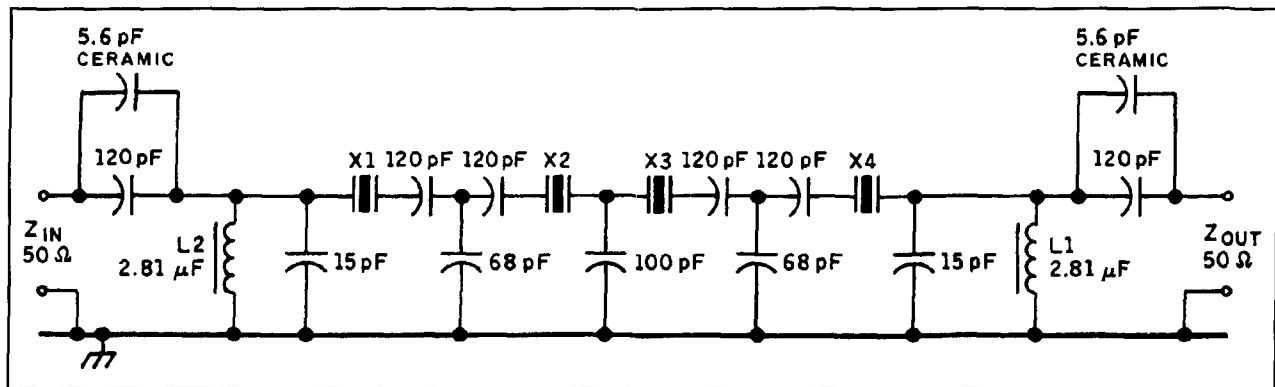


Figure 11. 2.5-kHz crystal filter assembly (SSB). Components X1, X2, X3, X4 IQD (Crewkerne) stock No. A164A 9-MHz 30-pF parallel resonance HC49 holders. All capacitors except 5.6 pF ceramic 2.5 percent Suflex. L1, L2 (2.81  $\mu$ H) 31 turns of 0.31 mm diameter Bicelflux wire (RS Components) on Fairite T37-6 toroids (Cirkit components).

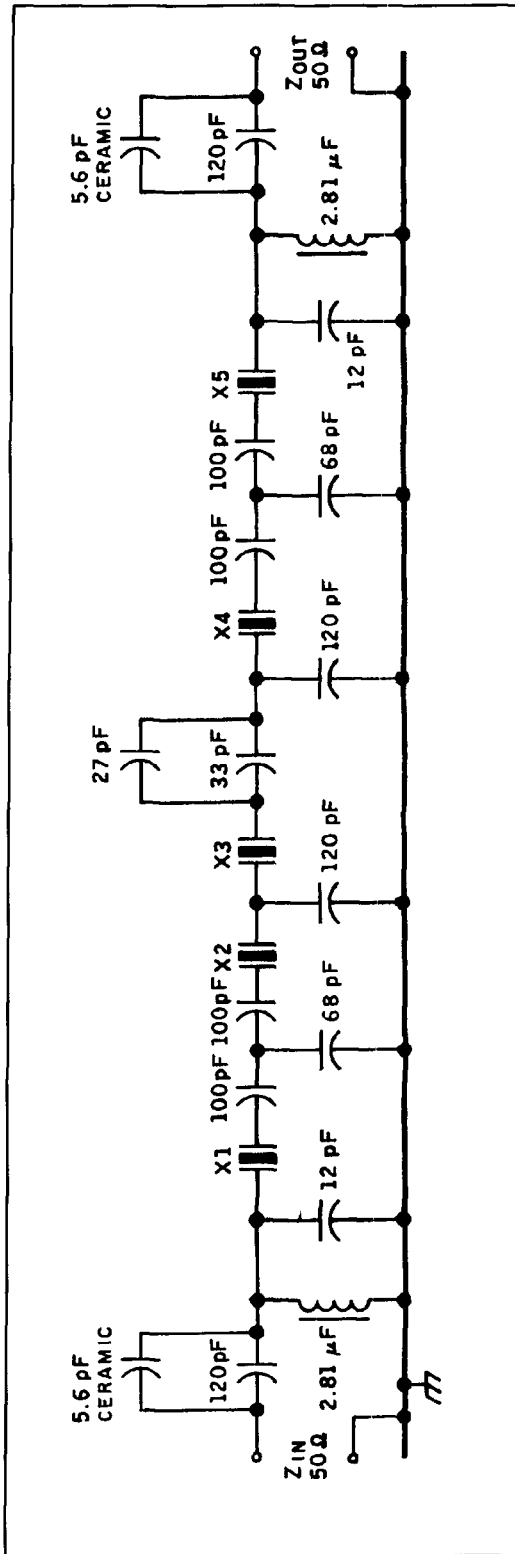


Figure 12. Five-section ladder filter (SSB). Performance -6 dB at 2.2 kHz, -60 dB at 8.5 kHz, insertion loss 1.4 dB, ultimate stopband -95 dB. Components X1-X5 IQD Stock No. A164A (9.0 MHz in parallel with 30 pF). All capacitors 2.5 percent Suffix except those shown as ceramic. Inductors (2.81  $\mu$ H) 31 turns 0.31 mm diameter Bicelflux enameled copper (RS Components) on T37-6 toroids (Cirkit components).

were used with the H-mode mixer plus a 10 dB-gain post-mixer amplifier, the effective mixer input intercept would be reduced from 53 dBm to about +38 dBm. A better approach is to eliminate the post-mixer amplifier and instead go straight from the mixer into a homemade ladder-filter quadrature hybrid assembly as shown in **Figure 10**. The quadrature hybrid and diplexer system will always present a 50-watt termination to the mixer, masking the impedance changes of the crystal filter with frequency. Using the design approach shown in **Figure 10** enables an antenna input intercept of about +54 dBm for a noise figure of 13.5 dB to be achieved, giving a two-tone dynamic range of 120 dB for a 2-kHz bandwidth. This could be increased to about +56 dBm if crystals of better intermodulation performance could be obtained, but this slight improvement would not really justify the likely cost compared with the stock IQD crystals used.

"Ideally, the output load to the low-noise post-filter IF amplifier should be of better shape-factor SSB and CW filters than can be expected from low-loss ladder filters. However, if this amplifier could be configured as a cascade-connected dual JFET, AGC could be applied fairly easily since the amplifier itself is likely to have an output intercept of some +30 dBm. If the gain were 20 dB, its input intercept would be +10 dBm so that coming down the slope of the ladder filter by 30 dB (with a filter input intercept of +40 dBm) the antenna intercept figure would be +54 dBm for interfering signals more than 3 kHz off the receiver tune frequency using a four-section SSB ladder filter. Performance would degrade closer to the tune frequency giving an in-band intercept of about +20 dBm at the antenna. This approach could prove an acceptable compromise to avoid the complication of high-intercept amplifiers based, for example, on 7-GHz transistors with feedback and PIN diodes for AGC control.

"Improvements to the close-in intercept figures for both SSB and CW could be obtained by having post-mixer ladder filters with selectable bandwidth. It is possible that a five-section SSB ladder filter could be standard (1.4 dB loss) with a 600-Hz ladder for CW (3 dB loss). However, it should not be forgotten that a local oscillator system with compatible phase-noise performance (better than 150 dBc/Hz) would be needed if this degree of close-in signal path is to be achieved.

"All of the ladder-filter designs used for these measurements were based on the information in *Amateur Radio Techniques*, 7th edition, pages 68-69, stemming from an article by J. Pochet, F6BQP, in *Radio-REF* (May 1976) and are maximally flat designs. Jack Hardcastle, G3JIR, has found that the original

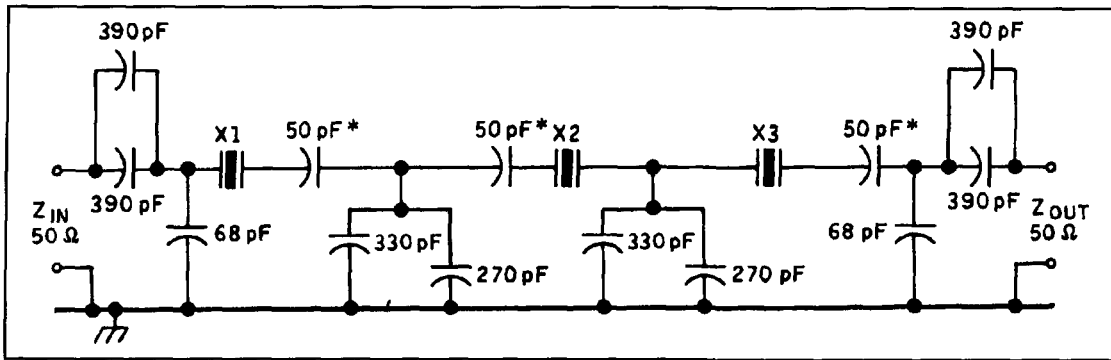


Figure 13. Three-section ladder filter (CW). Performance  $-6$  dB at  $400$  Hz,  $-60$  dB at  $4$  kHz, insertion loss  $4.0$  dB, ultimate attenuation  $-90$  dB. All capacitors 22.5 percent Suflex. Capacitors marked \* adjust the passband center frequency, in this case  $8.9993$  MHz, which is the center frequency of a lattice filter to be used further down the IF chain. A fixed capacitor plus ceramic variable could be used.

theoretical work used by F6BQP was done by J.E. Colin (France) whose paper gives coefficients for the capacitors for up to six crystal ladders (F6BQP provided coefficients for only up to four crystals.) In terms of insertion loss, the four crystal units proved the best in terms of loss per crystal used, but a five-section filter is probably the best compromise for insertion loss versus shape factor. **Figure 11** shows a four-crystal  $2.5$ -kHz SSB  $9$ -MHz filter in which a

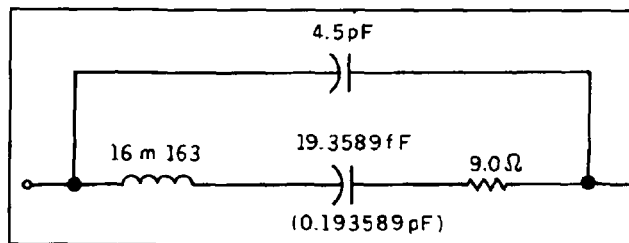


Figure 14. Typical parameters for an IQD A164A  $9$ -MHz crystal.

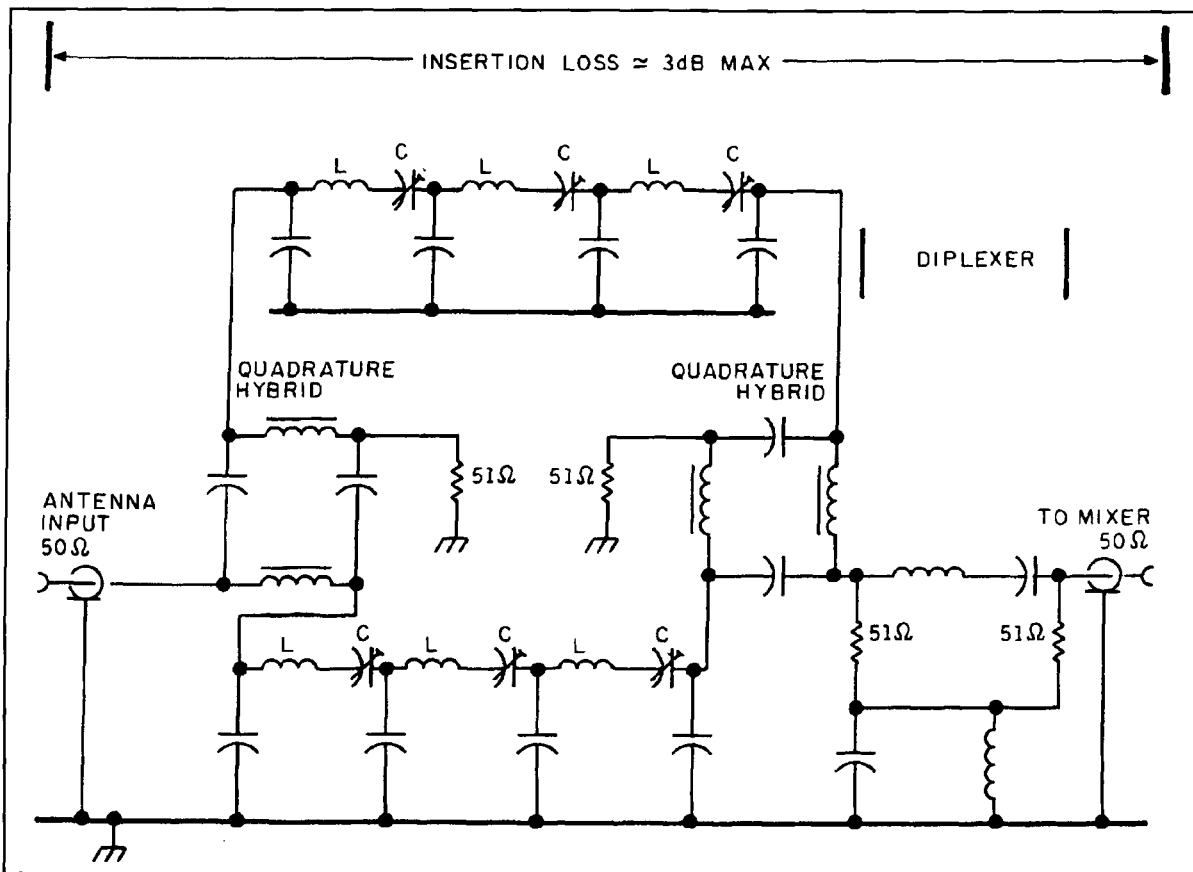


Figure 15. Antenna input filter. One circuit per band is required. Note that the bandpass filters are ladder networks with the capacitor coefficients with impedance the same as for the crystal ladder filters.  $L/C$  ratio determines bandwidth. Up to four sections of ladder could be used.

parallel L network is used to obtain the 50-ohm match. A five-section filter with 2.2-kHz (-6 dB) bandwidth is shown in **Figure 12**. A CW roofing filter is shown in **Figure 13**.

"All of these filter designs were first computer-simulated using a schematic entry package, Microcap 3. It was gratifying to find that the measured results were identical to the simulation. The crystal parameters were obtained by measurements on a Hewlett Packard 4195a network analyzer with an equivalent circuit-function facility. The individual crystal parameters used for simulation are shown in **Figure 14**.

"From this work it is possible to conclude that a low-insertion-loss crystal filter is necessary (ideally less than 1.5 dB) if it is to be used immediately following an H-mode mixer in order to avoid a noise-figure penalty. The SSB ladder filter described has the required low loss. To improve on this would require filters with better shape factors so that the intercept performance of the post-filter amplifier would be of less importance. Some work now needs to be done on a cascode amplifier to confirm that a noise figure of 1 dB can be achieved with some 20 dB gain for an output intercept of +30 dBm. This approach would lead to a relatively simple and low-cost front end of high performance. If a pre-mixer RF amplifier were to be used to provide increased sensitivity, a push-pull design similar to that shown in **Figure 3** would be needed to give a high output third-order intercept.

"The measured mixer input intercept performance on 14 MHz when used with the circuit shown in **Figure 11** is +51 dBm, a reduction of only 1.5 dB over a mixer output terminated by a 50-ohm resistor (straight into the spectrum analyzer). The question of the antenna input filter design has been investigated and it is likely that two identical LC filters coupled through quadrature hybrids and followed by a diplexer would be needed for each HF band (**Figure 15**) to maintain a broadband 50-ohm impedance match to the input of the H-mode mixer. Alternatively, a single LC filter followed by a diplexer could be tried. However, there would be impedance variations at the edge of the filter passband, so that a 20-kHz two-tone test may be satisfactory, yet tones at 1 MHz separation may show poor intermodulation performance. The question of implementing a low phase-noise local oscillator remains to be addressed if full advantage is to be taken of the excellent signal-path dynamic range shown to be possible.

## A Few Corrections

Three errors crept into Figure 1 showing the test assembly of G3SBI's new H-mode mixer. The Q, Q outputs from the 74AC74 should pass through 0.1 $\mu$ F DC-blocking capacitors. The 6k8 resistor to the left-hand bias-adjustment post should be joined to the junction of two 150R resistors to pins 3 and 6 of the SD5000 and not as shown. ■

## PRODUCT INFORMATION

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Models PQI-1115W and PQI-1115WD are based on a hybrid design that offers UL 1449 transient level suppression performance rating of 330 volts. It also allows bidirectional protection from source or load originated power disturbances.

The PQI unit can be plugged into any wall outlet and the power cord of the equipment to be protected, is plugged into the unit.

For more information, contact Superior Electric, 383 Middle Street, Bristol, CT 06010. Phone: 203-585-4500; FAX: 203-582-3784.





# QUARTERLY COMPUTING

*Introducing a new column exploring  
computer applications to amateur radio*

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A few years ago, a manufacturer of electronic components boasted in its ads that you were never more than a few feet away from one of its products.

Look around your ham shack. Chances are that even if you operate an all-vacuum-tube rig, carry a 17-jewel analog pocket watch, and swear that you'll never own a PC or touch a keyboard, you're equally close to an item that uses software directly or has benefited from contact with a computer somewhere along the way.

Beyond obvious examples (e.g., microprocessor-based pocket-size transceivers, synthesized multiband HF rigs, and packet radio modems), consider computer-aided programs for propagation and DX prediction, antenna design, band-pass filters, and mechanical components.

While computers and amateur radio equipment are interesting to look at and fun to build, they're inert assemblies of silicon and metal that don't come alive until they're handling messages and traffic—or software.

In "Quarterly Computing," we'll examine computer software relevant to amateur radio. We'll do so via hands-on reviews of interesting software, and we'll focus on affordable applications that make amateur radio more challenging—and more fun.

To inaugurate the column, we'll look at a pair of CD-ROMs. One's an update of a disk reviewed elsewhere in this issue,\* while the second disk covers alternative energy—a topic dear to the heart of any Field Day participant.

## The World of Ham Radio— May 1994 edition

Boasting almost 1,300 new and revised files, *The World of Ham Radio* from Amsoft represents something less than the total redesign

promised in my earlier review. However, there's a program here for every amateur's taste. Selections include new versions of Rig-EQF (control software for Kenwood radios) and Log-EQF (a logging program) from N3EQF, Total Ham Plus (another logging program), and PkGold/KaGold (packet radio programs for AEA and Kantronics TNCs, respectively). Also, all categories of amateur radio license exam questions have undergone updates to reflect changes in their question pools.

Among new software entries, DZ/Log (written by David Kylan, AA3DZ) enables several operators to share a single logging program while maintaining multiple individual QSO databases. In addition, given some free space on your PC's hard disk drive and 24 hours of undisturbed computer time, you can create a 600,000-entry callbook database from Walnut Creek's (QRZ) amateur radio CD-ROM.

Although DZ/Log's shareware version includes full logging, WAS statistics reporting, and notebook-style log printout capabilities, you can register DZ/Log for \$25 and receive worldwide QSO statistics in addition to Field Day logging functions. A Unix/Xenix version is also available.

DX-OnLine, another new entry, represents over five years and 1,500 hours of programming effort—according to its creator, Steve Brown, KD5ON. You'll need a PC equipped with at least an 80286 microprocessor and a color EGA or VGA display to view DX-OnLine's color world map and gray line.

To run DX-OnLine, you enter your QTH's latitude, longitude, and time zone. Select a location on the world map, and view its coordinates and distance to your QTH. You can also supply solar flux (sunspot number) data and obtain a current or 24-hour MUF prediction. Best of all, you can print a 20-plus page list of antenna bearings from your QTH as indexed by

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\*See "CD-ROMs for the Radio Amateur" on page ?? of this issue.

DX and local sites' names and prefixes. The list includes distances in nautical and statute miles and kilometers, and as a bonus provides grid squares and calling zones. For a registration fee of \$20, DX-OnLine rates as highly affordable; but to satisfy this program's hunger for memory, you may need to remove or disable any TSR (Terminate and Stay Resident) routines and other resource-eaters your PC uses.

The centerpiece of Amsoft's CD-ROM remains its CALLSIGN program, which can now search by ZIP code in addition to name and callsign. The program also prints a sorted-by-callsign mailing list of licensed amateur operators who reside within the ZIP code area you select—a highly useful feature for club newsletter publishers.

To examine results of a search, you use your keyboard's up-arrow and down-arrow keys to browse through the list. When you reach the list's beginning or end, CALLSIGN dumps you unceremoniously back to the introductory screen. You're forced to reselect your search criterion and go through the list again, an effect not unlike excessive hand capacitance in a regenerative receiver—you always overshoot the station you're attempting to tune in.

Shortcomings aside, *The World of Ham Radio* now sells for \$40, a significant price reduction that brings the disk more in line with other amateur radio CD-ROMs—good news for the compulsive information collectors among us.

## Solar I—Alternative Energy on Disk

Any operator who has sworn, "never again" after struggling through Field Day half-deafened and semiasphyxiated by the clatter and stench of a gasoline-powered single-cylinder generator will find something of interest in *Solar I*, a \$29.95 collection of alternative-energy data and shareware compiled by Sonoma Online.

Comprising almost 3,500 files in 323 MB of data supplied in ISO-9660 format, *Solar I* includes programs for DOS and Windows-based IBM-compatible PCs and Macintosh systems. To extract the Macintosh executable files, you'll need a copy of the MacBinary utility (available via Macintosh BBSes or on a floppy disk from Sonoma Online).

The jewel in *Solar I*'s crown consists of text and illustrations contained in issues 1 through 37 of *Home Power*, a publication akin in spirit to the much-missed *Ham Radio* magazine. Both journals share a practical, hands-on approach that includes sufficient theory to educate readers and encourage them to submit their own projects for publication.

*Home Power*'s illustrations are supplied in GIF format with white text and drawings on a

black background. While *Solar I* includes a shareware utility program called VSHOW that's capable of viewing and inverting the drawings to black-on-white for printing, the resulting images are postage-stamp size and viewable only via a magnifying glass. However, a separate graphics subdirectory includes several other GIF viewers, one of which may work better.

You'll also find schematics of energy-related circuits filed in the ENERGYENPROD subdirectory. Look for HPSCHEMT.ZIP, which includes GIFs of a pulsed NiCd battery charger, a temperature probe for DMMs, and more.

In the same directory, a program called EE11.ZIP contains digital filter design data and other electrical engineering applications, but requires a PC equipped with a math coprocessor or 80486 microprocessor in order to run.

Beyond *Home Power*'s back issues, *Solar I* offers a browser's delight of energy-related programs and text files that range from generator sizing to efficiencies of compact fluorescent light bulbs. A collection of GIF images (all tasteful) cover energy-related topics, but also include satellite and solar pictures in addition to nature scenes.

Macintosh programs of interest to radio amateurs who design their own equipment include DRCIRCUT (an analog circuit design aid), MACWAVE (a digital timing diagram plotter), and XLOGICCIR (a simulator that uses AND, OR, and NOT gates).

You'll find more amateur radio-related shareware in *Solar I*'s PC\GENERAL subdirectory. A total of 18 programs cover exam practice, Yagi and discone antenna design, packet radio, and more. The disk also includes the same version of DXOL found on *The World of Ham Radio*.

*Solar I*'s \GENERAL subdirectory contains a few programs covering topics of peripheral interest to amateur radio. A room layout program could help you plan your new shack, and another utility called CONCRETE can help you decide how much of the stuff you'll need for foundations or tower footings.

For diversion, explore the \GAMES subdirectory, which contains up-to-date versions of several popular shareware adventure games and word puzzles. Dig around some more, and you can find a Commodore C-64 emulator that runs on a PC. A \TEXT subdirectory includes the U.S. Constitution, collected speeches of Mark Twain, and other interesting reading material.

Unlike *The World of Ham Radio*, *Solar I* doesn't include a browser or front-end program to help you navigate through the disk. Instead, you can use a commercial or shareware shell program or DOS' DIR function to locate and print or examine on screen a subdirectory's FILES.BBS file list, noting files for transfer to

your working directory. Several lists aren't in alphabetical order, however, and the disk would benefit from an easier-to-search consolidated index file.

## For more information

You can obtain a copy of *The World of Ham Radio* CD-ROM from Amssoft, P.O. Box 666, New Cumberland, Pennsylvania 17070. You can also call (717) 938-8249 (voice) or (717) 938-6767 (fax).

To purchase a copy of the *Solar I* CD-ROM, contact Sonoma Online, P.O. Box 7518, Santa Rosa, CA 95407, or call (707) 545-7533 (voice) or (707) 545-0746 (Sonoma Online BBS).

## Conclusion

If you own a CD-ROM drive, either of these disks will make a worthwhile, useful, and interesting addition to your disk library. Although it lacks the depth of amateur radio-specific coverage and the callsign directory offered by *The World of Ham Radio*, *Solar I* provides better browsing for eclectic hams who share an interest in alternative power sources and energy conservation.

In future columns, we'll explore standalone programs relating to amateur radio in addition to CD-ROMs. Please contact me with suggestions of programs you'd like to see reviewed, or to offer review copies of amateur radio-related commercial software or shareware. ■

## PRODUCT INFORMATION

### A New Breed of CAT?

Computer Automation Technology announces their full-featured CAT-1000 repeater controller. Based on the TM80C188EB-8 microprocessor, the controller requires 9 to 15 volts at 155 mA for power. Memory is stored in a 64-K nonvolatile clock and RAM Dallas chip. Sixty-four on/off control functions are arranged in eight zones with eight channels in each zone. A 60-position scheduler may be used to fire announcements at preset times based on the internal clock and calendar, or change repeater parameters. A 40-position macro table and 40-position voice message table are also included. Each voice message table position allows up to 31 words for each message, constructed from a 475-word male/female voice vocabulary list. An optional low-cost 16-channel digital voice recorder with soft partitioning is available. All of the autopatch, control, and user codes can be up to seven digits in length and are readily changed.

A powerful feature of the CAT-1000 is its eight memory files, which may be loaded into active controller memory by a control operator, or the scheduler. Each memory file holds unique settings for the 64-control channels, 18 timer settings, 12 voice messages, autopatch and control codes to give the repeater a different personality for each file—such as during nets, emergencies, peak traffic, or other repeater situations.

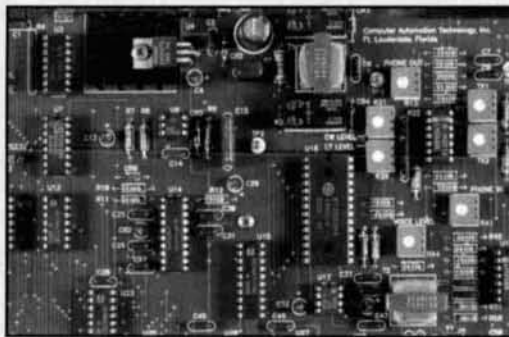
The full-featured autopatch may be set for rotary or DTMF dialing, and includes a 300-position speed dialer, and a 10-position emergency phone number speed dialer. Telephone number and area code lockout tables are provided. If desired, the voice synthesizer will repeat manually entered telephone numbers, or

information stored with any of the speed dialer numbers before dialing. The controller is capable of storing 40 sets of Motorola two-tone sequential pager tones, or 40 sets of DTMF paging tones.

The CAT-1000 incorporates two MT8870 DTMF decoders to ensure positive control operator access. An on-board 300-baud modem (password protected) or on site 4800 baud RS-232 jack may be used for programming. DTMF programming may be done via phone line, the repeater input, or a control receiver port on the controller itself.

For remote base operation, the CAT-1000 is compatible with the Doug Hall remote base interface for multiple transceiver hookups. It can also provide for link serial tuning, 40 preset channels, and HF base remote control—the CAT-1000 interfaces directly with the Kenwood TS-440 or Yaesu FT-767GX.

A CAT-300 controller is also offered, and is intended for tight budgets and those not needing the remote base or linking features found in the CAT-1000. For more information, write Computer Automation Technology at 4631 N.W. 31st Avenue, Suite 142, Fort Lauderdale, Florida 33309, or phone (305) 978-6171.



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- **VLF-LF and the Loop Aerial**  
Lloyd Butler, VK5BR  
*Spring 1991, page 54*

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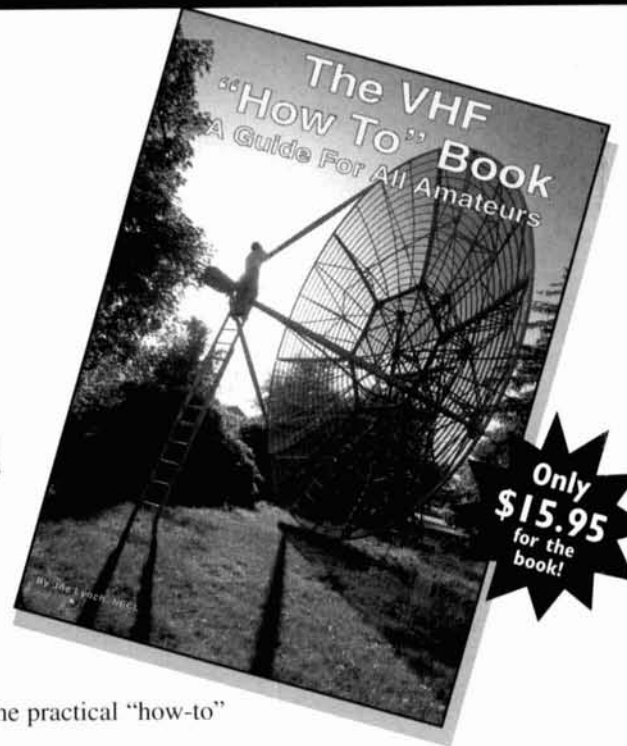
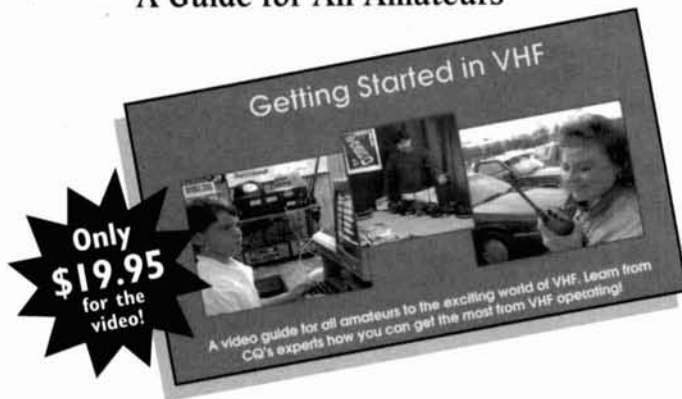
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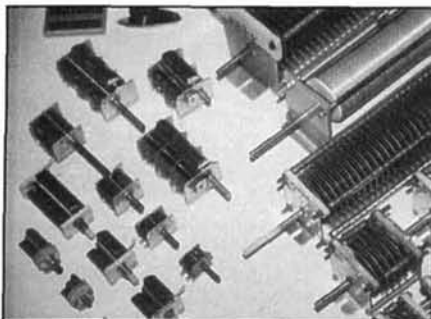
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## TECHNICAL CONVERSATIONS (from page 9)

and  $n$ . This makes  $f$  a straight line function of  $n$  with  $v/L$  its slope and  $av/L$  its intercept. A plot of  $f$  versus  $n$  will show right away if things are behaving as expected. If they don't fall on a straight line, then either you made a mistake, or you have gotten hold of some unusual cable.

Assuming they do fall on a straight line (Mr. Barton got four beautiful examples) fit a straight line to the points, either with a computer program or by hand. Find the slope and, hence,  $v/L$ . Since  $L$  is just the length of the line, multiply the slope by  $L$  to get  $v$ . If you prefer  $V_f$ , the velocity factor, divide  $v$  by the speed of light.

Coke Darden, W4DHA  
Lexington, South Carolina

Finally, David Barton sent the following clarification to his letter in the Spring 1994 issue of "Technical Conversations."

### Dear Editor:

Some readers took a statement in my letter in your Spring issue regarding the MFJ-249 as a blanket endorsement of the product. I do feel the concept is terrific: a single instrument combining a signal generator, counter, and SWR bridge (and a one-coil, general coverage dip meter per my article in the November 1993 QST).

So, I'll limit my endorsement to the concept and hold my product endorsement.

David Barton, AF6S  
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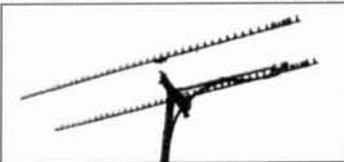
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| 1844 LY                                      | 44 el | Loop Yagi Assembled | 1691 MHz | \$115 |
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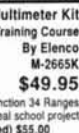
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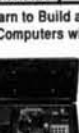
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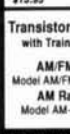
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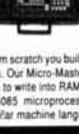
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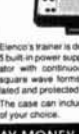
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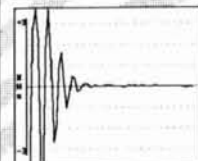
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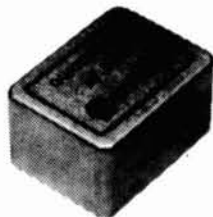
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