

# COMMUNICATIONS QUARTERLY

THE JOURNAL OF  
COMMUNICATIONS  
TECHNOLOGY

Winter 1994

\$9.95



- Multimedia Communications
- Simplified Frequency Synthesizer IC Interfacing
- Transitional Audio Active Filter
- Deluxe QRP Station

- Simple Very Low Frequency (VLF) Receivers
- The Solar Spectrum
- Quarterly Devices
- Double Resonant Antennas With Loading Reactors

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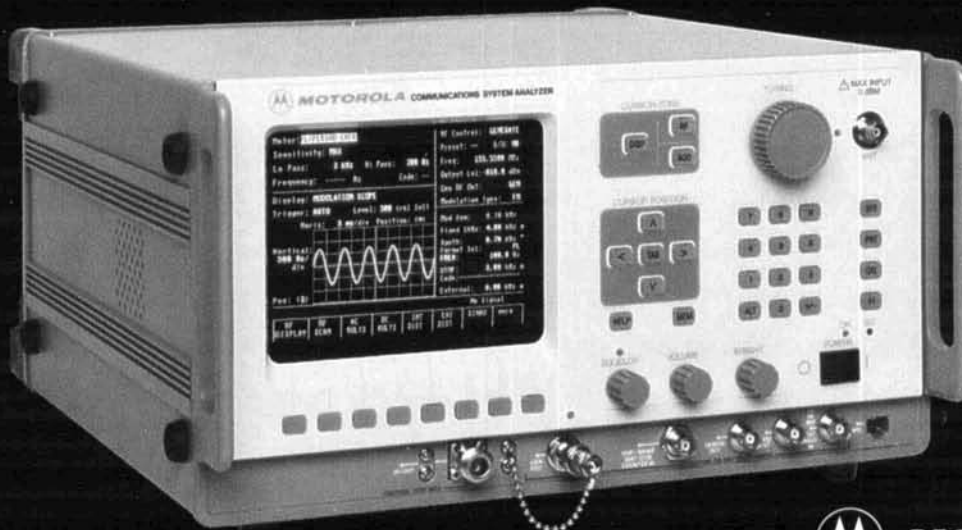


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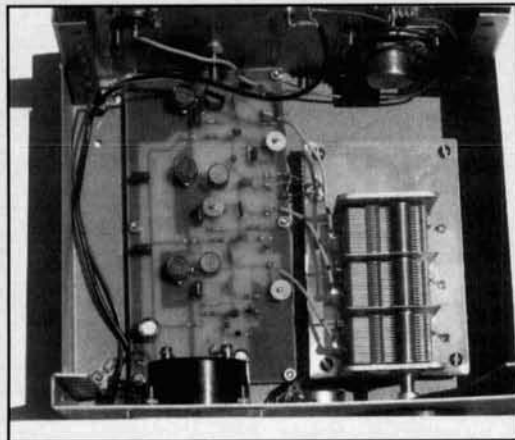
# COMMUNICATIONS QUARTERLY

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Cover Photo: One man's vision of a multimedia communications workstation. Shown are the usual microcomputer input devices (trackball and keyboard), supplemented with a video camera, straight key, and microphone (see story beginning on page 13). Photo by Bryan P. Bergeron, NU1N.

# EDITORIAL

## A Virtual Leap Into The Future

When computers first made their debut in the ham shack less than 20 years ago, I think few of us realized how they would revolutionize amateur radio. Although some resisted the encroachment of this new technology, many curious hams embraced it. Apples, Commodores, and TRS-80s—early ham shack residents—have long since been replaced by IBMs, Macs, or clones. The old dot matrix printers haven't given way to laser printers. Fleamarket tables at hamfests contain the relics of our early ham shack computers—unwieldy, ponderous looking things, dinosaurs that became extinct with the advent of sleek, new models with more memory, sharper monitors, greater processing speed.

From the beginning, computers have slowly been revolutionizing the way we operate. There are propagation programs and specialized DX logging programs, antenna programs and weather programs. You can use CAD programs to design circuits or create pc boards for your latest project, then print out templates on your HP Laserjet. Need to upgrade? There's a program for that too! A vast array of reference material, including on-line atlases and on-line logbooks, is also available. And you can get *The Callbook for CD-ROM*. Those with modems can check out the various bulletin boards and on-line services such as Prodigy, CompuServe, and Internet—many of which have amateur radio nets.

It's now possible to use your computer to control your radio. This technology, called virtual instrumentation, is enjoying popularity in the electronics industry. Test equipment is now being built with few exterior controls—those controls appear on the computer screen instead. While you can't go out and buy a transceiver totally incorporating this technology (most commercial transceivers, however, are equipped with built-in computer interfaces and some have control software), you can interface your computer and radio in such a way that you can monitor and modify your radio operations

from the computer screen. Imagine changing frequency with a simple keystroke! Your monitor will show a representation of your radio's front panel with options (in menu form) that you can select using your keyboard or mouse. There's commercial software available that will help you transform your current setup to a "virtual" one, or you can read the article by Howie Cahn, WB2CPU, "Connecting Your Radio To Your Computer," on page 13 of the fall issue of *Communications Quarterly*.

Now that computers have found a home in our shacks, what's the next technological advance? In this issue, Bryan Bergeron, NU1N, asks us to think *multimedia communications*. His article, "Multimedia Communications: The Future of Amateur Radio," discusses how to create your own multimedia communications workstation using existing hardware and software products.

Would you like automated data collection and display or remote data display of information from your power supply, antenna, or rotor control unit? How about graphic data displays for solar index or weather? Maybe you'd like to add digital audio or video capabilities to your operating area. A multimedia system can really help you expand your operating options.

I know there are some skeptics out there, but try to keep an open mind. After all, a multimedia approach to ham radio may help you get in shape for the next technological leap. How about artificially intelligent radios containing human DNA that correct you when you go off frequency, or forget to give your callsign, or talk too long. Or maybe someone will come up with a virtual reality mobile. Just think of it: You could drive out to those exotic grid squares without even leaving your driveway. It boggles the mind.

**Terry Littlefield, KA1STC**  
Editor

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# TECHNICAL CONVERSATIONS

Brad Thompson, NIJJ, had this to add to Joe Carr's article on small loop antennas ("Small Loop Antennas: Part 2," *Communications Quarterly*, Spring 1993).

**Dear Editor:**

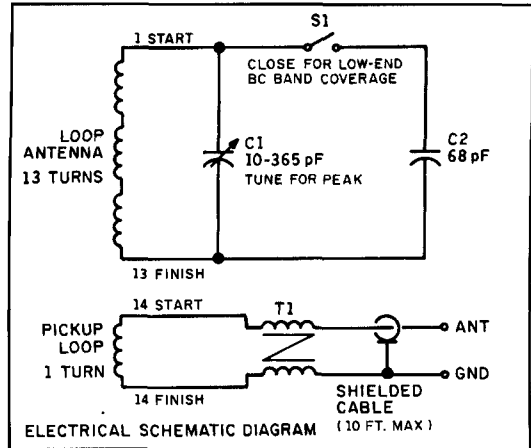
In his comprehensive review ("Small Loop Antennas: Part 2," *Communications Quarterly* for Spring 1993), Joe Carr didn't mention an important advantage of using of using multi-conductor ribbon cable as winding material for multiturn-loop receiving antennas.

You can shorten antenna assembly time significantly by terminating the ribbon cable in insulation-displacement connectors designed expressly for the cable. While you can create the loop's windings by separating and soldering all of the ribbon cable's conductors, the cable's PVC insulation turns to mush when heated. In addition, most wire strippers tend to nick the ribbon cable's small-gauge strands.

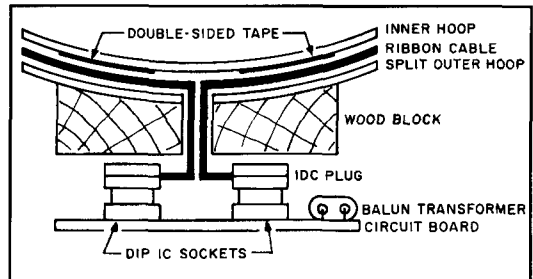
**Figure 1** shows a schematic diagram for a broadcast-band loop antenna fabricated from an 18-inch wooden embroidery hoop. As **Figure 2** shows, a 60-inch (1.52 meter) length of 14-conductor ribbon cable fits neatly around the hoop's circumference and leaves enough slack to allow plugging the cables' connectors into an interconnection board. **Figure 3** illustrates one possible pc board layout.

While conventional loops often include an electrostatic shield to minimize detuning due to hand-capacitance effects, you can further improve the performance of an unshielded receiving loop by inserting a common-mode choke between the loop's pickoff winding and the feedline to the receiver.

Hand capacitance induces a voltage across

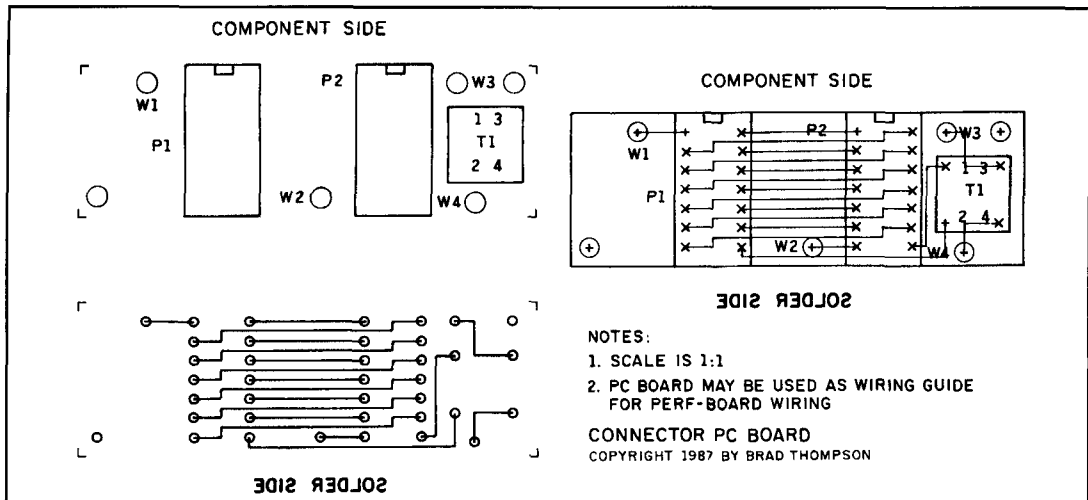


**Figure 1.** Schematic diagram for a broadcast-band loop antenna made from a wooden embroidery hoop.



**Figure 2.** A 60-inch length of 14-conductor ribbon cable fits neatly around the hoop's circumference, leaving enough slack to allow the cables' connectors to be plugged into an interconnection board.

the entire antenna and injects an equal current into both sides of the signal-pickup loop winding. Given an equal number of turns on T1's primary and secondary, a current flowing through one winding produces an equal and



**Figure 3.** Possible pc board layout.



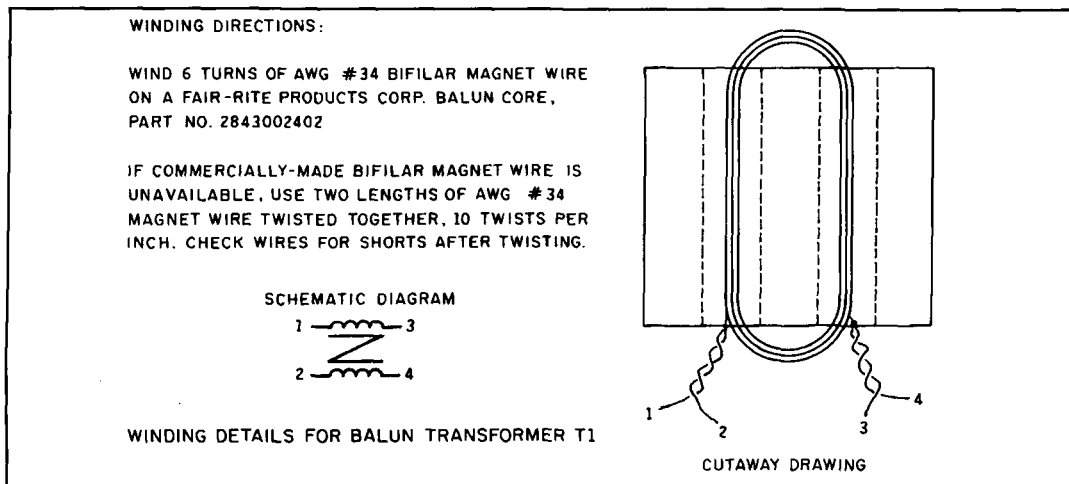


Figure 4. Details of the common-mode choke's design.

opposite current in the remaining winding, which cancels the common-mode current. Differential current induced in the pickup loop by a legitimate signal passes through unaltered. **Figure 4** shows the details of the common-mode choke's design.

Mass-terminating a loop's ribbon cable offers antenna experimenters an additional advantage. You can investigate various loop configurations by expanding the terminating board to accept jumper plugs that alter the loop's turns ratios.

For example, you can easily test the effects of interleaved pickoff and tuning windings, tie loop windings in parallel to enhance high-frequency response, and alter turns ratios without destroying the cable via repeated soldering and unsoldering. For VLF experiments requiring large inductances, ribbon cable comes in widths of up to 64 conductors with connectors to match. Also paralleled windings may offer QRP transmitting-antenna possibilities.

Bibliography

1. Brad Thompson, "AM Broadcast Band Loop Antenna," *Modern Electronics*, September 1987, pages 56-64.

**Brad Thompson, N1JJJ  
Acton, Massachusetts**

*The article by Roberto Craighero, I1ARZ, "Transmitting Short Loop Antennas for the HF Bands: Part 1," in our Summer 1993 issue, brought back the following memory.*

**Dear Editor:**

A brief remark by Roberto Craighero, I1ARZ, in his article "Transmitting Short Loop Antennas for the HF Bands: Part 1" in the Summer 1993 *Communications Quarterly* calls for a short comment. The remark on page 63 says that "the first attempt at using a transmit-

ting loop antenna in the amateur field was made by Lewis McCoy, W1ICP" and "was reported in the March 1968 issue of *QST*." In an important sense, this is true, for modern ham loop antenna investigation seems to arise about that time. However, in a strict historical sense, the remark errs by about 40 years.

Enclosed is a copy of page 10 of *The New York Telegram* for February 11, 1928 (see **Figure 1**). It describes a Hartley oscillator transmitter for 80 and 40 meters. The unusual feature of this one-tube transmitter is that it uses its "tank" coil as an antenna by winding it in a planar loop. Although acknowledged to be less than most efficient, the planar loop provided many a contact while avoiding most of the matching problems that accompany conventional loop antennas of modern design.

I would not argue that this is the first loop antenna, but only that it is a loop, an antenna, and 40 years older than the 1968 work cited. I have the article in my files because its author, Jim Cebik (IATG then, KA1TXF nowadays) just happens to be my father.

Another curious fact about the use of a planar loop as the tank coil in the oscillator circuit is that it predates a patent announcement I saw about a decade ago: using circuit board techniques, the patentee claimed rights to planar coil technology that was already almost a half-century old. Rather than using copper foil, the IATG coil was "wound with 5/16-inch phosphor bronze strip," a remarkable foreshadowing of things to come.

Let me add just one more note: the *Telegram* column in which the article "Loop Antenna Offers Simple Emergency Radiating System" appears was called "Below 200: A Continuous History of Amateur Activities." I hope we do not lose that continuity by neglecting older sources of experimentation, invention, and information. Editor Uda Ross, 2UD, Jim Cebik, IATG, and a host of other early hams are ama-

# "BELOW 200"

Editor: THE TELEGRAM RADIO, 2-10-2400  
Associate: J. S. CEBIK, W4RNL, 2R1-24FR

## "HAM-MONICS"

**POST-TEST STATIONS.**  
Official bulletins of the Central Committee are being furnished by station W4RNL at Louisville, Ky., every Saturday night at 12 P. M. EST. Until the next publication are now being made to other stations to appear before the board of directors meeting of the ARRL on February 22, provided we receive the consent of the majority of the board of directors. In your letter we mentioned:  
1. Headquarters movement as part of its organization a competent technical radio editor.  
2. Sufficient space be allotted in our column "QST" for station data and articles on this matter to be of benefit to our readers.  
3. Promote and stimulate communication to traffic and message handling stations that are being included on CW tower and 4. State data on the advantages and disadvantages of the various bands for use.  
5. Re-establish a part of the no meter band for four and other advantages equal to those our CW member has enjoyed.  
6. Re-test radio if you haven't done so yet.  
7. In your last  
Write to the Central Committee 4055 22d Street, Chicago, Illinois, Detroit, Michigan and in your letter state the National Education. Give some of your views if you do not have a license should also mention if interested in acquiring four foot test stations.  
The Central Committee (CNC), 22d Street, Chicago, Illinois, Detroit, Michigan, reports on February 1, of this number 60 are from the Second district. From a comparison of the kind a reliable estimate would be that the number of stations are actually operating in our nation and that another 100,000 are in the air.

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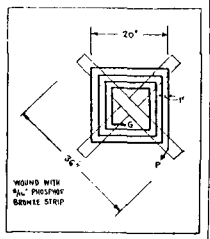
## Loop Antenna Offers Simple Emergency Radiating System

### Its Directional Properties of Great Advantage in Short Wave Transmission.

By JAMES S. CEBIK, IATG.

RECENTLY I lost both my forty and eighty meter antenna systems in a fierce wind storm. It was too cold to go out and put up another antenna or hit upon the idea of trying loop transmission for working the locals.

I started out to make a three-foot loop, but wound up with one twenty inches on a side. The loop is the only inductance in the circuit and is used as both oscillator and radiator. What could be simpler? The regular transmitter, with all the usual coils removed, was used with one condenser to tune the loop to the desired frequency. The Hartley oscillator circuit works with a fifty watt having an input of one hundred and twenty watts. With the tube acting in the normal fashion, over two hundred miles were covered in daylight on both forty and eighty meters. As I have



Loop Construction.

not tried it at night I do not know what the night range may be. The advantages of loop transmission are that the set is very simple, the transmitted wave is steady and one need not worry about a swinging antenna.

**Directional Effects.**  
In tests made several years ago, a transmitting loop was found to have

**"SWX" SPEAKING.**  
2. Ams. one of the Bronx Radio Club members, has just added another record to his long list of low power DX. With a mere 15 watt input on a 2X1 tube, he has worked 100 miles on 40 meters. Low power is getting to be the rage, and it won't be long before all of the gangs will be using penant tubes and working everything on the phone. AAMA claims he will be back on the air some day with a 210 using "D" battery supply for the plate. Perhaps this will patch up the trouble with the DX'ers in his vicinity.

Quite a large attendance was noted at the Bronx Radio Club last Friday night. News from all parts of New York and the Bronx were well represented. The reason being that due to the unseasonable temperatures Mr. Egan, the speaker, could not attend. In his place, Fred Parsons, a new W2 AAM gave a very good talk on atmospheric conditions. He stated that if more people would use the "D" battery would be cheaper, but we and him that one had had all our antennas on test.

Most of the old timers will remember Bob Rabin, Radio 2 CIX, who is back in town after an extensive trip through the South. He didn't like being a country boy, so he had himself a job doing the K. L. work, and if you know exists to hear some "real" music. It is his last act ended. The Commission will be re-announced in our next publication 2/12 ever had, had

a very marked directional effect on a station located four miles away. With the side of the loop facing the observing station, an audibility of six was recorded. Giving the loop a quarter turn reduced the signal strength to four. When the side of the loop was revolved to a position at right angles to the test station, the signal was reported as two.

The loop employed in these tests consisted of six turns spirally wound on a twenty inch frame. The input to the transmitter was six watts and the wave eighty meters. A similar loop using only four turns situated by a .00025 mfd. variable condenser will cover both the forty and eighty meter bands.

**Operation.**  
For transmission on forty meters, one plate turn is used, with three turns in the grid circuit. The wave length range of this arrangement is from forty-five to eighty-five meters. By sliding the centre tap connection on the loop in the proper direction, any power input to the tube may be obtained.

The transmitter is placed on the table in the radio room, located on the second story of a private house. The writer's loop is stationary, being suspended from the ceiling. In experimenting with the loop it is desirable to have the loop made fast

**Calls Heard**  
Howard R. Girler, 121 Harrison Avenue, Baldwin, L. I., N. York.  
(December 12 to January 10)  
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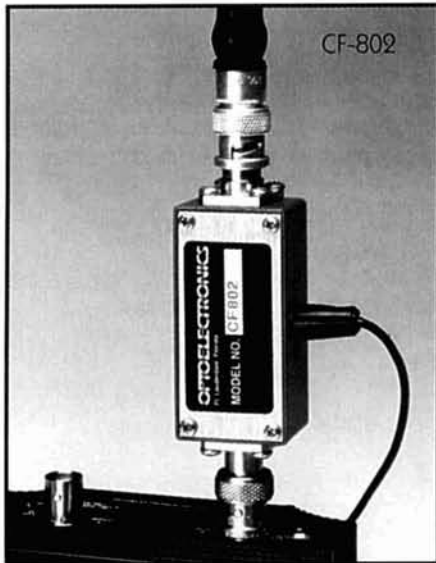
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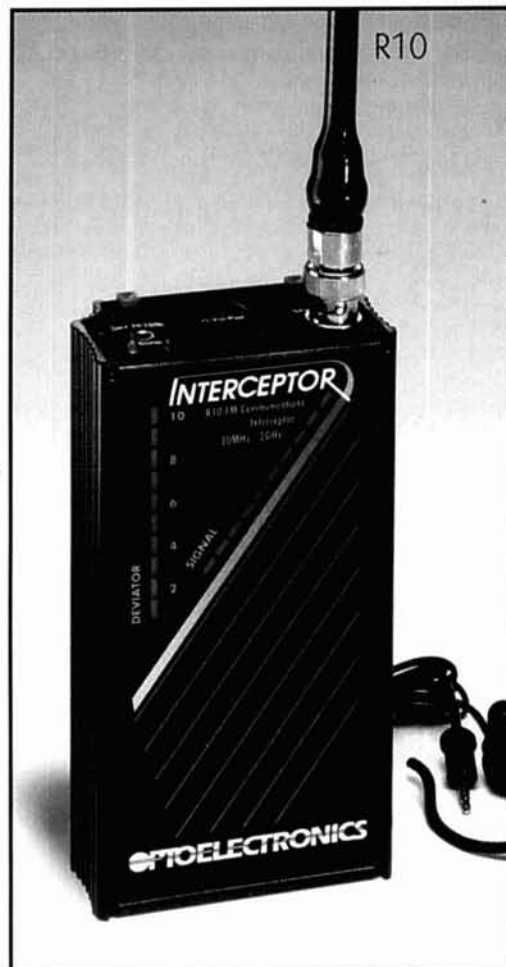
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# MULTIMEDIA COMMUNICATIONS

## *The future of amateur radio?*

---

As social creatures, humans have a profound need to communicate their thoughts, experiences, desires, dreams, and ambitions to others. Although nothing comes close to the quality of a face-to-face exchange of ideas, we have, over time, developed the means of communicating over greater and greater distances. Today, distance is no longer an obstacle; we can communicate with virtually anyone on the planet through a variety of means. However, voice and text, the two most common modalities used in modern communications, leave much to be desired. In an attempt to provide a richer communications experience, there has been a move to incorporate a variety of media, including video, graphics, and sound effects, along with the more traditional voice and text. Proponents of these multimedia systems promise to enrich the communications process by including the expressions, sights, and sounds that make face-to-face communications so special.<sup>1</sup> I'd like to examine the potential of multimedia communications and offer ideas on how radio amateurs can explore and help extend this new technology.

### Technological evolution

Virtually all technological innovations progress through a set of predefined stages, and each stage attracts enthusiasts with different interests. Take photography for example. When photography was first introduced, interest centered on the mechanics of picture taking, the relative merits of various film sizes and compositions, and the attributes of various lens designs—not to mention the numerous alternatives to developing and printing. Early photog-

raphers spent a good deal of effort determining optimum exposure and depth of field, and experimenting with various chemical developers and printing techniques. With the advent of commercial standardization of cameras and processing, photography not only became an affordable endeavor, but it was also no longer necessary for photographers to have an understanding of the intimate details of the photographic process.

Thanks to standardization and ease-of-use, contemporary photography attracts a wide audience, from those interested in photography as art form to those who want a simple means of recording images. Most photographers are content to have their microprocessor-controlled cameras calculate exposure, fill-flash, focus, and other intricacies, and let their corner photo finisher handle the details of printing. Of course, a relatively small number of photographers still spend time in the darkroom, experimenting with various developers and printing techniques. However, even these photographers are being pushed by technology towards digital still and video image capture, transmission, and storage.

There are many parallels in the evolution of photography, computers, and amateur radio. In amateur radio's infancy, hams focused on component-level details, trying to improve on basic circuit designs. Even commercial radio manufacturers followed a similar focus up until only a few years ago. (I still own a transistor radio that boasts the number of transistors and diodes on the front panel.) Today, most amateurs have no idea how many active components are contained in their handheld or HF transceiver. Professional and amateur radio enthusiasts have enough difficulty simply keeping up with the

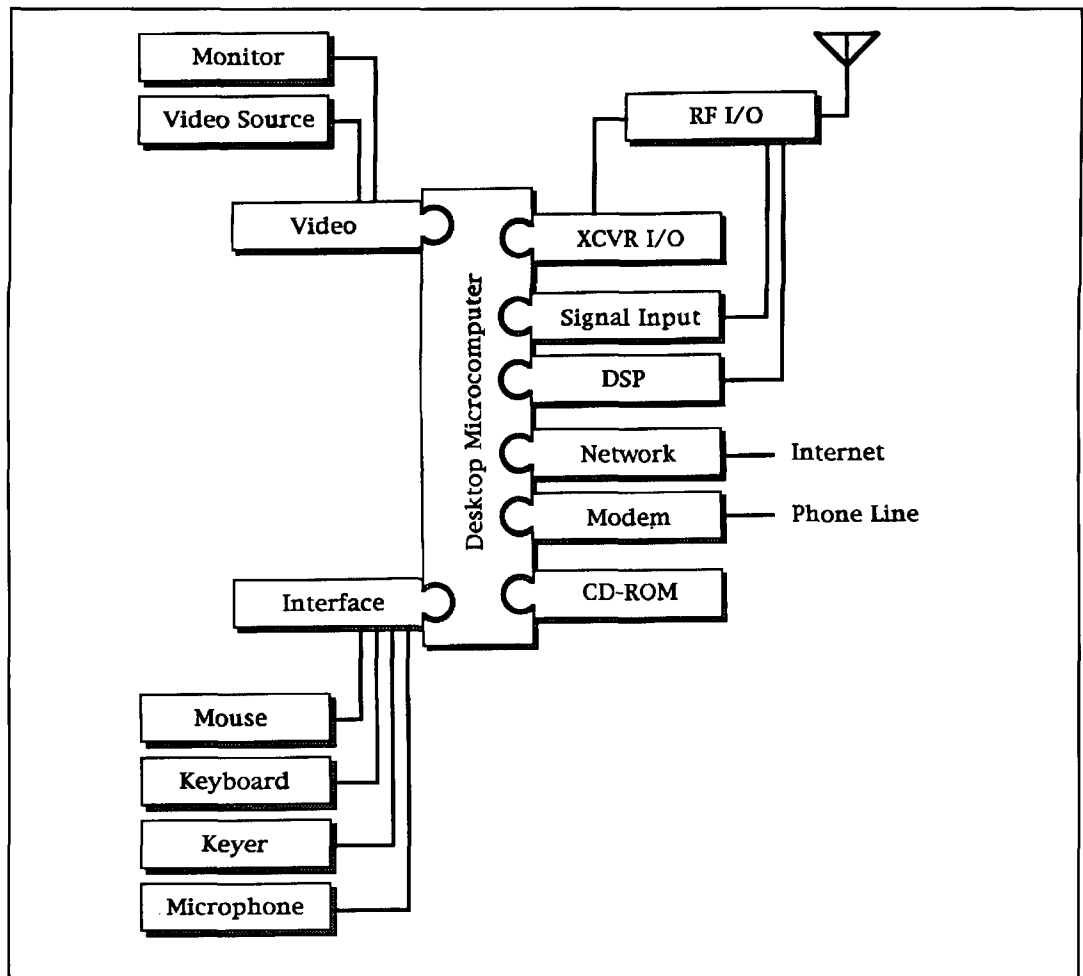


Figure 1. High-level diagram of one possible multimedia workstation configuration. As shown here, the microcomputer is the key component of the workstation. Plug-in cards provide access to network services accessible via phone lines and the internet. DSP and video processor cards provide capabilities for manipulating sound and video data. Signal acquisition hardware provides the basis for virtual instrumentation, which can be used to monitor parameters within the transceiver or other RF I/O device.

sweeping changes in communications technology, much less making original contributions at the component level.

Amateurs, for the most part, have become less concerned with actual circuit details than with the art of communicating and contesting. Accordingly, there is increased emphasis on the quality of the user interface, overall ease-of-use, and the quality of communications. We demand compactness, attention to ergonomics, reliability, clear, crisp audio, freedom from interference, and, most importantly, ease of use—with minimal regard to the underlying circuit design. Manufacturers have addressed our demands by introducing compact, feature-laden, microprocessor-controlled transceivers that provide a variety of utilities, from memory channels to spectrum analyzer-style views of the band in use.

Where does this leave the radio amateur who is not only keenly interested in communica-

tions, but also in pushing communications technology to the limit? Well, thanks to the enabling technologies available through desktop computers and microcontrollers—including digital signal processing (DSP), direct digital synthesis (DDS), image compression and decompression, on-line storage, and a variety of digital error correction techniques—the modern radio amateur can improve upon and expand the utility of the various modes of communications available.<sup>2</sup> There's still much low-level work to be done, but this work is better addressed by a computer keyboard, high-level programming languages, and a knowledge of systems integration rather than with a soldering iron.

## Multimedia and amateur radio

Many computer enthusiasts frequently exchange huge quantities of data including pictures, animations, video sequences, text, and



audio over networks consisting of commercial dial-in services and the internet. These multimedia users are pushing the envelope in multimedia communications by designing systems that can integrate, manage, and exchange video, sound, image, and text data in a number of formats.

Interestingly, amateurs have been working in a variety of media for many years. Amateur television (ATV), slow-scan television (SSTV), weather facsimile (WEFAX), packet radio, voice, and CW are but a few of the more popular communications modes amateurs use. However, with the exception of packet radio, we haven't had much success in the area of integration and mass dissemination of these technologies. For example, amateurs interested in SSTV tend to work with other amateurs who share their interest, if for no other reason than to establish a contact with another SSTV station. Until recently, the entry costs associated with some of these specialized modes of communications have been rather prohibitive. Relatively inexpensive multi-mode controllers have made it possible for virtually any amateur to try packet, SSTV, WEFAX, and the rest. However, these units fail to provide the sufficiently rich, integrated communications environment available through networked multimedia workstations.

Fortunately, any amateur with a modern transceiver capable of external control, an appropriately configured desktop computer, and a few peripherals can get involved with multimedia communications. The transceiver provides the communications channel, while the computer provides the storage and data handling utilities—as well as the routines and hardware for multimedia data display and capture. The computer also provides the power and flexibility necessary for experimentation. **Figure 1** is a diagram of one possible multimedia workstation configuration.

Given the basic hardware configuration capable of supporting multimedia communications, an almost endless variety of communications utilities can be created. For example, computer applications that support automated logging and frequency control of HF transceivers have been commercially available for years. With very little programming, these control applications can be enhanced through the use of alternative input devices, including inexpensive voice recognition hardware.<sup>3</sup> Similarly, machine learning techniques can be used to automatically configure transceivers to the users' preferred style of operation, as a function of time, band, or mode of communications.<sup>4</sup>

In addition to the basic multimedia hardware and software extensions that allow microcomputers to process sound and handle image capture, compression, and decompression, there

are virtual instrumentation extensions capable of providing almost any signal capture, analysis, and display options imaginable.<sup>5</sup> Readily available data capture hardware and supporting software let a microcomputer perform as a spectrum analyzer, frequency counter, oscilloscope, VOM, or just about any other electronic instrument on the market.<sup>6-8</sup> For example, a spectral display of the adjacent frequency spectrum available is an especially useful aid when contesting. Although spectral displays are available on at least one commercial amateur transceiver, it's possible to replicate and expand upon this feature with one of the many DSP-based virtual instrumentation systems. Unlike a hard-wired spectrum analyzer system, the characteristics of a virtual spectrum analyzer aren't fixed and can be defined in software. Virtual instrument configuration is especially attractive, given the availability of high-level graphic programming environments that can be quickly mastered by just about anyone with minimal programming experience.

## A multimedia communications workstation

Given that a multimedia communications workstation is both technically and economically feasible with existing commercial hardware and software products, exactly what features should be implemented? I've prepared a list of features for a multimedia station, based on my own desires and the availability of commercial products. A visual representation appears in **Photo A**.

**Multi-Mode Communications.** A variety of microcomputer-aware peripherals, developed specifically for amateurs, support image, voice, and data communications (AEA, Kantronics, HAL, MFJ, and others). Although these stand-alone systems work as advertised, a much more integrated system could be created with a little effort. An integrated system would allow the multimedia data collected to be used in a variety of ways by microcomputer-based applications.

**Automated Data Collection and Display.** The diversity of microcomputer-based virtual instruments makes it possible to automatically acquire data from any device, transform it to an appropriate format, and analyze or display the resulting data in whatever format is most informative. Virtual instruments capable of automated data collection and display are available in a variety of configurations (e.g., stand-alone instruments with RS-232 or IEEE 488 interfaces; plug-in analog input/output (I/O) boards; and microcomputer-based systems), price ranges (from a few hundred dollars and up), and computer interfaces (MS-DOS, MS-Windows, and Apple Macintosh are most common).



Photo A. One vision of a multimedia communications workstation. You can see the usual microcomputer input devices (trackball and keyboard), supplemented with a video camera, straight key, and microphone. The screen display shows a world atlas (upper lefthand corner), live video from the other station (center), an on-line logbook (lower lefthand corner), various indicators for operating frequency and power, a display of transmit audio on a virtual oscilloscope display (upper righthand corner), and a user-definable filter curve (lower righthand corner). Along the bottom of the display are various control buttons and indicators for controlling the transceiver and accessing various computer resources.

**Remote Data Display and Control.** One of the greatest potential benefits of virtual instrumentation technology is that it provides a means of integrating data from a variety of sources. For example, it's almost a trivial matter to acquire remotely and display locally data from your transceiver, power supply, and rotor control unit. Transmit and receive frequency, mode, audio envelope, receive spectrum, antenna heading, antenna SWR, power output, receive signal strength, frequency deviation, as well as power supply voltage and current drain could all be displayed on your computer screen, either as raw data or as computed values or graphics. Most of the modern commercial HF transceivers come equipped with built-in computer interfaces that support remote control and some degree of remote monitoring. Some manufacturers (e.g., Kenwood) offer fairly sophisticated software that can be used to control their transceivers remotely, as well as providing other utilities.

**Video Support.** The ability to transmit and receive video is a key feature of multimedia communications. The two basic requirements for generating video are a video source, typically a video camera with an NTSC analog output, and some form of frame grabber to transform

the analog video signal into a matrix of digital values that can be stored and manipulated. Add-on video support cards off-load the burden of image processing computations from the main CPU to an on-board processor. Video processors are usually equipped with their own high speed RAM and support software in ROM, and may be complemented by their own coprocessor chips.<sup>9</sup> Once in digital form, video sequences can be stored to disk for instant access. For example, Video Spigot (Creative Labs, Inc.) is a high performance video capture and display card for the Apple Macintosh and PCs running MS Windows. For about the same price (\$500), the Video Blaster kit contains Microsoft Video for Windows software and a Video Blaster card for capturing, compressing, decompressing, editing, and displaying full-motion video on a PC (Microsoft/Creative Labs, Inc.). Software support for microcomputer-based video ranges from basic video display and compression (e.g., Apple's Quicktime) to full-featured utilities capable of combining, editing, and mixing audio, still images, animations, video footage, and graphics (e.g., Adobe Premiere). Image editors, such as PhotoStyler for the PC and Adobe Photoshop for the Macintosh, can be useful for filtering and

manipulating individual images prior to transmission and after reception.

**On-Line Atlas.** Inexpensive (less than \$50) world atlas programs are available today for most microcomputers. A few products designed for amateurs also provide satellite tracking and grey-line information. The optimum atlas would provide access to any location by name, coordinates, or callsign prefix. Given an agreed-upon data exchange format, the coordinates of the transmitting station could be used to automatically bring up a world map with graphics indicating the exact location of the transmitter, superimposed on a map displayed at any arbitrary level of magnification.

**On-Line Callbook.** For PC users with CD-ROM drives, the HamCall/CD-ROM (Buckmaster Publishing) provides access to the names and addresses of most amateurs. Alternatively, dial-up services are available for those equipped with modems. With a little programming, this data could be displayed automatically as soon as a callsign is acquired, perhaps as a graphic overlay on a world atlas.

**On-Line Logbook.** With the excellent selection of computer-based logbooks available for amateurs, acquiring this feature is simply a matter of shopping around.

**Graphic Data Displays.** Data, such as solar index, local weather, and UTC, whether acquired from local instrumentation or downloaded from the internet or a packet network, can be displayed both numerically and graphically. For example, temperature could be displayed on a simulated mercury thermometer. With a standard data format, the graphic data displays on each user's communications station could automatically reflect the conditions at the other station's location. Simple weather data communications, a significant part of contemporary QSOs, could become automatic and available at a glance—leaving time to pursue other topics.

**Digital Audio Capabilities.** The ability to digitally record, manipulate, and playback voice and other audio can not only facilitate contesting, but also provide the foundation for any number of audio applications. For example, the digital recording of a QSO affected by heavy QRM and QRN can be processed with off-the-shelf utilities to maximize chances of recovering meaningful data. Although amateur transceiver manufacturers are beginning to offer digital voice recorders as optional equipment—e.g., the Yaesu FT-890AT—it's possible to incorporate the same features in your existing transceiver by purchasing one of the inexpensive digital audio interface cards available for PCs and Macintoshes. (The latest generation of Macintosh Computers come digital-audio ready.)

One of the most alluring digital audio technology-based capabilities is voice recognition, where speech commands are translated into keyboard equivalents. Prices start at about \$100 for hardware and software. The main variations in voice recognition systems for microcomputers concern working vocabulary size, recognition accuracy, training requirements, recognition of continuous speech versus individual commands, whether the hardware is external or internal, and, if internal, whether it makes use of special DSP chips or relies heavily on the microcomputer's CPU.<sup>10-14</sup> Some distributors of digital audio systems, including Microsoft, bundle speech recognition software with their standard digital audio hardware.

**User-Definable Audio Filters.** The same hardware and software used to provide basic digital audio capabilities can be configured to provide custom filtering of transmit and receive audio. For maximum ease-of-use, the characteristics of individual filters should be definable by manipulating on-screen graphics.

**Multi-Modal User Interface.** Although I spend most of my air time operating 20-meter CW with a Bencher paddle, most people would agree that the straight key (or paddle) leaves a lot to be desired as a user interface. The interface to a multimedia communications workstation should support a variety of devices—from the more traditional microphone and keyer, to the keyboard, mouse, trackball, pen pointing devices, sketch pads and touchscreens, speech recognition devices, and perhaps even eye, head, or body position sensors.<sup>15</sup>

Body position sensors may seem a bit far-fetched for a communications device, but body position sensing is the basis for much of the work in virtual reality. The goal of reality work is to bring a virtual world to life through databases or real-time objects and sounds. The computer I/O consists of tactile-sensitive gloves or other sensors, and some form of display. A local database of objects and sounds minimizes the information that must be sent through the communications channel. The Nintendo PowerGlove is an inexpensive hand-position sensor useful for experimenting with this exciting technology.

**Transparent Data Access.** Given the focus of amateur radio, it's sometimes difficult to think of data coming from sources other than RF. However, to take full advantage of available technology, data resources could be accessible from a variety of areas including RF reception, phone line connections (modem), local storage, and the internet. Most importantly, this access should be transparent. That is, some information could be pulled in via internet and some obtained from local storage; to the user, the data simply appears. Knowledge of the mode of

transport or origin should be unimportant. For example, national weather information could be obtained from a dial-in bulletin board service and displayed on the communications workstation screen with graphical map data residing on a local CD-ROM.

Transparent, multimedia data access is especially important in providing collaborative computing environments.<sup>1</sup> To get a feel for this type of communications environment look at Windows for WorkGroups (MicroSoft) and Apple's System 7. These products allow groups of computer users to communicate and share a variety of data types over a network.

**Multi-Media Library Management.** One problem with storing large quantities of data in various forms—e.g., received video, graphics, and sounds, along with data that could be used for transmission—is that there must be some efficient way to access the data at a later time. A number of multimedia management systems are available, ranging from Kodak's ShoeBox system for cataloging images in Photo-CD format, to applications capable of managing all types of multimedia data; e.g., Aldus Fetch for the Macintosh.

**Smart Alarms.** Alarms that warn of operation near band limits for a given license class, excessive SWR or key-down time, and other station operating characteristics are possible given a microcomputer with basic data acquisition capabilities. The usual time-based alarms for lunch dates, important events (for instance, dinner with the family), and the like are available through off-the-shelf software.

**Compact, Multi-Use Construction.** Given the scarcity of desk real estate, my dream communications workstation would be based on an RF docking system that accepts a laptop computer. Like the current docking systems sold for laptops, a communications docking station would provide extra RAM and local storage, and, most importantly, would also provide RF transmit and receive functions, as well as out-board DSP processors for filtering functions.

## Discussion

Multi-modal communications isn't new to amateur radio; it's difficult to find an issue of *QST* that doesn't mention SSTV, WEFAX, ATV, or packet. What has changed is that, thanks to advances in computer technology, there are now multimedia standards. In addition, given that computer power is now so affordable, the average amateur can experiment with a wide variety of communications modes. You needn't focus only on SSTV or WEFAX, but can integrate all available modes into something more valuable than the individual parts.

I see a primary role for amateur radio in the

future as the test bed of new modes and uses for multimedia communications. Such pioneering will include discovering new and innovative uses for the personal computer and communications hardware. Given that we're moving away from a component-oriented hobby to one centered on the process of communications, we should use our collective consciousness to develop and enhance the various communications modes through programming, system integration, and by developing systems of communications networks.

Does all of this progress in communications technology signal an end to experimentation? Far from it. There's significant work to be done in developing routines for image compression and decompression, in optimizing DSP noise cancellation techniques, in developing new means of sending real-time video and still images, in evaluating and developing new modulation techniques, and in creating more effective error-correction schemes. Of course, there will always be a place for those of us who are comfortable with a screwdriver and soldering iron. The point is, we are moving to the stage where, instead of simply exchanging weather and RST information, we can actually get to know the person on the other end of the communications link.

## For more information

The products mentioned in this article are intended to serve as a point of illustration only. There are literally hundreds of multimedia and virtual instrumentation products on the market. If you are unfamiliar with virtual instrumentation or multimedia, a good place to start is product literature. Two virtual instrumentation vendors that provide excellent, informative catalogs are Omega Engineering, Inc. (One Omega Drive, P.O. Box 4047, Stamford, Connecticut 06907, 800-826-6342) and National Instruments (12109 Technology Boulevard, Austin, Texas 78727, 512-250-9119). For the latest in multimedia software and hardware, I've found the catalog from JDR Microdevices (2233 Samaritan Drive, San Jose, California 95124, 800-538-5000) especially helpful. MacConnection (14 Mill Street, Marlow, New Hampshire 03456, 800-800-2222) and PC Connection (6 Mill Street, Marlow New Hampshire 03456, 800-800-0030) handle a broad assortment of software for Macintosh and PC Multimedia work. Your local computer store can also be an invaluable resource.

If you'd like to learn more about multimedia computing, stop by your local bookstore and pick up a few computer magazines. *Byte* (technical, general coverage), *MacWorld* (Macintosh specific), and *Windows Magazine* (MS Win-



dows specific) are three publications worth looking into. For more information on virtual reality, the article by Fisher<sup>16</sup> is a good place to start. A number of in-depth articles on multimedia are included in the references section.<sup>17-24</sup> For more information on interface design, check **References 25 through 36**. To learn more about the inner workings of speech recognition systems, see **References 12, 14, 37-39**.

#### REFERENCES

1. T. Yager, "Better Than Being There," *Byte*, 18(5): 129-34, 1993.
2. G. Glass, "The Video Experimenter," *QEX*, (Dec): 13-5, 1992.
3. B.P. Bergeron, "Control Your Transceiver By Voice," *QST*, 76(8): 35-8, 1992.
4. B.P. Bergeron, "Artificial Intelligence Applications in Radio Communications," *Ham Radio*, 22(10): 30-7, 1989.
5. T. DeSantis, "The Past, Present, and Future of PC-based Test," *Eval Eng.*, 31(12): 24-9, 1992.
6. B.P. Bergeron, "Microcomputer-Based Instrumentation Systems," *Communications Quarterly*, 2(1): 36-45, 1992.
7. G. Jacob, "DVMs/DMMs: DMMs Communicate, Self-Calibrate, Provide More Functions," *Eval Eng.*, 28(8): 26-30, 1989.
8. G. Jacob, "Spectrum Analyzers: Exploring the Frequency Domain," *Eval Eng.*, 28(8): 70-2, 1989.
9. R. Clouthier, Plug-in Modules Allow Image Processing On Non-Dedicated PC's," *Computer Technology Review* (Fall): 115-23, 1986.
10. D. Bradburn, "Kurzweil Voice System: A 1000 Word Vocabulary," *Voice Processing '86*, 57-62, 1986.
11. K.W. Church, *Phonological Parsing in Speech Recognition*, 1987. Kluwer Academic Publishers, Norwell.
12. G. Chollet, and C. Montacie, "Evaluating Speech Recognizers and Data Bases," *Recent Advances in Speech Understanding and Dialog Systems*, Niemann, Lang and Sagerer editors, 1988. Springer-Verlag, London.
13. I. Scherr, "Pepperoni and Paperwork: The Dream—and the Reality—of Voice/Document Delivery From Off-the-Shelf Hardware and Software," *Byte*, 14(13): 309-16, 1989.
14. A. Waibel, and J. Hampshire, "Building Blocks for Speech," *Byte*, 14(8): 235-45, 1989.
15. E. Tello, "Between Man and Machine," *Byte*, 13(9): 288-93, 1988.
16. S.S. Fisher and J.M. Tazelaar, "Living in a Virtual World," *Byte*, 15(7): 215-21, 1990.
17. S. Loeb, "Architecting Personalized Delivery of Multimedia Information," *Comm ACM*, 35(12): 39-48, 1992.
18. M. Veljkov, "Managing Multimedia," *Byte*, 15(8): 227-32, 1990.
19. T. Shetler, "Birth of the BLOB," *Byte*, 15(2): 221-6, 1990.
20. D. Woelk and W. Kim, "Multimedia Information Management in an Object Oriented Database System," *Thirteenth Very Large Database Conference*, 1987.
21. R. Lippincott, "Beyond Hype," *Byte*, 15(2): 215-8, 1990.
22. B. Fox, "Multimedia in a Muddle," *New Sci.*, 132(Sept): 35-9, 1991.
23. S. Christodoulakis and C. Faloutsos, "Design and Performance Considerations for an Optical Disk-Based, Multimedia Object Server," *Computer*, (Dec): 45-56, 1986.
24. M.E. Hodges, R.M. Sasnett, and M.S. Ackerman, "A Construction Set for Multimedia Applications," *IEEE Software*, 6(1): 37-43, 1989.
25. R. Baecker and W. Buxton, *Readings in Human-Computer Interaction: A Multidisciplinary Approach*, 1987.
26. S. Brand, *The Media Lab: Inventing the Future at MIT*, 1987, Viking Penguin, Inc., New York.
27. B. Cabral and C.L. Hunter, "Visualization Tools at Lawrence Livermore National Laboratory," *Computer*, 22(8): 77-84, 1989.
28. J.H. Carrol, *Interfacing Thought: Cognitive Aspects of Human-Computer Interaction*, 385, 1987.
29. D. Dakins, *Virtual Reality Redefines the Meaning of Real-time, Diagnostic Imaging*, 14(11): 77-239, 1992.
30. H. Eglowstein, "Reach Out and Touch Your Data," *Byte*, 15(7): 283-90, 1990.
31. B. Howard, "Point-and-Shoot Devices," *PC Magazine*, (Aug): 95-6, 1987.
32. D. Mcallister, "3-D Displays," *Byte*, 17(5): 183-8, 1992.
33. G.M. Nielson and B. Shriver, *Visualization in Scientific Computing*, 1989, IEEE Computer Society Press, Los Alimitos, California.
34. L.J. Rosenblum, "Scientific Visualization in Research Laboratories," *Computer*, 22(8): 68-70, 1989.
35. B. Shneiderman, *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, 1987 Addison-Wesley, Reading, Massachusetts.
36. E. Tufte, *Envisioning Information*, 1990 Graphic Press, Cheshire, Connecticut.
37. W. Alexander, *Prosody and Speech Recognition*, 1988, Pitman Publishing, London.
38. T. Ivall, "Commercial Speech Recognizers," *Electronic Speech Recognition*, Bristow editor, 1986, Collins Professional and Technical Books, London.
39. E.J. Yannakoudakis and P.J. Hutton, "Techniques for Digital Coding of Speech," *Speech Synthesis and Recognition Systems*, 1987, John Wiley & Sons, New York.

## PRODUCT INFORMATION

### QUALCOMM expands VCO Series to 3.5 GHz.

QUALCOMM Incorporated VLSI Products Group announced their expanded Q3500 Series of wide-band microwave Voltage Controlled Oscillators (VCOs). The expanded Q3500 series covers frequency ranges from 100 MHz to 3500 MHz in octave and near-octave bandwidth selections.

Key Q3500 applications include DBS (Direct Broadcast Satellite) Systems, VSAT (Very Small Aperature Terminal) Systems, Satellite Communication Systems, Mobile & Airborne Radio, Local Oscillators, Frequency Synthesizers, High Performance Instrumentation and Spread Spectrum Systems.

The Q3500 VCOs are contained in a pin type package with dimensions of 0.81" L x 0.81" W x 0.312" H (0.125" H for Q3500C-2235T).

For more information, please contact QUALCOMM Inc., 10555 Sorrento Valley

Road, San Diego, CA 92121-1617; telephone: 619-597-5005.

### QUALCOMM offers VLSI Product Selection Guide.

QUALCOMM Incorporated VLSI Products Group announced their revised Master Selection Guide that features their ASIC line of systems-on-a-chip solutions. The 40-page catalog covers the line of VLSI products including Viterbi Decoders, Trellis Codecs, Variable-rate Vocoders, Direct Digital Synthesizers (DDSs), Digital to Analog Converters (DACs), Phase-Locked Loop (PLL) Frequency Synthesizers, Voltage Controlled Oscillators (VCOs), and Synthesizer Boards. It also includes product applications, block diagrams, and tables.

For more information, please contact QUALCOMM Incorporated, VLSI Products Division, 10555 Sorrento Valley Road, San Diego, CA 92121-1617 or call 619-587-1121.

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# TRANSITIONAL AUDIO ACTIVE FILTER

*Use this filter to improve your  
transceiver's selectivity*

A problem common to older transceivers is lack of selectivity, especially in CW mode. Even with the addition of optional filtering, adjacent channel interference still may not be adequately suppressed. There are a number of commercial filters available; however, these products are often costly and complex.

This article describes an audio active band-pass filter that provides characteristics for good CW reception.

## Transient properties

The qualities required for a good CW filter are: a flat passband, narrow bandwidth, and a sharp rolloff in the stopband. To achieve these

qualities, a high Q is essential along with a number of filter sections cascaded together. Unfortunately, narrowband multi-section filters are prone to ringing. Ringing, an undesirable howling sound heard in the audio, makes it difficult to copy a CW signal.

Before continuing, let's take a closer look at the characteristics of ringing. The transient response of a system is a measure of its stability when subject to a sudden change. The DC unit step is a common nonsinusoidal signal used in transient response, and represents a sudden change. A unit step has an amplitude of zero at  $t=0$  and unity for  $t>0$ .

Figure 1A shows the waveform of a unit step. The step response of an ideal low-pass fil-

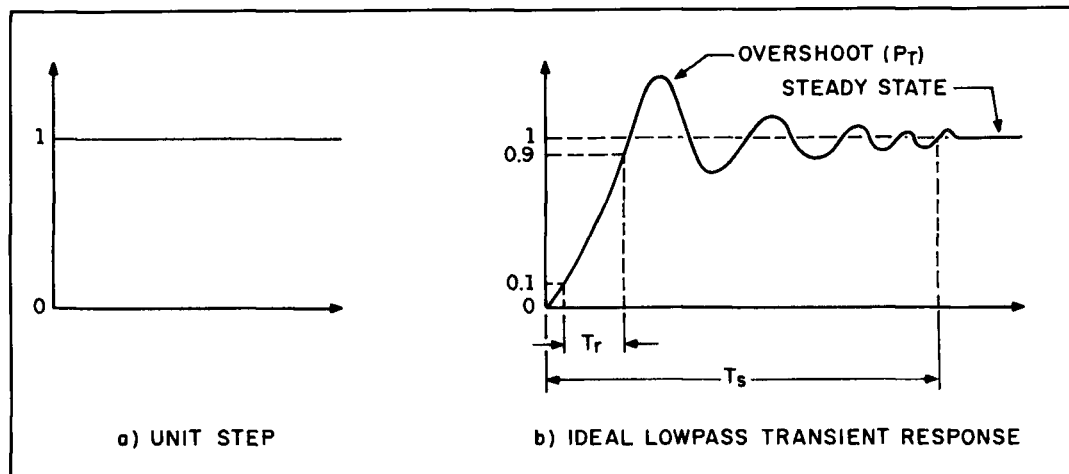


Figure 1. (A) The waveform of a unit step. (B) Step response of an ideal low-pass filter.

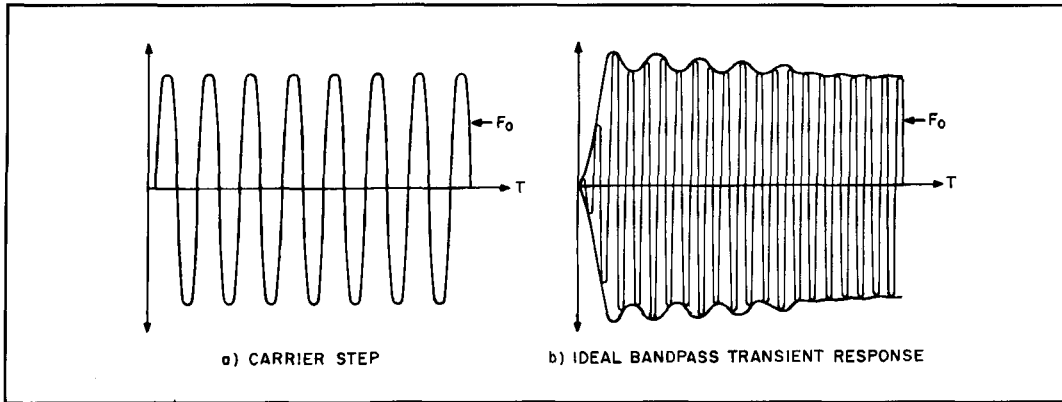


Figure 2. The carrier step response of an ideal bandpass filter. (A) Carrier step. (B) Ideal bandpass transient response.

ter is shown in **Figure 1B**. It's evident from looking at the figures that distortion has been introduced. However, note that, even though an ideal filter has linear phase, a small degree of ringing and overshoot occurs because of the abrupt change in amplitude at the cutoff (the shape factor of an ideal filter is one).

The rise time,  $T_r$ , is the result of a finite bandwidth, and is the time required for the response to rise from 10 to 90 percent of the final steady-state value. The rise time in our case is of lesser importance, and can be approximated by  $(0.35/BW)$ . The percent overshoot,  $P_t$ , is the difference between the peak amplitude and the final steady-state value. The settling time,  $T_s$ , is the time required for the response to settle within a specified percent of the steady-state value (usually 2 or 5 percent). As **Figure 1B** illustrates, within the time span of  $T_s$ , the response is an exponentially damped oscillation referred to as "ringing."

The step response of a bandpass filter is evaluated by applying a carrier step to the filter instead of a unit step. The carrier step can be thought of as a tone burst with a carrier frequency that is equal to the filter's center frequency. This is an excellent analogy as to how the filter will respond to a CW signal. **Figure 2** shows the carrier step response of an ideal bandpass filter.

The ideal bandpass filter also has an oscillatory transient behavior for the same reasons as the ideal low-pass filter. The same transient principles for the low-pass filter apply to the bandpass filter. If a filter is to pass a series of pulses or tone bursts like those in a CW signal, overshoot and ringing are highly undesirable. It's vital to have linear phase and a defined rolloff for low transmission distortion.

## Choosing a filter response

Armed with an understanding of some basic transient properties, we can now select a filter response. It's important to select a response

with well defined transient properties as well as good selectivity. The three most common responses are Butterworth, Chebychev, and Bessel filters.

A Butterworth filter is a medium Q filter with a flat passband and a moderate initial descent into the stopband. Its phase, however, varies nonlinearly with frequency, therefore its transient behavior is fair. The Chebychev filter is a high Q filter that has ripple in the passband with an even steeper initial descent. The phase shift of a Chebychev filter also varies nonlinearly with frequency and its transient response is very poor. Bessel filters, on the other hand, have a phase shift that varies linearly with frequency and a smooth rolloff in the passband. The Bessel filter has excellent transient properties and will produce a delayed, but accurate, replica of the input signal. The main disadvantage of this filter is its poor selectivity, which is due to a sluggish rolloff in the stopband.

Each of these filters lacks one of the qualities needed for a good CW filter. The transitional filter is a compromise between a Bessel and Chebychev filter. This transitional filter offers good selectivity and excellent transient properties. It has near linear phase and a smooth rolloff within the passband, which is required for distortionless transmission. Outside the passband, attenuation increases more abruptly, providing the required selectivity.

The filter described in this article and shown in **Figure 3** is a 6-dB transitional filter. This means the 6-dB bandwidth has a gaussian response similar to the Bessel characteristics. The transient properties within this 6-dB bandwidth are very good. Beyond the 6-dB bandwidth, which occurs at approximately 1.5 rads/sec, the rolloff is comparable to that of a Butterworth filter.

## Filter design and construction

We chose an active over a passive filter for several reasons. Since the frequency is in the

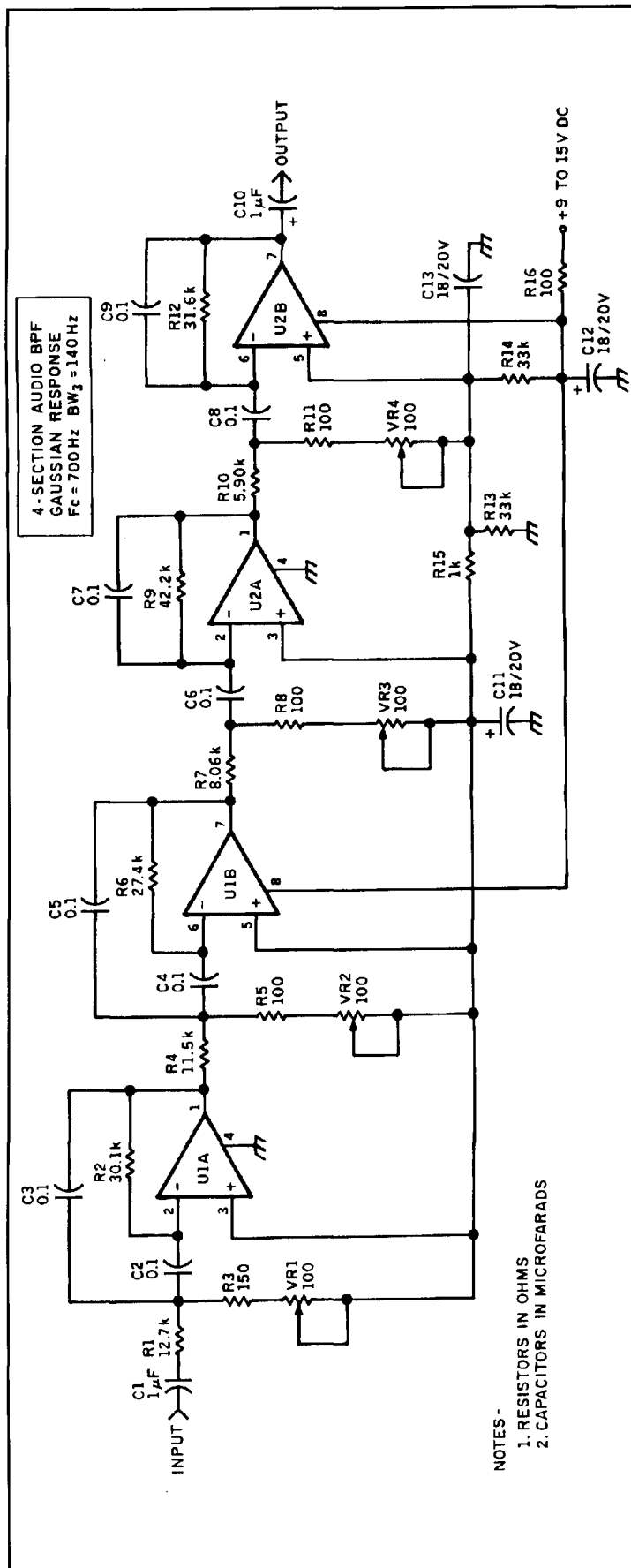


Figure 3. A 6-dB transitional filter.

audio range, very large inductors on the order of 10's of millihenries are required. Inductors of this magnitude have a higher resistance due to the many turns of wire. Because of the increased resistance, the Q of the inductor is low. This translates to an increase in passband loss, and the response at the cutoff becomes rounded. Also, the filter would be physically large.

Active filters are physically smaller and use capacitors rather than inductors. Most capacitors at these frequencies have low dissipation factors with inversely high Q. Because the filter is configured around an op-amp, circuit gain and isolation (high input impedance and low output impedance) are now available.

The filter is configured as a multi-feedback bandpass (MFBP) that has the advantage of minimum components and a lower sensitivity to component tolerances.<sup>1,2,3</sup> The center frequency was selected on the assumption that the offset frequency of most transceivers is 700 Hz. The bandpass filter was designed with the following requirements:

- Center frequency ( $F_0$ )=700 Hz
- Bandpass Q ( $Q_{bp}$ )=5
- Bandwidth (BW 3dB)=140 Hz
- Gain=1
- Filter sections ( $N$ )=4

The pole locations were determined from a normalized design table for a 6-dB transitional gaussian low-pass filter. Next, a low-pass to bandpass pole transformation was performed. The data calculated for each filter section is shown in **Table 1**. This data was then used to calculate the circuit components for each filter section using the standard MFBP equations.

The four-section transitional filter was constructed on a small 2-inch by 2-inch circuit board. The op-amps are Texas Instruments TL-082 dual FET inputs. Two op-amps are required, and they are available in the 8-pin mini DIP style. The capacitors are 0.1  $\mu$ F ceramic CKO5 style. These are temperature sensitive, but adequate for use in a controlled environment. Polycarbonate or polystyrene capacitors will provide more stability over varying temperature conditions, but for a given value are physically larger than ceramic types. One could use smaller value capacitors in the design, e.g., 0.01  $\mu$ F or 0.005  $\mu$ F. This would allow a degree of flexibility in controlling the physical side of the poly capacitors.

Each section of the filter was designed separately. **Figure 4** illustrates the basic frequency-determining components and gives the equations for calculating their values. Use **Table 1** to modify the resistors and capacitors. Bear in mind that the table is for a unity gain centered at 700 Hz. Any other frequency, bandwidth, or overall gain will require a new table of filter

|           | Section 1 | Section 2 | Section 3 | Section 4 |
|-----------|-----------|-----------|-----------|-----------|
| Gain (AR) | 1.1852    | 1.1852    | 2.6719    | 2.6719    |
| Fo        | 665.579   | 736.210   | 600.233   | 816.349   |
| Q         | 6.305     | 6.305     | 8.025     | 8.205     |

Table 1. Data calculated for each filter section.

elements. Its calculation is beyond the scope of this article.<sup>1</sup>

The capacitors shown as C in Figure 4 should be measured and selected to be within a few percent of the design value. The resistors are 1 percent metal film type, 1/8 or 1/4 watt. Resistor R2 should be adjustable in order to tune Fo. The other resistors used for biasing and power supply decoupling can be 1/4-watt carbon composition.

### Tuning the filter

Each section of the transitional filter is designed to be resonant at a different frequency. Connect an audio signal generator to the input of the filter. A level of 1 to 2 volts RMS is adequate. Observe the output of each filter section on an oscilloscope or audio voltmeter. Using Table 1 as a reference, set the generator frequency to Fo of section 1 and adjust R2 of section 1 for a peak reading. Refer again to Table 1, and set the audio generator to Fo of section 2. Adjust R2 of section 2 for a peak reading. Continue with this procedure for sections 3 and 4. Repeat all of the adjustments, and the filter should be tuned and ready for use. At this point, the overall gain can be measured. The output amplitude should be very close to the input amplitude unity gain.

#### Measured data:

Center frequency Fo=710 Hz

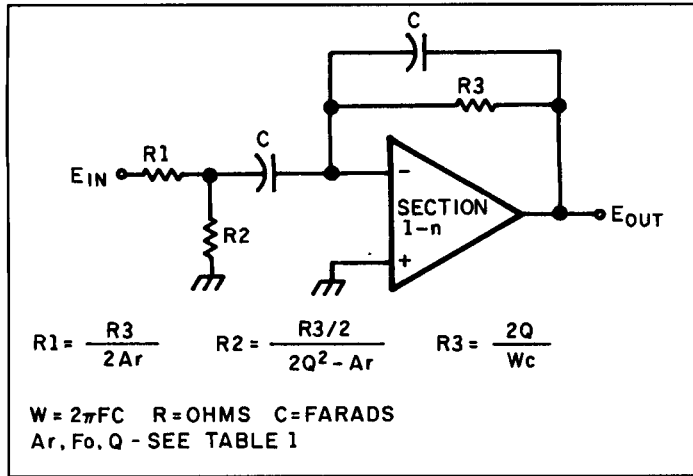


Figure 4. The basic frequency-determining components and equations for calculating their values.

Bandwidth (3 dB)=140 Hz

Attenuation=-40 dBc at 450 Hz and 1050 Hz

Gain=0.95

Output is linear for an input up to 3.5 volts rms using 13.8 volts DC power supply.

### Installation in a Kenwood TS-520

The filter described in this article was designed to improve the CW reception of the Kenwood TS-520. The filter board was installed on the bottom of the chassis over the

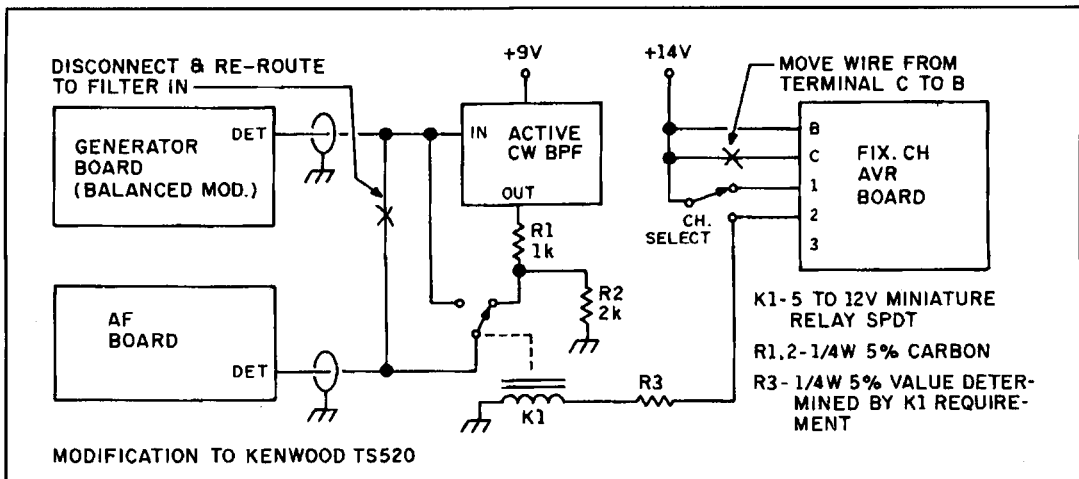


Figure 5. Modification to the Kenwood TS-520.



balanced modulator (BM) board. The filter board was secured on one end to a pair of small brass threaded standoffs. The standoffs were soldered to the top of the steel wall that separates the RF section from the remaining circuitry. The relay (K1 of **Figure 5**) used to switch the filter in and out, was located adjacent to the filter board. It could be included on the filter board if desired.

The only wiring in the TS-520 that needs to be modified is easily accessible. The FIXED CH. switch is wired to serve as the filter in/out control. The switch, which is located on the upper left of the front panel, does not require access. All the wiring changes are made easily at the terminals of the FIX CH AVR board. Position 1 of the switch becomes "Filter Out" and position 2 becomes "Filter In."

Resistors R1 and R2 of **Figure 5** are used to

control the discharge current of C10 in **Figure 3**. Without the resistors, a "pop" will be heard in the audio when the filter is switched in.

## Conclusion

CW operation with the TS-520 is now much more enjoyable. The narrowband crystal filter used in the TS-520 has a poor stopband response. The addition of the transitional active filter reduced the QRM considerably without introducing ringing.

## REFERENCES

1. Doug DeMaw, W1FB, "Understanding and Using Audio Filters," *QST*, April 1983.
2. Arthur B. Williams, *Electronic Filter Design Handbook*, McGraw-Hill Book Company, 1981.
3. *The ARRL Handbook*, The American Radio Relay League, 1993.

# PRODUCT INFORMATION

## RF Applications, Inc. Two Meter Deviation Monitor

RF Applications, Inc. introduced their Model D-144 Two Meter Deviation Monitor which provides a way to measure the deviation of narrow band FM signals.



The monitor is FCC Part 15 Subpart C compliant as a communications receiver. D-144 is a near field two meter receiver with a calibrated, multicolor LED display. The LED display indicates deviation from 0.3 kHz to 5 kHz, and has a 1 watt speaker output for connection to an optional speaker or oscilloscope. It can also be used as a monitor receiver. Tuning is indicated by an LED that comes on when the D-144 is center tuned.

The D-144 operates on 12 volts DC at about 300 mA and is housed in an aluminum enclosure that measures approximately 6 5/8" wide by 3 3/4" deep by 1 3/4" high. The price is \$139.95 and the optional speaker is \$14.95.

For additional information, contact RF Applications, Inc., 7345 Production Drive, Mentor, OH 44060, telephone 216-974-1961.

## Harris HF/VHF Radios offer FM operation on all frequency bands.

The new RF-3201 HAWK Series covers both HF and VHF bands for both long- and



short-range communications. This includes low-band VHF (30-32 MHz) for interoperability with manpack radios, as well as high-band VHF (146-172 MHz) for communication with VHF handheld radios, police and fire units, marine craft and other local services.

The transceiver, its antenna coupler and accessories, have been constructed for protection from shock, vibration, humidity and extreme temperatures.

Internal options available with the RF-3201 include a wideband 5-watt VHF amplifier and a plug-in Automatic Link Establishment (ALE) module. The ALE option is interoperable with both the MIL-STD-188-141A and FED-STD-1045 systems.

It operates on 12 or 24 volts DC. A selectable front-panel power output control is provided for extended operation with battery/solar powered or LPI applications.

For more information, contact Harris Corporation, RF Communications Group, 1680 University Avenue, Rochester, NY 14610 or phone: 716-244-5830.

# DELUXE QRP STATION

*Build this ham-tested project*

Looking for a way to reacquaint yourself with homebrewing? This direct conversion (D-C) receiver and QRP transmitter is ham tested and approved. It was built by seven members of the Mount Diablo Radio Club (MDARC) and three hams from other radio clubs. I also prototyped the project four times during the design process.

I call my project the Deluxe QRP Station because it has a number of innovations not ordinarily found in run-of-the-mill QRP rigs. For example, it includes:

- A peaking circuit to improve selectivity.
- A nulling circuit to reduce heterodyne interference.
- A switch for selecting upper or lower sideband.

- Receiver incremental tuning (RIT).
- Plug-in pc boards for receiver and transmitter.
- Optional digital frequency readout.
- VFO control of transmitter and receiver.
- 4 watts output from a Power-FET transistor.
- Optional side tone (sinewave oscillator).

## Receiver description

Because it contains less circuitry, a direct-conversion receiver is much easier to build than a superhet. Direct-conversion receivers differ from superheterodynes because the local oscillator operates at the same frequency as the incoming signal. In addition, all of the gain rests primarily in the audio circuit. There are no intermediate amplifier stages or second detectors.

However, D-C receivers have several short-



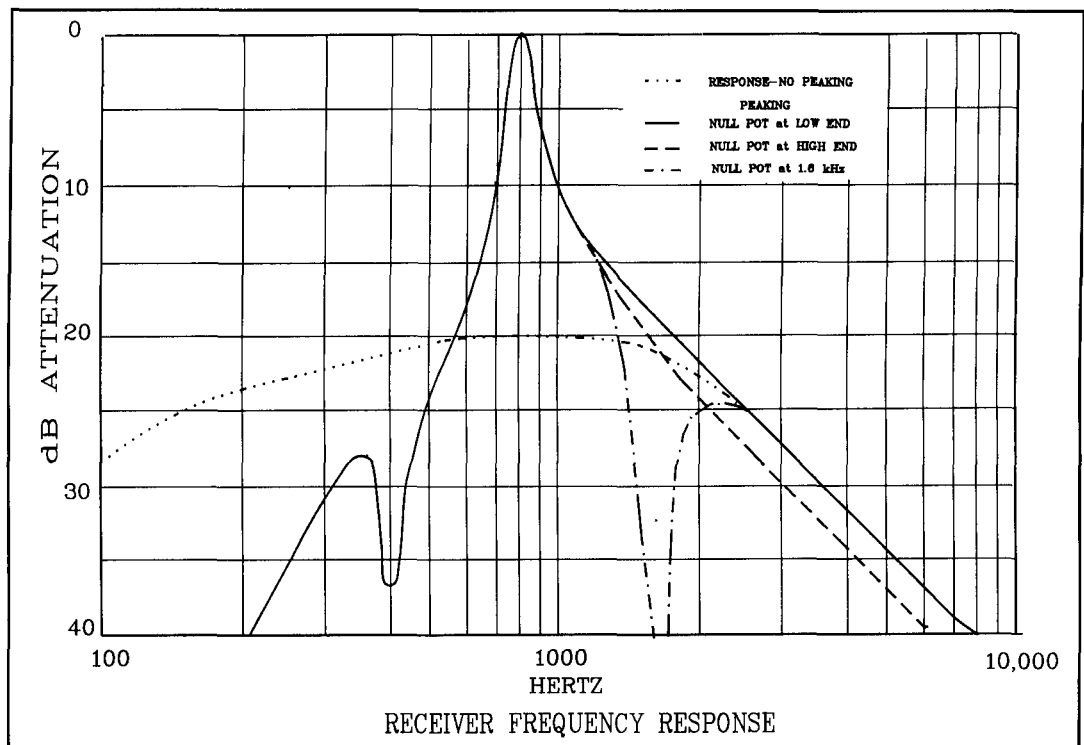


Figure 1. Receiver frequency response.

comings. First, they lack the sensitivity of the superheterodyne receiver. Second, they're prone to AC hum modulation from incoming signals due to ground loops. Third, because they require large amounts of audio gain to amplify the weak radio frequency signals to audio level, these receivers are subject to microphonics—a form of audio feedback that can cause the receiver to go into a continuous state of audio oscillation. Fourth, there's broadcast station feedthrough due to poor front-end selectivity and dynamic range.

After reading a number of recent articles on direct-conversion receivers that use the NE602N, I decided to try building one for CW operation.<sup>1,2,3,4</sup> Information on these D-C receivers indicated that the NE602N solves two problems—the hum modulation and the AM broadcast station feedthrough. The microphonics can be controlled with good mechanical design.

With these problems solved, I needed to improve selectivity. In this type of receiver, the incoming signal appears on both the upper and lower side of the transmitted signal. The receiver oscillator must be offset from the transmitted signal to create an audible beat note against the incoming signal. The audio tone goes from a zero beat to a frequency well above the audible range on both sides of the incoming carrier. Because these are audio frequencies, I found that to improve selectivity, I needed a lowpass filter with a very sharp cutoff at a frequency just above the one desired for best CW recep-

tion (approximately 800 hertz).

I've used a very simple peaking circuit in previous projects.<sup>5</sup> This circuit uses an operational amplifier and four components. It provides about 20 dB of peaking and is adjustable from 300 Hz to 3 kHz. Because this receiver is designed as a CW rig, the adjustment is set internally to approximately 800 Hz. **Figure 1** shows the peaking selectivity curve. The gain without peaking is shown as a reference.

Now all that remained was the signal's presence on both sides of the received carrier. I decided to take advantage of the situation instead of considering it a limiting factor. I used a circuit that shifts the oscillator from one sideband to the other via a front panel switch. When interference is present on one sideband, it's possible to flip the switch and reduce the interference as shown in **Figure 2**. This method is preferable to retuning the dial to check the other sideband, risking loss of some information or the other person's signal. A notch filter<sup>5</sup> also helps to improve the selectivity. This adjustable filter attenuates any frequency approximately 20 dB over the range of 300 Hz to 3 kHz. The combination gives my D-C receiver better selectivity when compared to a standard D-C receiver.

I designed the receiver to operate on the 80 or 40 meter CW bands, so the oscillator tunes about 130 kHz on the 80 meter band and 150 kHz and the 40 meter band. (For greater range, increase the capacitor between the varicap, D1,

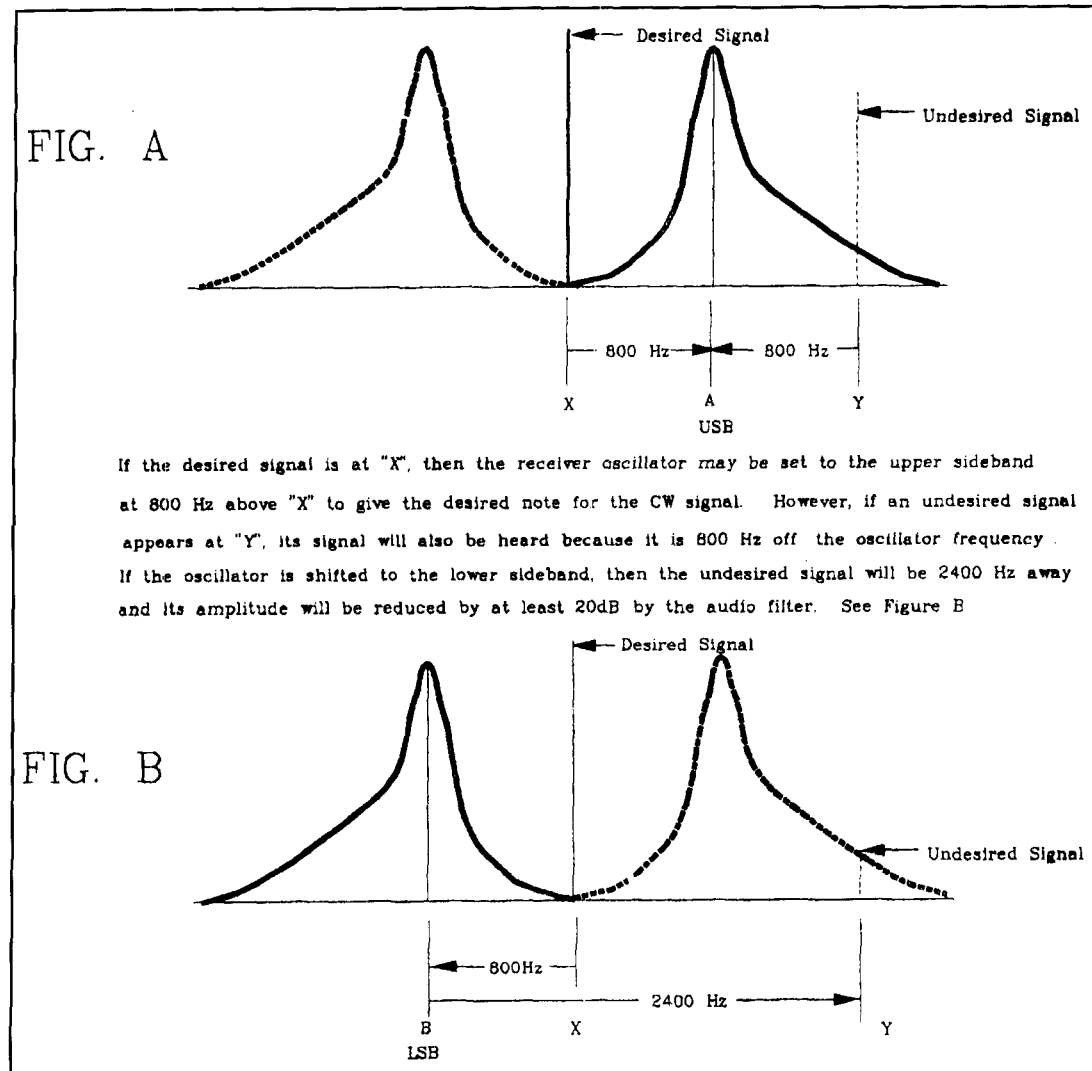


Figure 2. Sideband selection.

and the oscillator coil, L3.) A 10-turn potentiometer that controls the varicap tuning capacitor yields a range of approximately 15 Hz per revolution of the tuning dial. The fine-tuning resolution is necessary because the audio filter peaks sharply. The varicap is temperature sensitive but, because the main heat source (the power supply) is housed in another cabinet, the only major source of temperature change is the result of ambient temperature variation. Normally, this drift is minimal and has little effect on QSOs. Because the varicap's capacitance represents about one third of the total capacitance of the tuned circuit, its drift has less total temperature effect than if it supplied total tuning capacitance. Data derived from observations of 12 receivers containing this circuit showed an average initial turn-on drift (three minutes) of less than 300 Hz. Drift due to ambient temperature changes was about 50 Hz per degree F, measured over 12 hours. With constant temperature, there was no apparent drift.

The capacitance of the tuning varicap is a function of its reverse-bias level. Reverse bias is controlled by a 10-turn potentiometer that acts as an adjustable voltage divider. The varicap has a nonlinear voltage-to-capacitance curve—the greatest change in capacitance occurs when the reverse voltage is lowest. I compensated for this by using a resistor from the arm of the pot to ground, which greatly improves the linearity.<sup>6</sup> A resistor in series with the lower part of the pot eliminates tuning over the nonlinear portion of the curve when the voltage nears zero.

The receiver is built on a plug-in pc board to facilitate construction, modifications, or repairs. This modular construction provides the option of building plug-in boards for different bands. The present design allows operation on either the 80 or 40-meter band. The pc board plugs into a 22/44 connector (Radio Shack no. 276-1551 or equivalent). I used only one side of the connector pins, so a 22-pin connector

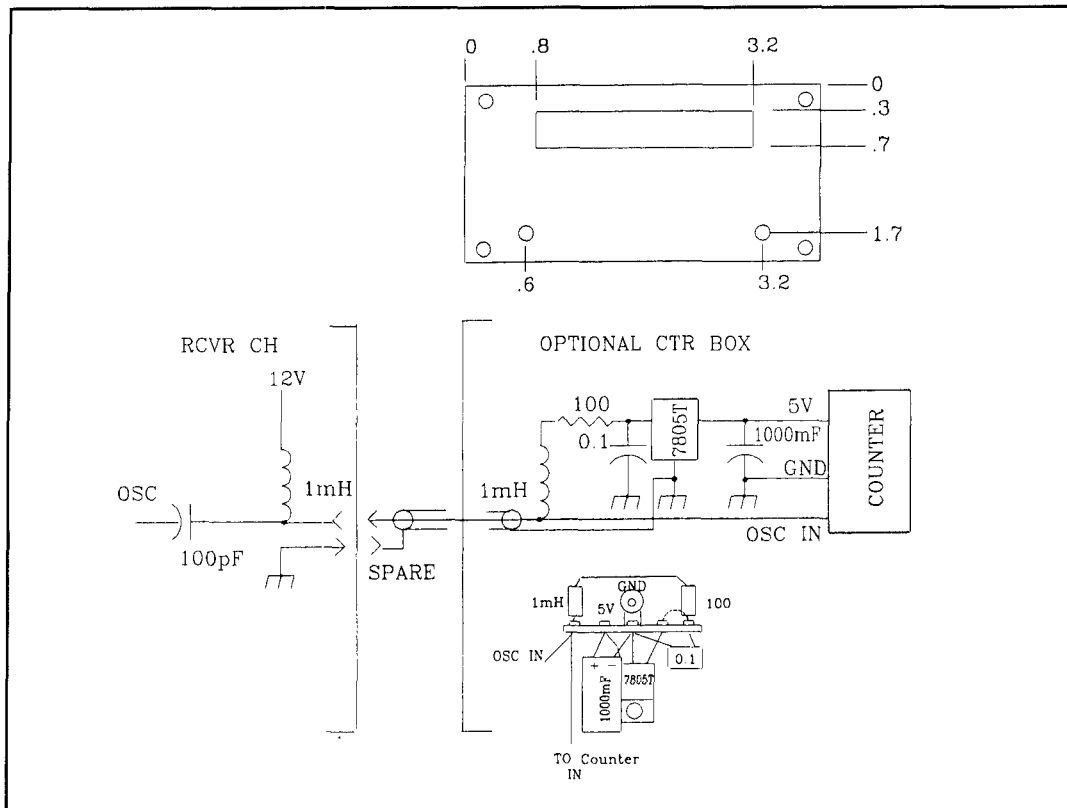


Figure 3. Connecting the optional frequency counter.

will work just as well providing the pin spacing is correct (0.156").

## QRP transmitter description

I decided to incorporate a low-power (QRP) transmitter to work with my receiver. Because the receiver's oscillator operates on the same frequency as the incoming signal, the receiver oscillator can also be used to drive the transmitter circuit directly. However, during transmit, the oscillator frequency must be offset by 800 Hz—up or down—depending on which side of the incoming signal you're tuned. This shift is performed automatically when the unit is switched to transmit. I'll cover the transmitter in more detail later.

## Frequency counter

As an added (optional) feature, I incorporated a frequency counter based on Intersil's ICM7216D. Because the oscillator frequency is on the same frequency as the incoming signal, no special circuitry is needed to offset the counter. The counter increases the overall cost of the receiver/transmitter by 30 percent, but is a worthwhile accessory. As a low-cost alternative, you can substitute a mechanically driven frequency indicator.

The 5-digit frequency counter reads the incoming or the transmitted frequency to 100 Hz. The Intersil IC makes the counter very simple; everything except the crystal and 8 discrete components is contained in the ICM7216D. The pc board measures 1.8 x 2.8 inches and includes the five 7-segment displays.

If you want to add the frequency counter as a separate unit at a later date, you can connect it as shown in **Figure 3**. The spare phono connector on the receiver rear panel supplies the signal to the counter. The 5-volt regulator and filter are mounted in a separate box (Radio Shack no. 278-230) with the display board. The pc board is installed in the same way as the receiver assembly, and the 5-volt supply is mounted on the rear of the small cabinet. The oscillator signal and power are carried over the same line.

## Receiver circuit

As I've said, the receiver is designed to work on either 80 or 40 meters with some minor component changes. **Figure 4** is a block diagram of the receiver and transmitter. **Figure 5** shows the receiver schematic. The NE602N is a double-balanced mixer (or in this case a product detector) similar to the MC1496, but with all of the required external resistors built in.

I originally used the oscillator circuit of the NE602, but found the frequency shifted about



500 Hz on transmit when the key was closed. I believe this was due to the lack of isolation in the antenna changeover relay. Some RF was being fed back into the NE602, causing the internal oscillator to shift. I cured this problem by using a separate oscillator. The local oscillator uses an MPF102 in a Clapp circuit. The frequency is shifted from one sideband to the other via a circuit controlled by a front panel switch. The frequency is changed by connecting a 1N4002, acting as a varicap, in the oscillator circuit.

The detector input is tuned with a variable capacitor (C1). The circuit is broad enough that retuning isn't needed over the 150 kHz range. The audio recovered from the NE602N is fed differentially to an amplifier stage with a voltage gain of approximately 10. The output from this stage is capacitively coupled to the audio peaking stage. The null circuit follows this stage. It consists of two operational amplifiers in a dual package (MC1458).

The power amplifier uses the LM386 and can deliver about 0.5 watts to an 8-ohm load. (Oscillations may develop if the load is greater than 8 ohms.) Audio is ample with this circuit. The gain of the amplifier stage is set to 200 by the capacitor across pins 1 and 8 of the LM386.

Because of the optional QRP transmitter, I've included RIT and audio muting circuits. The transmit switch disables the voltage source to IC2 to mute the receiver when transmitting. Once again, an 1N4002 diode is used as a varicap in the RIT circuit. R2 shifts the oscillator offset by 800 Hz when transmitting. An audio

tapered pot helps linearize the RIT pot. It must be connected as shown in the component placement drawing.

## Power supply

A second cabinet houses the receiver power supply and, if desired, the QRP transmitter. A Radio Shack transformer no. 273-1352 is used with a bridge rectifier circuit and a 4700  $\mu\text{F}$  @ 25-volt capacitor for filtering (see **Figures 6, 7, and 8**).

The supply voltages are carried through a pigtail cable to a 4-pin connector (Radio Shack no. 274-002) and plug (Radio Shack no. 274-001) on the receiver chassis rear panel. The transmitter control signal is also carried on this cable. Separate pigtails for the receiver antenna input and the oscillator output for the transmitter are also located on the back of the chassis, and are terminated with RCA type phono jacks and plugs. (I used Radio Shack no. 274-346 jacks and a phono-plug-to-phono-plug cable from All Electronics cut to 8-inch pigtails.) The power supply front panel also has an AC power switch and a LED that's keyed with the transmitted signal.

## Building the direct-conversion receiver

I used Radio Shack cabinets (RS 270-253) as enclosures. One houses the receiver, the second the power supply and optional QRP transmitter.

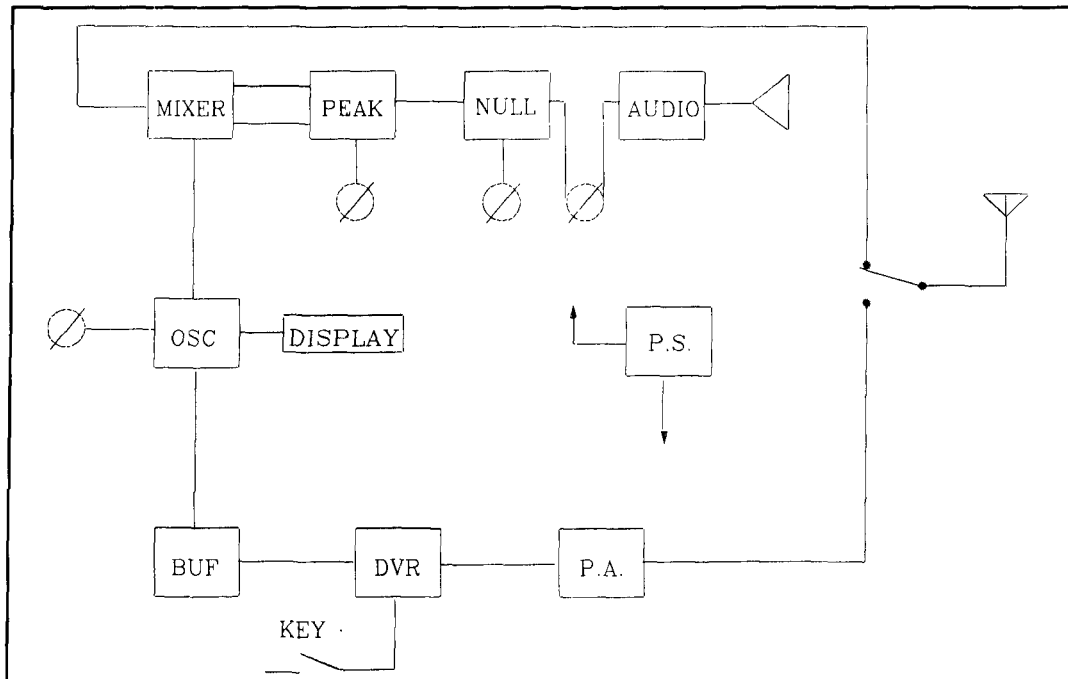


Figure 4. Block diagram of the receiver and transmitter.



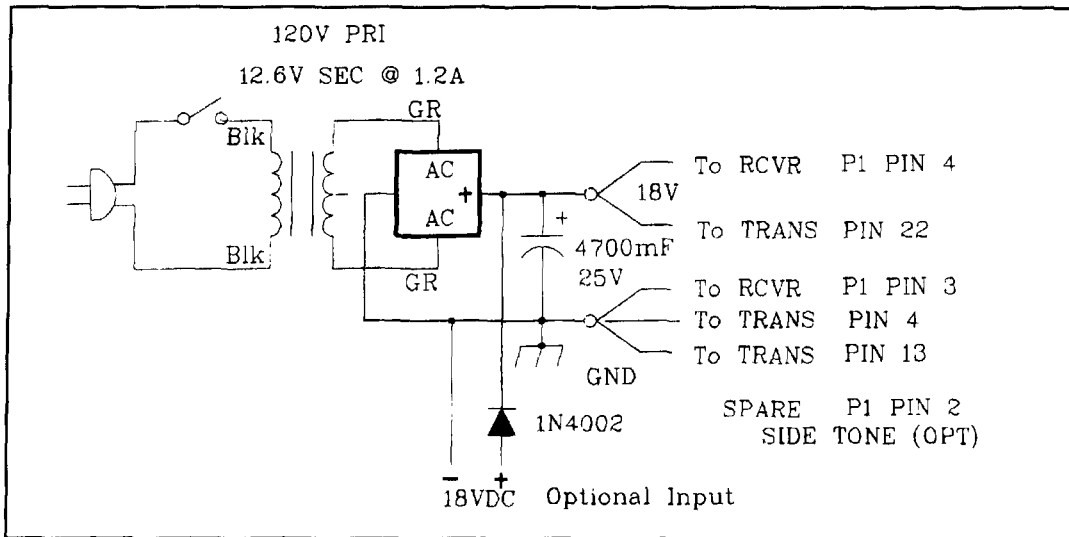


Figure 6. Power supply.

The panels of these cabinets are constructed of very light metal and bend easily. To make the holes on the front and rear panels, I used a piece of 2 x 4 wood reinforcement cut to fit the inside of the box from front to rear (see **Figures 9 and 10A**). The board stiffens the panels so you can center punch and drill without distorting them. You can cut the counter display hole by making a series of small holes and filing them to fit. A nibbler tool also works.

The 12 and 5-volt regulators that supply the receiver and display boards are mounted on the rear of the receiver chassis. (The 5-volt regulator is only necessary if you add the counter.) They are mounted directly to the metal chassis wall and don't require insulators. Tie points are used on the rear panel to mount the counter's 1000  $\mu$ F filter capacitor and the regulator terminals (see **Figure 9**).

The following controls are installed on the

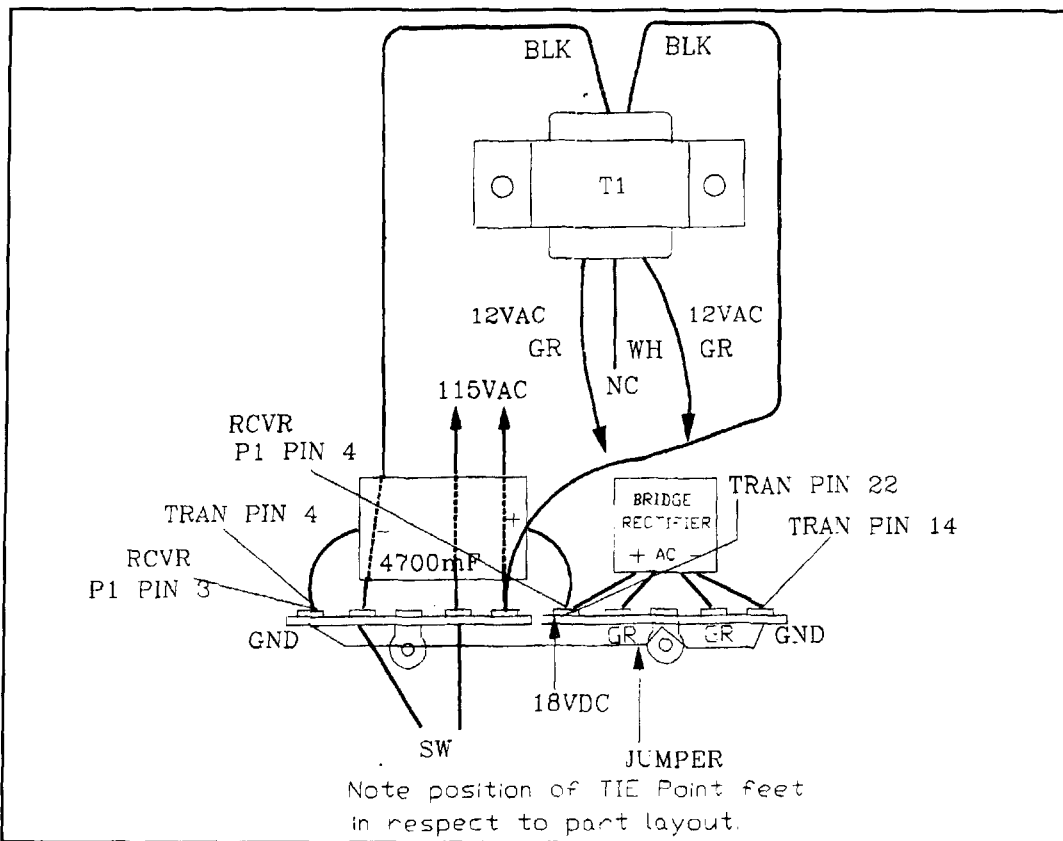


Figure 7. Bridge rectifier circuit..

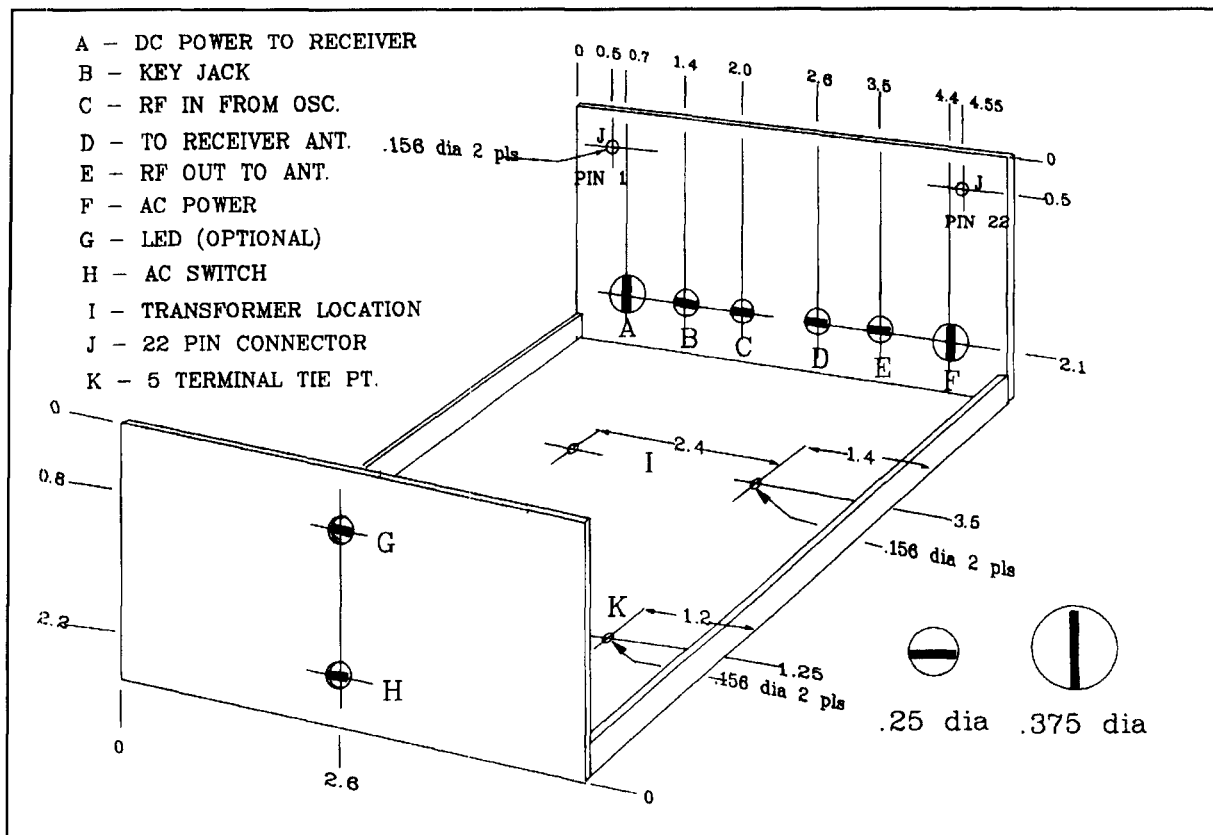


Figure 8. Power supply chassis.

front panel: the ten-turn pot used to set the VFO frequency, two switches (one for sideband shift and the other for transmit/receive), a null control, an RIT pot, and an audio gain pot. Before working on the pc board, I suggest you wire the various controls and the pc board connector as per the diagram in **Figure 11**. The pots must be wired as their terminal numbers indicate for proper operation. (Note: Look at the pots from the front of the panel to determine the numbering scheme.)

To give the front panels a more professional appearance, I sprayed them with high-gloss white paint. I then covered the receiver panel with transparency material labeled with the various control functions. Negatives for the film are shown in **Figure 10B**. If your receiver doesn't contain the built-in counter, use the second negative option. It's a reverse negative, so the printing will be on the inside when placed on the panel. The material, called Type 101 transparency, is manufactured by Kodak. It comes in an 8-1/2 x 11 sheet and is available from photocopy stores. I suggest that you copy the artwork onto a sheet of regular copy paper first. Make three copies, and combine all three on one sheet. Place this composite sheet into a

copier, insert the film in the paper drawer, and print. Choose the best copy for your project and keep the others as spares in case you make a mistake. Cut the completed film to fit the outline indicated. Carefully cut out the holes with a hobby knife. Mount the various pots and switches on the front panel over the film; they will hold it in place.

Because the pc board head room is restricted, it's necessary to flatten the connector solder terminals so they're at right angles to the connector. The component placement drawing, **Figure 11**, indicates in which direction the terminals should be bent. The connector is mounted to the chassis with 4-40 screws using 6-32 nuts as spacers. To prevent the terminals from shorting to the chassis, I cut a 3 x 5 card 1 inch wide and placed it under the terminals. The receiver requires one shielded cable that runs from the oscillator output phono jack on the cabinet rear to the counter. To make this cable, use any shielded phono cable leftover after making the antenna and oscillator pigtailed. The shield is grounded on both ends.

### Receiver pc board construction

Use **Figure 11** as a parts placement guide. All pc boards are available from FAR Circuits for a nominal fee.\*

The receiver requires two coils—one for the

\*Printed circuit boards can be obtained from FAR Circuits, 18N640 Field Court, Dundee, Illinois 60118. Prices are as follows: receiver board, \$5.60; transmitter board, \$4.40; counter board, \$3.50; side-tone board, \$3.50. A set of boards is \$14. Please add \$2.00 shipping and handling per order.

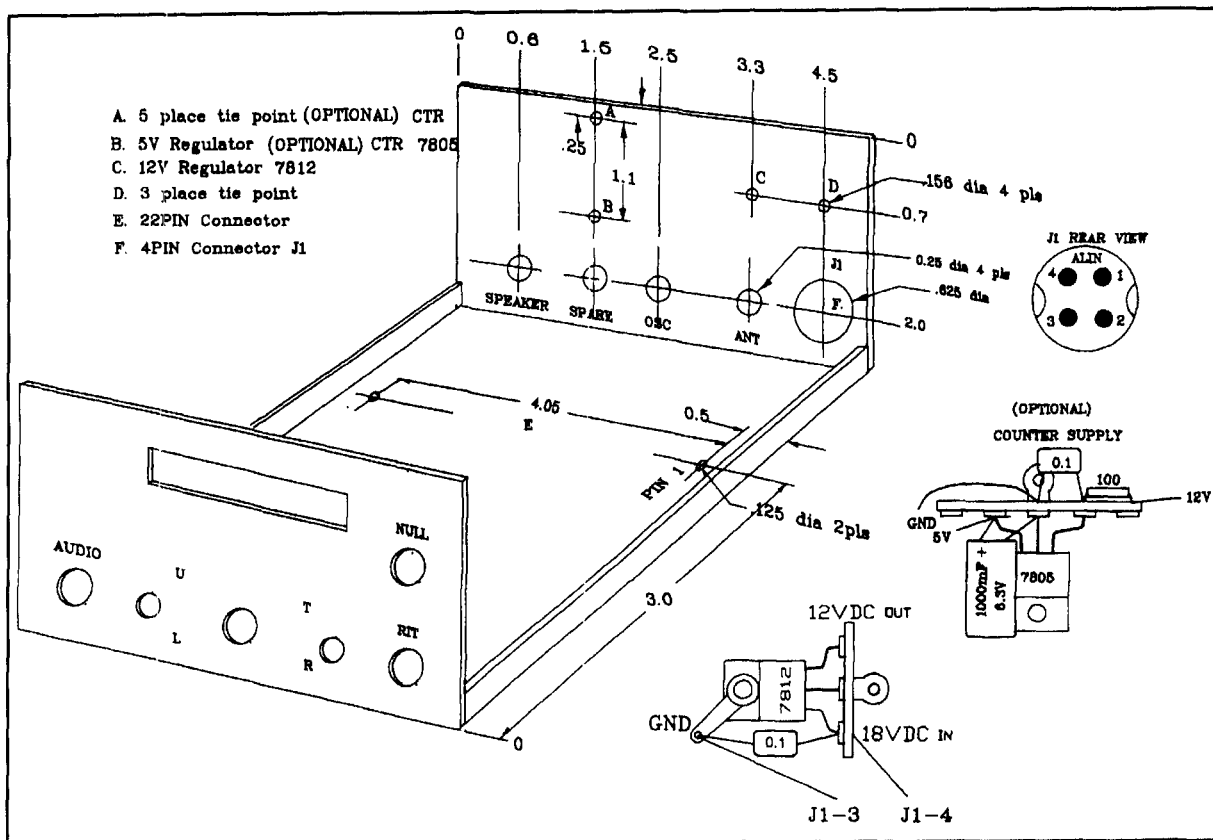


Figure 9. Component mounting locations, receiver chassis.

oscillator and one for the detector—wound on T50-6 toroids. Coil and capacitor data are provided in **Table 1**. Use NPO ceramic or polystyrene capacitors in the oscillator circuit to ensure temperature stability. I obtained the best results when capacitors C2 and C3 were polystyrene and the others associated with the oscillator circuit were NPO type. Several articles have indicated that poly capacitors have a temperature coefficient that counteracts the temperature shift produced by the toroid<sup>7,8</sup> My experimentation has proven this to be true. All 12 units I investigated showed a reduced fluctuation with temperature when they were used in this configuration.

The ICs are mounted in 8-pin sockets. Be especially careful of the tantalum and electrolytic capacitors' polarization. The bar on the symbol indicates the plus terminal correspond-

ing to the plus sign on the capacitor.

If you include the QRP transmitter, mount the pc board connector on the rear panel of the power supply cabinet. Even if you're not planning to build the transmitter now, it would be wise to drill the connector holes while making the other holes, so you can add it in the future.

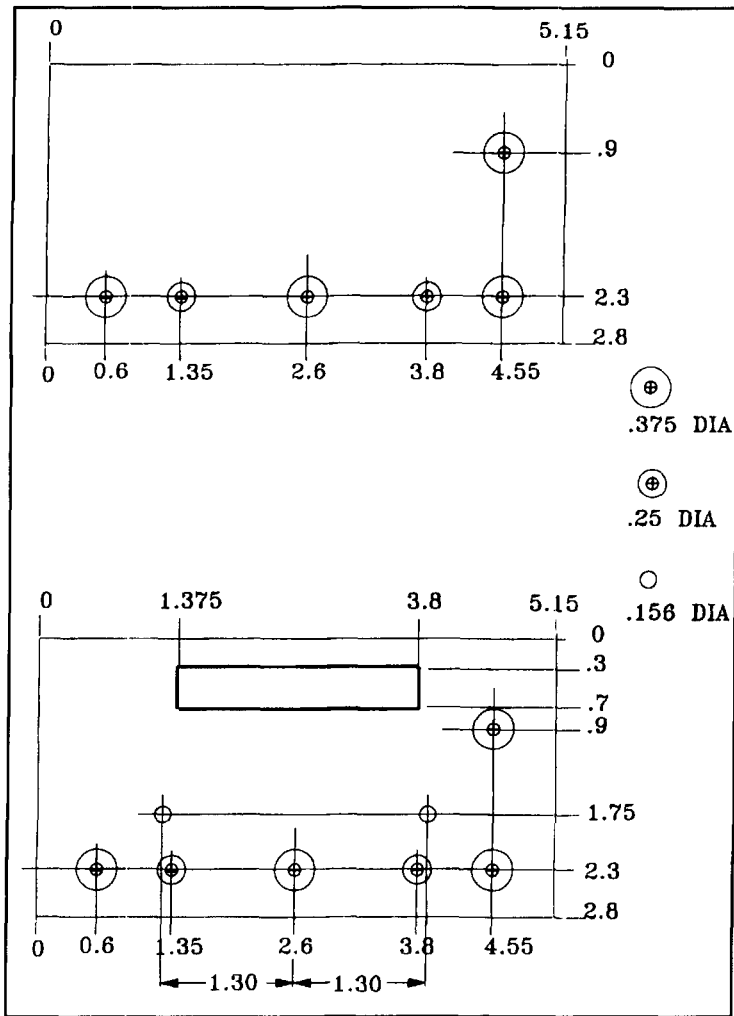
## Frequency counter construction

As I mentioned earlier, the frequency counter is also built on a pc board. The component placement and circuit schematic are shown in **Figures 12A and B**. **Figure 13** shows the eight jumper wires that must be installed on the back of the pc board; i.e., D1 goes to D1, and so on. The pc board consists of the Intersil ICM7216D, a driver transistor, and the dis-

| Band | C1     | C2   | C3   | C4      | C5      | L1    | L2    | L3    |
|------|--------|------|------|---------|---------|-------|-------|-------|
| 80M  | 10-200 | 1000 | 1000 | 100pF   | 33pF    | 3T    | 38T   | 50T   |
|      | pF     | pF   | pF   | ceramic | ceramic | 26AWG | 26AWG | 26AWG |
| 40M  | 10-200 | 470  | 470  | 10pF    | 5pF     | 2T    | 27T   | 27T   |
|      | pF     | pF   | pF   | ceramic | ceramic | 26AWG | 26AWG | 26AWG |
|      |        | poly | poly |         |         | 3"    | 29"   | 31"   |
|      |        | poly | poly |         |         | 2"    | 18"   | 18"   |

Table 1. Receiver coil and capacitor data.





plays. I used MAN74s for the displays; they're readily available and inexpensive. All ICs are mounted in sockets. The power for the counter is obtained from the 5-volt regulator on the rear panel of the receiver chassis. The ICM7216D is designed to work with a crystal calibrated in parallel. Unfortunately, almost all the 10-MHz crystals are calibrated in series. Consequently, the receiver oscillator readings were low. After some experimentation, I recalled the "rubber crystal" technique, where an inductance in series with a crystal lowers its frequency. Lowering the oscillator frequency increases the count time, allowing a higher number of cycles through, and a higher frequency reading. A 10  $\mu$ H choke solved my problem and let me calibrate the counter correctly. A trim capacitor mounted on the board allows exact adjustment of the crystal frequency. One-half inch threaded spacers and screws mount the pc board to the front panel. A piece of transparent red plastic is placed behind the display panel opening. I used "see-thru report covers" from the stationary store. There are many types available. Try to obtain the darkest red possible. It may take two

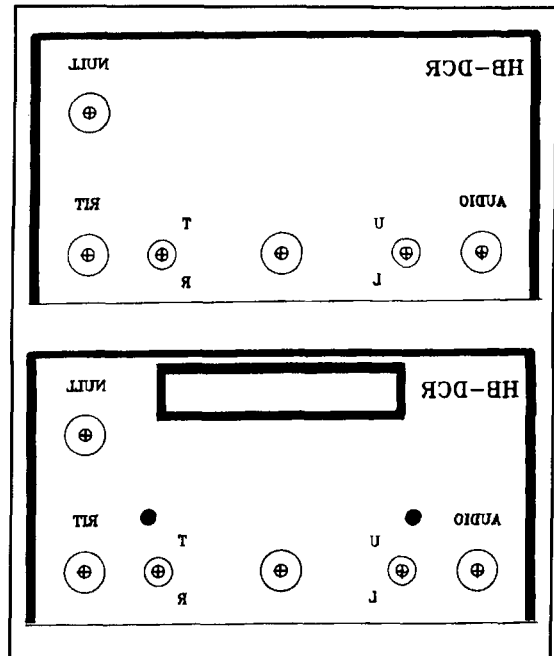


Figure 10.(A) Hole template, receiver chassis. (B) Control function template, receiver chassis.

layers of the material cut to size and secured to the panel with DUCO cement.

## Receiver adjustments

Before inserting any ICs, check to see that all test points have the proper voltages. The voltage across the 4700  $\mu$ F capacitor should be about 18 to 19 volts; all others on the pc board should be 12 or 5 volts. A 78L05 regulator provides the 5 volt source on the receiver board and this supplies voltages to the NE602 and the oscillator.

If your voltages are correct, it's time to check out the receiver. Set the REC/TRANS switch on REC. If you have another receiver, use it to help determine if the oscillator is working and the frequency to which it's tuned. If you've incorporated the counter, it will provide the oscillation frequency. (The counter displays 0.0 if the oscillator isn't working.) If the receiver is working, connect your dipole or long wire antenna to the antenna input. You should hear an increase in background noise when the detector capacitor (C1) is rotated to the oscillator's resonant frequency. (Because the capacitor rotor is floating in this circuit, you must use a nonmetallic adjustment tool to set it to the right spot. I used a wooden dowel with a slot in the end to fit over the shaft.) The audio gain should be at the 3/4 position for this check. The peaking potentiometer (R3) on the pc board should be set at approximately 1/2 clockwise for 800 Hz peaking.

If nothing is heard, look for a problem in the

audio section. Remove the NE602N and connect a wire to pin 6 of the next stage (IC2). Touch this wire with the power on. You should hear a loud buzz in the speaker. If not, repeat the procedure with pin 3 of the output stage (LM386). This should help you locate the problem area.

Now that you've finished troubleshooting the audio section, you're ready to set the receiver frequency limits. Set the lower edge to 3595 kHz for the 80-meter band, or 6980 kHz for the 40-meter version. Turn the 10-turn pot to its full counterclockwise position. Determine its frequency, either by using the counter or a receiver located nearby. If the frequency is too high, try pushing the turns on oscillator coil L3 closer together. If it's too low, do the reverse. There's no setting for the high end, but it should be about 130 kHz higher. Use the same technique for the 40-meter band. When you're sure you have the proper settings, cement the wires in place. I recommend that you start at one end and do about three quarters of the coil. This lets you make minor adjustments after the cement dries. You must also cement the coil to the pc board for stable frequency operation. (I used DUCO cement here.) The frequency will change when you put the cover on, so allow for this in your settings.

You should now hear CW signals (for 80 meters, listen at night; for 40 meters, listen day

or night). You should also notice a definite increase in the received signal as you approach the 800 Hz audio frequency. This indicates that the peaking circuit is working.

Now check the null or notch circuit. Tune off a received signal until its audio note is about 1200 Hz in frequency and then rotate the null pot. Start with the pot in the clockwise position and slowly rotate it counterclockwise. The null is very sharp; you should hear a definite drop in the signal level. The null pot is normally left in the full clockwise position when not in use.

Next check the RIT circuit. Set the RIT pot to its center position. Zero beat a signal and rotate the pot from one end to the other. There should be a change in frequency of approximately plus or minus 2 kHz. The knob is normally set in the center position to allow for the plus or minus variation.

It's a little more difficult to set the upper/lower sideband selection switch because you need a steady signal. (With a little patience, you can set it using a loud CW signal.) A signal source, like a signal generator, etc., makes this operation much easier.

First, set the RIT control to the CENTER. Then set the sideband switch to LOWER sideband. With the switch in this position, the full capacitance of the 1N4002 is across the circuit. (In the lower sideband position, no voltage is applied to the 1N4002, placing it at full capaci-

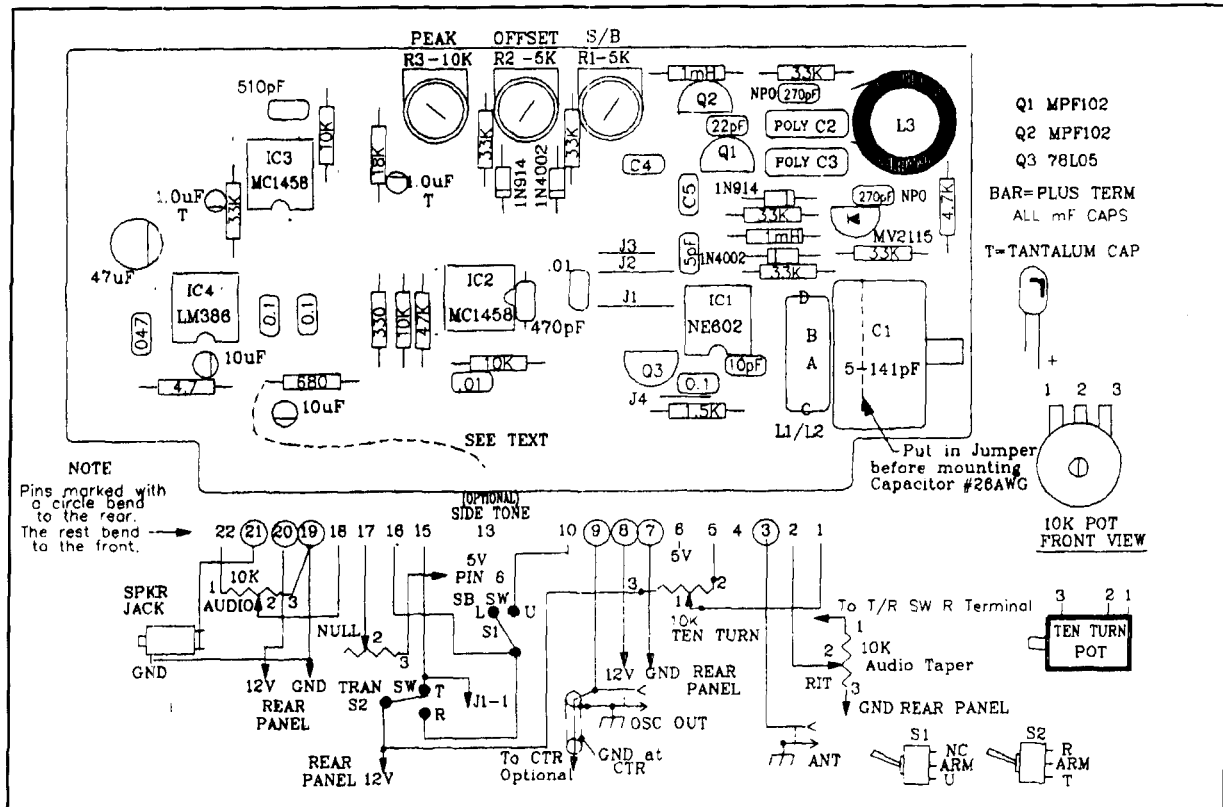


Figure 11. Receiver board layout. Component side.

| Band | C1     | C2     | C3    | L1           | L2           | L3           | L4           | RFC          |
|------|--------|--------|-------|--------------|--------------|--------------|--------------|--------------|
| 80M  | 1000pF | 1800pF | 680pF | *23T         | *23T         | 17T          | 20T          | 50T          |
|      | mica   | mica   | mica  | 26AWG<br>18" | 26AWG<br>18" | 26AWG<br>11" | 26AWG<br>15" | 26AWG<br>37" |
| 40M  | 680pF  | 1000pF | 470pF | *23T         | *23T         | 12T          | 16T          | 50T          |
|      | mica   | mica   | mica  | 26AWG<br>18" | 26AWG<br>18" | 26AWG<br>9"  | 26AWG<br>10" | 26AWG<br>37" |

\*Bifilar wound, 5 twists per inch.

Table 2. Transmitter coil and capacitor data.

tance.) Tune the receiver to the lower sideband of a signal until you reach a point where the tone peaks at 800 Hz. Now switch to the upper sideband. You should still hear the signal, although it may be at a different pitch. Adjust R1 until the tone peaks at 800 Hz again. Switch back to the lower sideband and retune the receiver to the peak CW note once more. Return to the upper sideband and recheck. If you still don't have the right frequency, readjust R1 and repeat the operation until there's only a minimal change in pitch from one sideband to the other. It may not be possible to get a perfect match from one band to the other, but it will be close enough to know that you're hearing the same signal.

The oscillator frequency is offset for transmitting in a similar fashion. The transmit switch on the front panel connects potentiometer R2 to the 1N4002. R1 is disconnected when the transmit switch is in the transmit position. (At the same time, it disconnects the supply voltage to IC2, which mutes the receiver in transmit.)

To make the adjustment, set the sideband switch to lower sideband (LSB). Connect a temporary wire from pin 8 of IC2 to pin 8 of IC3 on the pc board. This activates IC2 in transmit, so you can hear the audio. Set the RIT in the CENTER. Remove the transmitter board and jumper pins 2 and 4, or connect the receiving antenna directly to the receiver input. If you don't remove the transmitter board, the receiving antenna will be disconnected by the changeover relay in transmit. Tune the receiver to a signal on the lower sideband, peaking the signal at 800 Hz. Turn on the TRANSMIT switch. Set the RIT to full counterclockwise position and adjust R2 until the signal is zero beat. Switch back to RECEIVE and readjust the receiver to 800 Hz with RIT back in the CENTER. Repeat the process until no change is required when going from lower sideband to zero beat. Reset the RIT to the center position and remove the jumper on the pc board.

If the counter is in the circuit, you should see

the frequency shift upward by approximately 800 Hz. When moving in the opposite direction, upper sideband (USB) to zero beat may not shift down the same amount, but should be close enough that it won't create a problem for any station listening to you.

With the counter, the sideband offset adjustment is much simpler. Set the receiver oscillator frequency to 7100.0 kHz with the sideband switch in the lower position. Move the sideband switch to high. Adjust R1 to give a reading of 7101.6 kHz. Check to see if the LSB still reads 7100.0 kHz.

To set the transmit offset circuit, put the sideband switch in LSB with the counter reading 7100.0 kHz. Turn on the transmit switch and adjust R2 to give a frequency reading of 7100.8 kHz. Move the sideband switch to the USB. The reading should still be about 7100.8 kHz.

I've noticed some stations don't shift the same amount; this is where the RIT control comes in handy. You can tune in their signal without changing your transmitted frequency.

*Caution: Do not use the RIT to tune the station before you make a contact. Once you have made a contact, you can use the RIT to retune without upsetting your original transmitting frequency. After a contact, always reset the RIT back to the center position.*

## Tuning the receiver

There's a special tuning method you must follow to use the receiver with the transmitter. Set the RIT control to the CENTER. If you're tuning across the band from the low end up, make sure the sideband switch is in LSB. If you come across a station on LSB, you can move the sideband switch to the USB to see if the signal has less QRM. Don't touch the dial when performing this operation. If you've chosen the correct sideband, the signal will still be present. If not, you're on the wrong sideband. If you tune from the upper end of the band downward, the sideband switch must be in USB. This feature lets you shift the received signal from

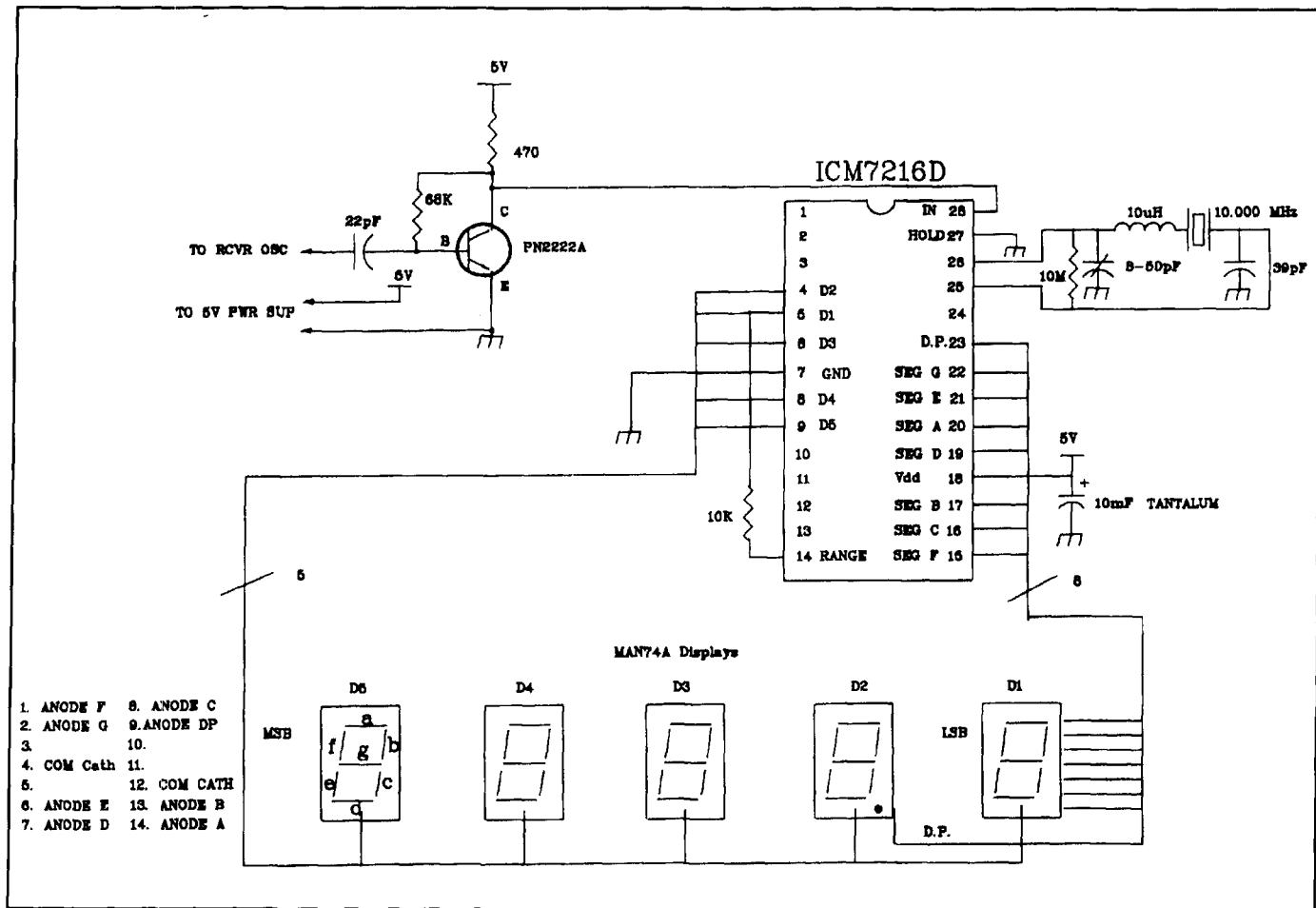
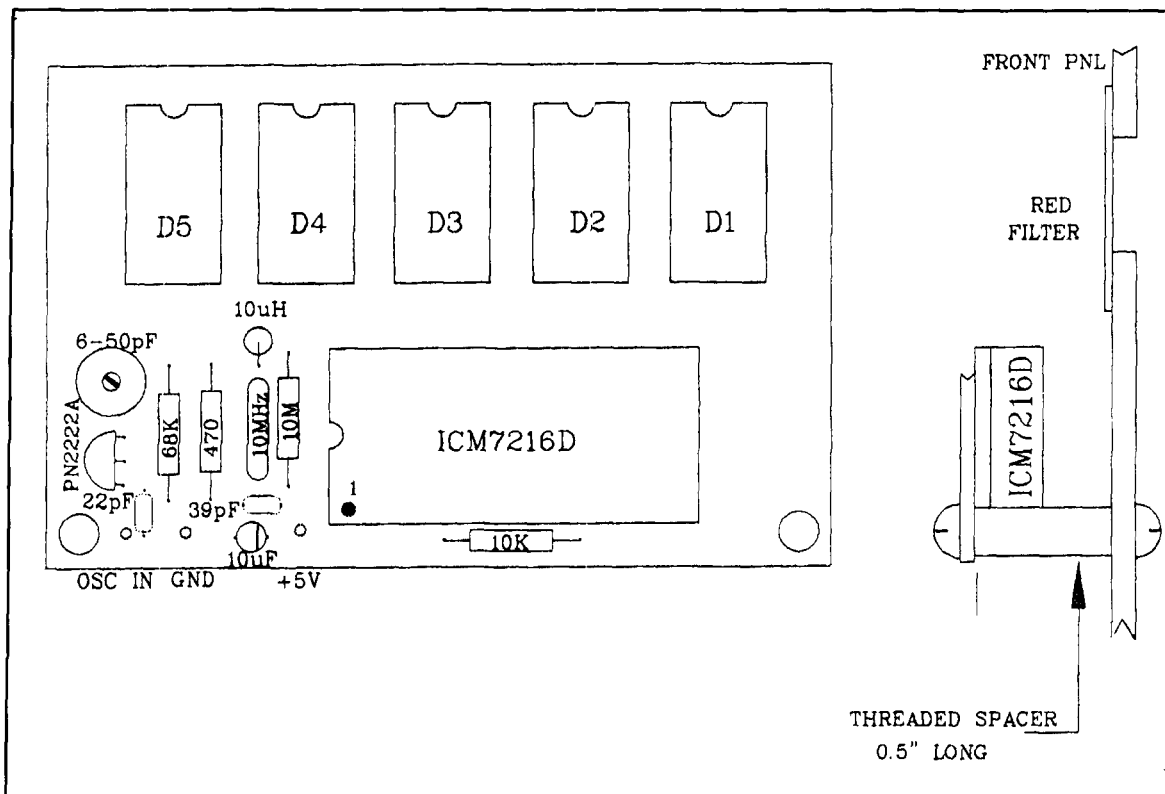


Figure 12. (A) Frequency counter board layout. Component side. (B) Circuit diagram..

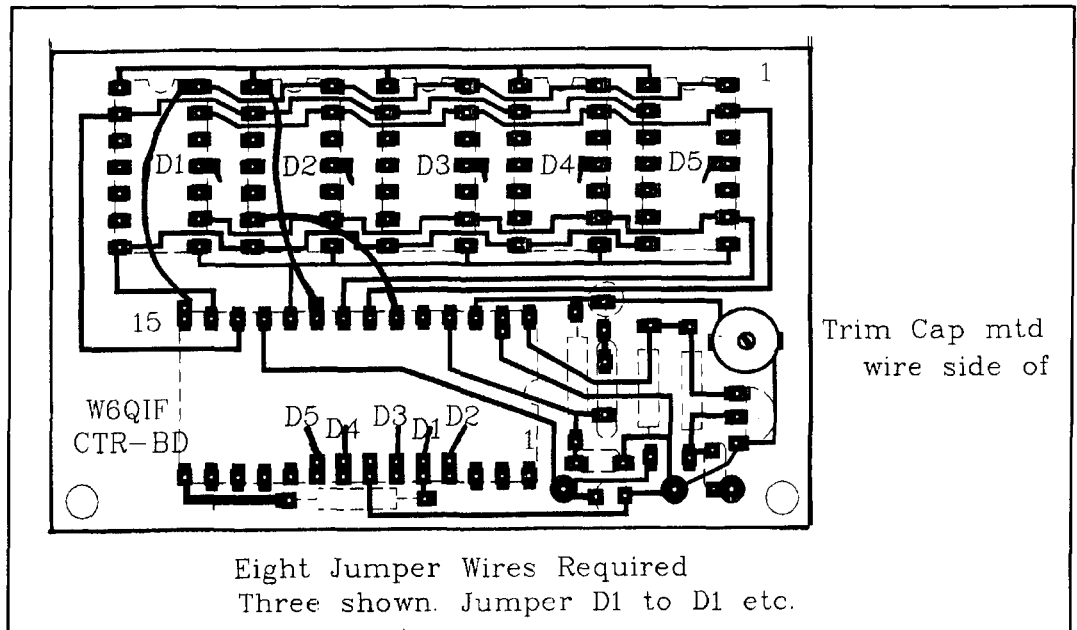


Figure 13. Location of eight jumper wires that must be installed on the back of the frequency counter board.

upper sideband to lower sideband to see which side is in the clear. If there's QRM on both sides, adjust the notch filter to remove one of the interfering stations.

### Antenna requirements

The receiver is designed to use a low input impedance antenna. If you use a short antenna for receiving, you'll need some sort of matching network to obtain the best results. If you operate the receiver with the transmitter, use either a 50 to 75-ohm impedance dipole antenna; you'll need a matching network for any other type of antenna. I use both a 40-meter dipole and a 250-foot end-fed long wire with a matching network.

### The QRP transmitter

The QRP transmitter is also built on a plug-in board. It's capable of producing 4 watts output to a 50-ohm load. Don't let the low power turn you off. Many people have been able to work some fantastic distances using low power.

### Transmitter description

The QRP transmitter fits into the cabinet that houses the power supply. The transmitter connector is mounted on the rear panel of the cabinet and the pc board is located above the power transformer.

The transmitter frequency is controlled by the receiver oscillator (see schematic in **Figure**

14). A source follower (MPF102) on the transmitter board improves isolation. The follower's output is connected to the base of a PN2222A transistor that acts as a driver to the output stage. The power output stage is a power MOSFET. I chose the power FET because it is easy to drive and can stand an open output circuit without damage, thus it isn't affected by high SWRs.<sup>9</sup> The power FET is rated at 20 watts dissipation, and with this low power I used a small heat sink.

The voltage to the source follower, driver, and bias for the output stage are keyed by an 2N2906 transistor, Q1. The voltage source for the keying stage is taken from the receiver (TRANS CTRL) and is controlled by the TRANSMIT switch on the receiver front panel. This switch also activates the transmit frequency offset, transfers the antenna over to the transmitter, and deactivates the RIT control.

When the key is closed, voltage is applied to driver Q3 by activating Q1. A properly shaped CW signal appears across L1 and is coupled to L2 to provide a gate signal for the power MOSFET, Q4. The output FET feeds a lowpass filter designed to match its output to a 50-ohm load.

If you're contemplating field operation, I suggest using three 6-volt lantern batteries in series. The one disadvantage of the power MOSFET is that it's not very efficient with low source voltages, so don't try 12-volt operation. The drain on the battery is about 800 mA key down. If you don't use the digital display, drain is about 100 mA less. You could include a switch to turn off the display if you want to operate using batteries. In receive, drain is





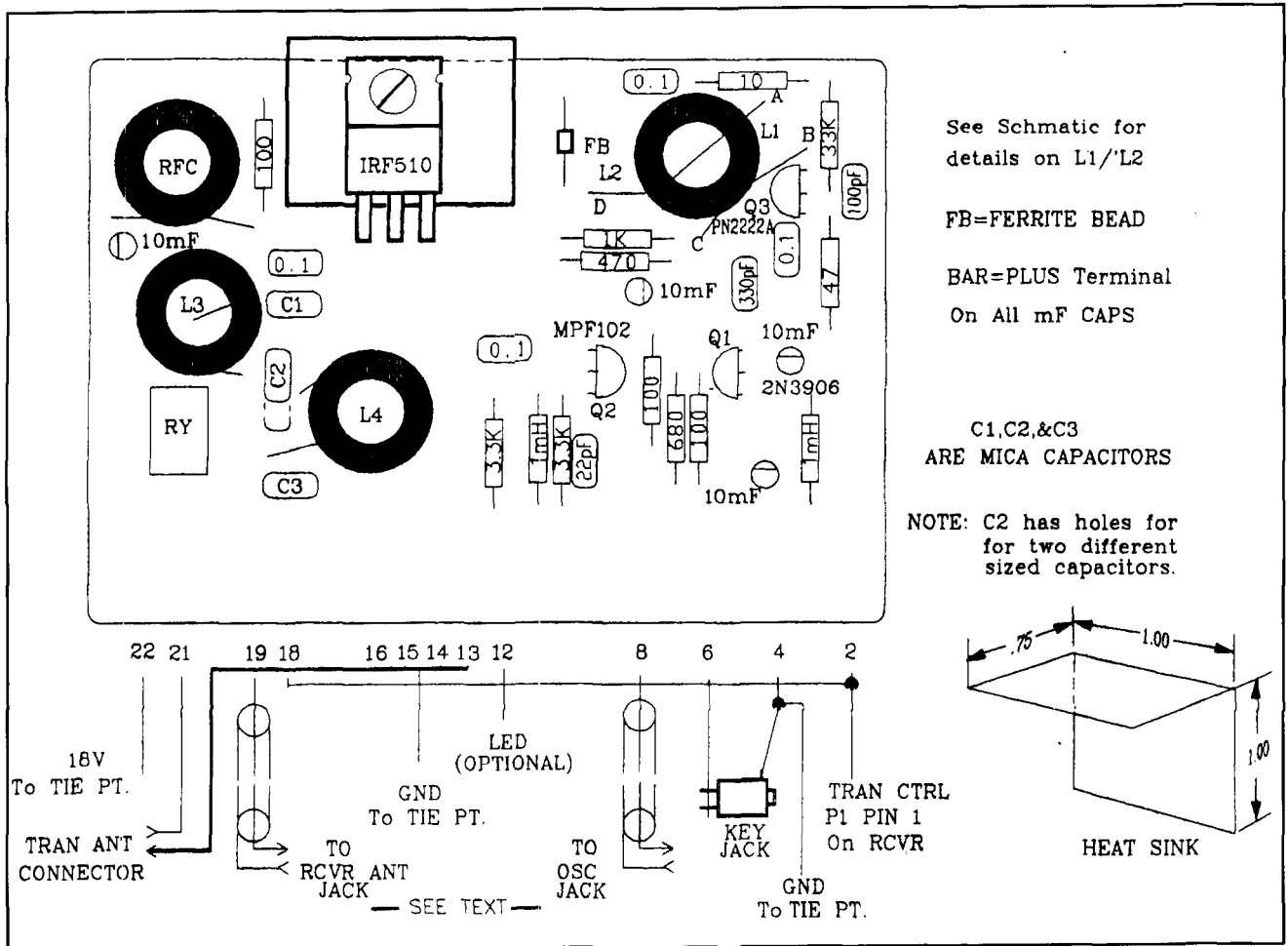


Figure 15. Transmitter board. Component side.

ver bifilar coil. It makes things easier if you use different color wire. Twist the two wires together so there are about 5 turns per inch.

### Transmitter operation

Connect the two shielded cables (oscillator and antenna) from the transmitter chassis to the proper terminals on the receiver, and connect your key. Put the TRANS/REC switch on the receiver in TRANSMIT.

The transmitter needs no adjustment. However, I do suggest operating into a 50-ohm dummy load before connecting the transmitter to an antenna. If you have an oscilloscope with sufficient bandwidth to give a correct voltage at 7 MHz, you can measure the voltage across a 50-ohm dummy load. The reading should be about 40 volts peak-to-peak, or 14 volts RMS. This is equivalent to 4 watts output. If you don't have a 'scope but want to see if there's an output, connect an incandescent lamp type 1891 (Radio Shack no. 272-1112) as a dummy load. It will light up brightly if there's output from the trans-

mitter. If you've incorporated the LED, it should also light when you close the key.

### Antenna matching unit

The antenna matching unit is housed in the third cabinet in the photo. The unit includes a directional power meter that indicates forward and reverse power. Other than the fact that it uses a 1 mA movement meter, there's nothing special about this circuit. To obtain sufficient signal from the RF transformer in series with the antenna line, I had to use a coil wound on a T68-6 toroid with 3 turns in series with the antenna lead and 50 turns on the secondary. Obviously, this wouldn't be satisfactory for VHF, but has little influence on the 40/80 meter bands' accuracy.

### Parts procurement

I've compiled a list of various sources that may be helpful in locating parts. When choosing a source, consider the minimum purchase order

each company requires. By doing a little comparison shopping, you might find the same item elsewhere, at a place that has other parts you need, with a smaller minimum requirement.

Some of my sources are:

1. **Radio Shack.** The Radio Shack chain carries a good assortment of standard parts, but no special parts.
2. **Digi-Key.** Located at 701 Brooks Avenue, P.O. Box 677, Thief River Falls, Minnesota 56701-0677. Digi-Key's minimum purchase charge is \$5 for anything less than a \$25 order. They have a wide assortment of parts and a good catalog.
3. **Circuit Specialists.** Write to P.O. 3047, Scottsdale, Arizona 85271-3047. There is no minimum order charge, but a \$4 shipping and handling charge.
4. **Mouser Electronics.** Write to P.O. 699, Mansfield, Texas 76063. Mouser adds a \$5 charge to any orders below \$20.
5. **Dan's Small Parts.** Located at 1935 So. Third West #1, Missoula, Montana 59801. Phone: (406) 543-2872. No minimum order; \$3.75 shipping and handling charge. Lots of special parts for builders.
6. **Oak Hills Research.** Located at 20579 Madison Street, Big Rapids, Michigan 49307.

No minimum order requirement; \$4 shipping and handling charge.

7. **Ocean State Electronics.** Write to P.O. Box 1458, Westerly, Rhode Island 02891. Carries some hard-to-find items. The minimum order is \$10; shipping and handling is \$4.

8. **BCD Electro.** Write to P.O. Box 450207, Garland, Texas 75045-0207. There is a charge of \$.95 on orders under \$30. Many hard to find items are available.

9. **All Electronics Corp.** Write to P.O. Box 567, Van Nuys, California 91408-0567. There is a \$4 shipping and handling charge on orders and a \$10 minimum order.

I suggest you send for these suppliers' catalogs and then decide where you want to purchase your parts. The parts list indicates where I purchased the various components. I tried to keep the number of sources to a minimum to reduce shipping costs. I've already listed the parts you should buy from Radio Shack. There are a few parts that can only be obtained from a couple of places. The NE602N or NE602AN, the upgrade version, the 10-turn wire-wound potentiometer, and the frequency counter IC are in this category. The first number is the lower price source.

• NE602N/AN: Listing numbers 5 and 2.

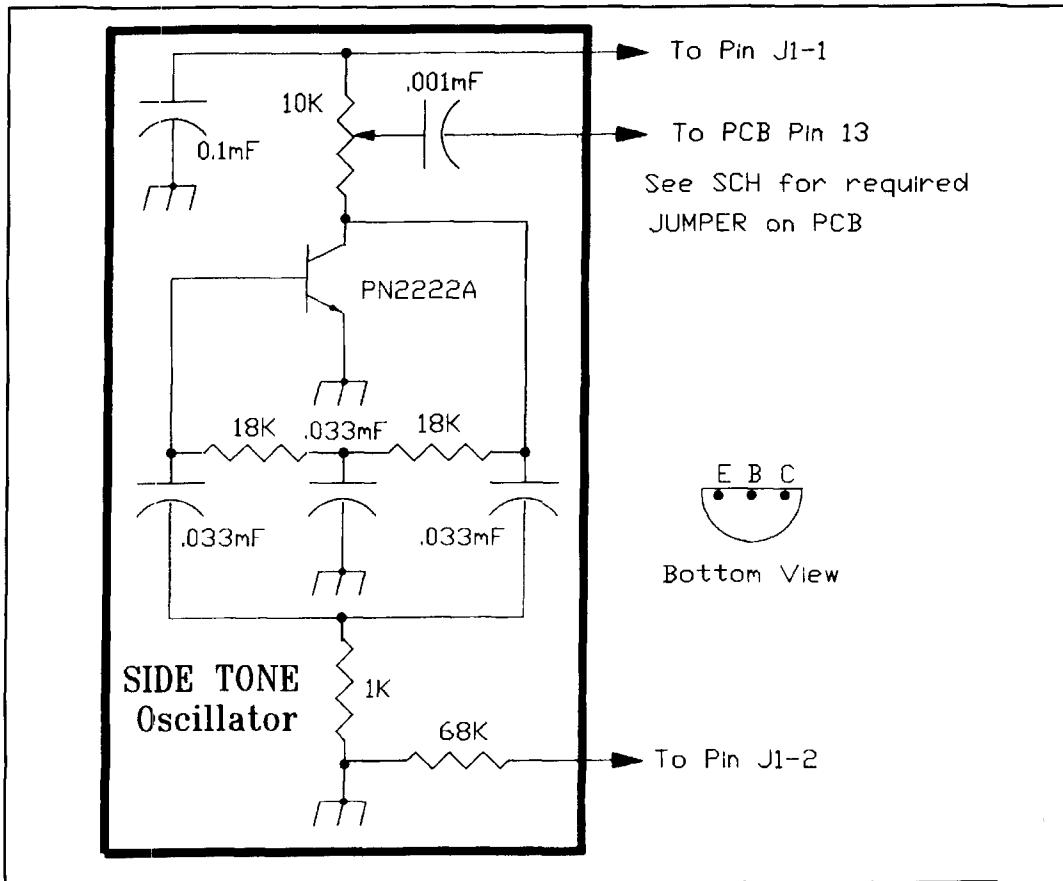


Figure 16. Side-tone oscillator schematic.

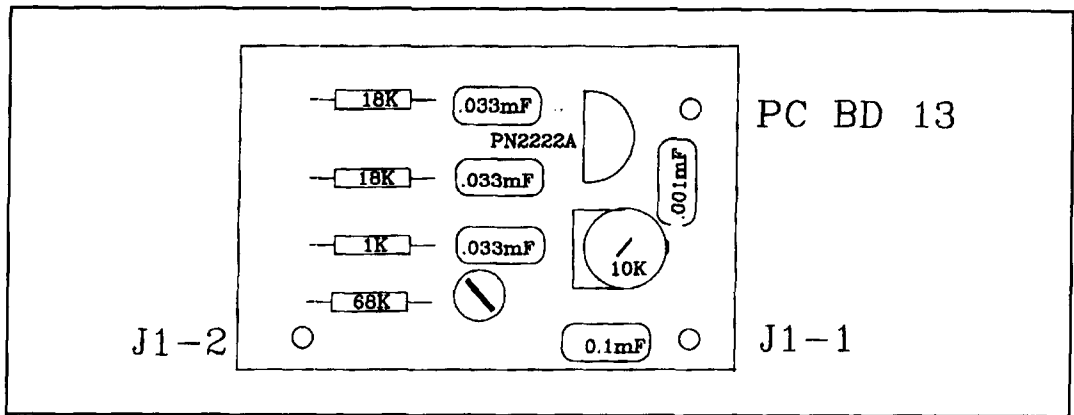


Figure 17. Side-tone oscillator board. Component side.

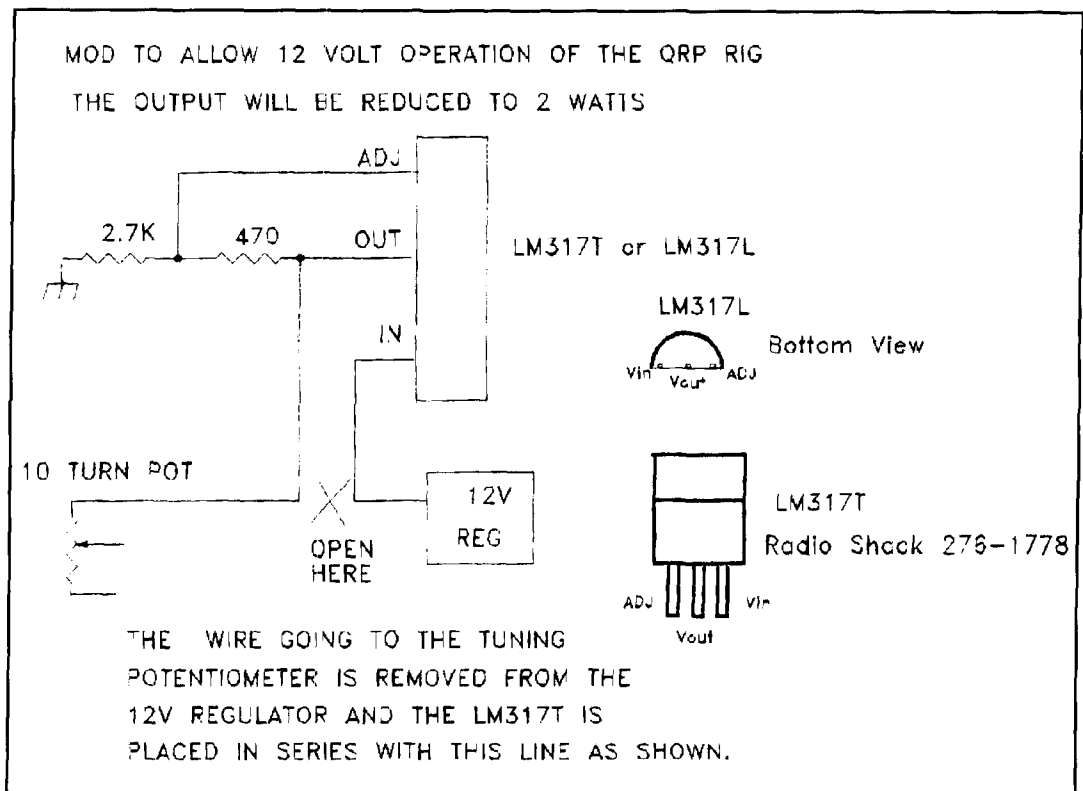


Figure 18. Modification to allow 12-volt of the QRP rig.

- 10-k, 10-turn pot: Listing numbers 3 and 2.
- ICM7216D frequency counter: Listing numbers 3 and 2.

All other parts can be found in one of these catalogs. I obtained my parts from listing numbers 1, 3, 5, and 9.

## Summary

In the final analysis, I met all of my goals for this project—and the other builders and I are very happy with the results. The cost of the receiver, transmitter, and power supply was just

over \$115. If you include the frequency counter as an integral part of the unit, the total cost is about \$140 dollars. If done as an auxiliary unit at a later date, the additional cost will be about \$40.

I use a 250-foot antenna on the receiver through a matching network. There's a small amount of standard AM broadcast feedthrough on 80 and none on 40. At night there's a small amount of feedthrough from a shortwave AM station on the 250-foot antenna, but none on the 40-meter dipole. The USB/LSB switching works well and the receiver selectivity is quite adequate. I was concerned that digital noise from the counter might be a problem; but with

enough filtering, there's only a trace—and it's well below the atmospheric noise level.

If you wish, you can incorporate a side-tone circuit. There's an extra pin on the power connector that could connect from the keying circuit to the side-tone oscillator. There's plenty of room on the receiver chassis for a small perf-board like the Radio Shack no. 276-150, or, you can purchase a pc board from FAR Circuits. The side-tone oscillator schematic is shown in **Figure 16**. The parts layout and pc board are shown in **Figure 17**. A jumper wire must be added to the receiver pc board to complete the circuit (see **Figure 11**).

## Acknowledgments

I'd like to thank Floyd Becker, W6RJY, for his help in checking the on-the-air performance of the transmitter, my wife for her patience, and my ten fellow amateurs who built the project and enabled me to improve construction data information.

## A final note

With the upcoming field day, a number of the hams who built my QRP rig wanted to know if they could operate using a 12-volt battery. Initially the unit was designed to operate from a 120 volts AC power source to obtain 4-

watts output. With the power MOSFET, the rig needs at least 18 volts DC on the final amplifier stage. However, the participants said they would accept less output if they could run off a 12-volt battery.

Twelve-volt operation requires a small change in the circuitry. The frequency tuning potentiometer obtains its voltage from the 12-volt regulator mounted on the rear of the receiver chassis. When operating from a 12-volt battery, the 12 volts from the regulator is no longer regulated, causing the frequency to shift every time the transmitter is keyed. The insertion of an additional regulator set for about 9 volts, restabilizes the frequency. The circuit is shown in **Figure 18**. The output is reduced to 2 watts, but you'll find that such a small change is hardly detectable.

## REFERENCES

1. Rodney A. Kreuter, WA3ENK, "A Simple Direct Conversion Transceiver," *Ham Radio*, December 1988, page 9.
2. Zack Lau, KH6CP, "The QRP Three Bander," *QST*, October 1989, page 25.
3. Michael A. Covington, "Single Chip Frequency Converter," *Radio Electronics*, April 1990, page 49.
4. Bill Parrot, W6VEH, "Simple Receivers from Complex ICs," *Ham Radio*, November 1988, page 10.
5. Jim Pepper, W6QIF, "The Magic Filter," *73*, November 1983, page 14.
6. Jim Pepper, W6QIF, "The Pepperdyne Receiver," *Ham Radio*, November 1988, page 33.
7. *The ARRL Handbook*, Chapter 10, Amateur Radio Relay League, Newington, Connecticut, 1989.
8. Doug DeMaw, W1FB, "The Practical Aspects of VFO Design Plus How to Build One," *CQ*, June 1991, page 16.
9. Doug DeMaw, W1FB, "Power-FET Switches as RF Amplifiers," *QST*, April 1989, page 30.

## Parts List

### Receiver PC Board

| Quantity | Part            | Unit Price | Extended | Source        |
|----------|-----------------|------------|----------|---------------|
| 1        | PC Board        | \$5.60     | \$5.60   | FAR           |
| 1        | NE602AN         | 2.25       | 2.25     | KA7           |
| 1        | LM386-3         | .75        | .75      | KA7           |
| 1        | 78L05           | .25        | .25      | KA7           |
| 2        | 1N4002          | .03        | .06      | KA7           |
| 2        | 1N914           | .03        | .06      | KA7           |
| 2        | T50-6 toroid    | 5/1.00     | .40      | KA7           |
| 2        | 1mH choke       | 6/1.00     | .32      | KA7           |
| 1        | Varactor MV2115 | 1.26       | 1.26     | CS MV2115     |
| 2        | MC1458          | .50        | 1.00     | CS MC1458     |
| 2        | MPF102          | .40        | .80      | CS MPF102     |
| 1        | RAD 47µF/16     | .15        | .30      | AE RAD47mF/16 |
| 2        | RAD 10µF/16     | .13        | .26      | AE RAD10mF/16 |
| 2        | TANT 1µF/35     | .24        | .48      | CS TAC005     |
| 2        | NPO 270pF       | .47        | .94      | CS 21RR627    |
| 1        | CER 510 5%      | .20        | .20      | CS 21CB510    |
| 1        | CER 470 5%      | .20        | .20      | CS 21CB470    |
| 1        | CER 22pF        | .16        | .16      | CS 21CB022    |
| 1        | CER 10pF        | .16        | .16      | CS 21CB010    |
| 1        | CER 5pF         | .16        | .16      | CS 21CB005    |
| 3        | MYLAR 0.1µF     | .19        | .57      | CS 23BK410    |
| 1        | MYLAR 0.047µF   | .14        | .14      | CS 23BK347    |
| 2        | MYLAR 0.01µF    | .14        | .28      | CS 23BK310    |
| 1        | 1/4W 10         | .10        | .10      | CS            |
| 1        | 1/4W 330        | .10        | .10      | CS            |
| 1        | 1/4W 680        | .10        | .10      | CS            |
| 1        | 1/4W 1.5K       | .10        | .10      | CS            |
| 1        | 1/4W 4.7K       | .10        | .10      | CS            |
| 3        | 1/4W 10K        | .10        | .30      | CS            |

| Quantity                                                       | Part                         | Unit Price | Extended | Source           |
|----------------------------------------------------------------|------------------------------|------------|----------|------------------|
| 1                                                              | 1/4W 18K                     | .10        | .10      | CS               |
| 7                                                              | 1/4W 33K                     | .10        | .70      | CS               |
| 1                                                              | 1/4W 47K                     | .10        | .10      | CS               |
| 1                                                              | C1 Trim Cap 5-141            | 1.38       | 1.38     | CS 24TR222       |
| 4                                                              | 8 Pin Sockets                | .10        | .40      | CS C8408         |
| 1                                                              | R1 H trim pot 1K             | .20        | .20      | CS 32AA301       |
| 1                                                              | R2 H trim pot 5K             | .20        | .20      | CS 32AA305       |
| 1                                                              | R3 H trim pot 10K            | .20        | .20      | CS 32AA401       |
| 1                                                              | Mag Wire Assem.              | 4.99       | .20      | RS 278-1345      |
| 1                                                              | Hookup Wire Assem.           | 2.50       | .50      | AE 22/ST         |
|                                                                |                              |            | \$21.38  |                  |
| <b>40 Meter Receiver</b>                                       |                              |            |          |                  |
| 2                                                              | 470pF Poly cap               | 2/1.00     | 1.00     | W6QIF*           |
| 1                                                              | CER 10pF                     | .16        | .16      | CS 21CB010       |
| 1                                                              | CER 5pF                      | .16        | .16      | CS 21C005        |
|                                                                |                              |            | \$1.32   |                  |
| <b>80 Meter Receiver</b>                                       |                              |            |          |                  |
| 2                                                              | 1000pF Poly cap              | .50        | 1.00     | W6QIF*           |
| 1                                                              | CER 100pF                    | .16        | .16      | CS 21CB100       |
| 1                                                              | CER 33pF                     | .16        | .16      | CS 21CB033       |
|                                                                |                              |            | \$1.32   |                  |
| * Part not available from my sources. I will supply this item. |                              |            |          |                  |
| <b>Receiver Chassis</b>                                        |                              |            |          |                  |
| 1                                                              | 10T POT 10K                  | \$6.49     | \$6.49   | CS 73JB10K       |
| 1                                                              | Mech. Ctr. Dial              | 9.85       | 9.85     | CS 316-11*       |
| 1                                                              | 7812 REG                     | .40        | .40      | CS 7812T         |
| 1                                                              | Cabinet                      | 6.99       | 6.99     | RS 270-253       |
| 2                                                              | RCA Jacks                    | 4/2.19     | 1.08     | RS 274-346       |
| 1                                                              | Phone Jack                   | 2/1.59     | .79      | RS 274-249       |
| 1                                                              | 5 lug tie                    | 4/1.29     | .32      | RS 274-688       |
| 1                                                              | 4 Pin Plug                   | 1.69       | 1.69     | RS 274-001       |
| 1                                                              | 4 Pin Socket                 | 1.29       | 1.29     | RS 274-002       |
| 3                                                              | Knobs                        | 4/1.69     | 1.29     | RS 274-415       |
| 1                                                              | Conn 22 pin                  | 1.00       | 1.00     | AE EBC-1G        |
| 2                                                              | SPDT switch                  | 1.00       | 2.00     | AE MTS-4PC       |
| 3                                                              | 10K pot aud. tpr             | .50        | 1.50     | AE PTA-10K       |
| 1                                                              | Trans Film                   | 1.00       | 1.00     | Copy Store KODAK |
| 101                                                            |                              |            | \$35.64  |                  |
| * Not required if Digital Counter is incorporated.             |                              |            |          |                  |
| <b>Power Supply Chassis</b>                                    |                              |            |          |                  |
| 1                                                              | Cabinet                      | \$6.99     | \$6.99   | RS 270-253       |
| 2                                                              | 5 lug Tie Purchased on Rcvr. |            | .64      | RS 274-688       |
| 1                                                              | Transformer                  | 5.99       | 5.99     | RS 273-1352      |
| 1                                                              | Bridge Rect.                 | .34        | .34      | CS KBP005        |
| 1                                                              | CER 0.01mF/500V              | .18        | .18      | CS 21FA010       |
| 1                                                              | Power Cord                   | .79        | .79      | CS PSC-2         |
| 1                                                              | SPDT SW                      | 1.35       | 1.35     | AE MTS-14        |
| 1                                                              | Phono Cable                  | .85        | .85      | AE ACB-6         |
| 1                                                              | 4700mF/25                    | 2.00       | 2.00     | AE Axial         |
| 1                                                              | Key Jack Purchased on Rcvr.  |            | .79      | RS 274-247       |
| 1                                                              | RCA Jack Purchased on Rcvr.  |            | .54      | RS 274-346       |
| 1                                                              | LED Ind.                     | .50        | .50      | AE LED-111*      |
|                                                                |                              |            | \$20.96  |                  |
| * Optional                                                     |                              |            |          |                  |



**Transmitter**

| Quantity | Part            | Unit Price         | Extended | Source        |
|----------|-----------------|--------------------|----------|---------------|
| 1        | PC Board        | \$4.40             | \$4.40   | FAR           |
| 1        | Conn 22 Pin     | 1.00               | 1.00     | AE EBC-1G     |
| 1        | IRF510          | 1.99               | 1.99     | RS 276-2072   |
| 1        | Relay           | 1.99               | 1.99     | RS 275-241    |
| 1        | Mag Wire assem. | Purchased on Rcvr. | .20      | RS            |
| 4        | T50-6 Toroid    | 5/1.00             | .80      | KA7           |
| 1        | PN2222A         | .05                | .05      | KA7           |
| 1        | 2N3906          | .05                | .05      | KA7           |
| 2        | Choke 1mH       | Purchased on Rcvr. | .13      | KA7           |
| 1        | MPF102          | .40                | .40      | CS MPF102     |
| 1        | Cer 100pF       | .16                | .16      | CS 21CB100    |
| 1        | Cer 330pF       | .16                | .16      | CS 21CB330    |
| 1        | Cer 22pF        | .16                | .16      | CS 21CB022    |
| 4        | RAD 10µF/16     | .13                | .52      | AE RAD10mF/16 |
| 4        | MYLAR 0.1µF     | .19                | .76      | CS 23BK410    |
| 1        | Ferrite Bead    | 12/1.00            | .08      | CS FBPK1      |
| 2        | 1/4W 10         | .10                | .20      | CS            |
| 3        | 1/4W 100        | .10                | .30      | CS            |
| 1        | 1/4W 470        | .10                | .10      | CS            |
| 1        | 1/4W 680        | .10                | .10      | CS            |
| 1        | 1/4W 1K         | .10                | .10      | CS            |
| 2        | 1/4W 3.3K       | .10                | .20      | CS            |
| 2        | 1/4We 33K       | .10                | .20      | CS            |

\$13.95

|   |           |           |          |            |
|---|-----------|-----------|----------|------------|
| 1 | Heat Sink | Home Brew | See Dwg. | 16GA Alum. |
|---|-----------|-----------|----------|------------|

**40 Meter Operation**

|    |                 |     |     |              |
|----|-----------------|-----|-----|--------------|
| C1 | Mica cap 680pF  | .64 | .64 | CS DM10-68IJ |
| C2 | Mica cap 1000pF | .68 | .68 | CS DM10-102J |
| C3 | Mica cap 470pF  | .54 | .54 | CS DM10-47IJ |

\$1.86

**80 Meter Operation**

|    |                 |     |     |              |
|----|-----------------|-----|-----|--------------|
| C1 | Mica cap 1000pF | .68 | .68 | CS DM10-102J |
| C2 | Mica cap 1800pF | .88 | .88 | CS DM10-182J |
| C3 | Mica cap 620pF  | .64 | .64 | CS DM10-68IJ |

\$2.20

**Digital Frequency Counter**

|   |                 |         |         |               |
|---|-----------------|---------|---------|---------------|
| 1 | ICM7216DIP1     | \$22.95 | \$22.95 | CS            |
| 5 | MAN74           | .99     | 4.95    | CS SC03-12HDB |
| 1 | PN2222          | .20     | .20     | CS PN2222     |
| 1 | Trim Cap 8-50pF | .72     | .72     | CS 24AA074    |
| 1 | 10mF Tant-16V   | .74     | .74     | CS TAC008     |
| 1 | 22pF Cer Cap    | .14     | .14     | CS 21CD022    |
| 1 | 39pF Cer Cap    | .14     | .14     | CS 21CD039    |
| 1 | 10 MHz Crystal  | 2.50    | 2.50    | CS C19        |
| 1 | 10uH Choke      | .39     | .39     | CS 43LS105    |
| 1 | 470 ohm 1/4W    | .10     | .10     | CS            |
| 1 | 10K 1/4W        | .10     | .10     | CS            |
| 1 | 68K 1/4W        | .10     | .10     | CS            |
| 1 | 10MEG 1/4W      | .10     | .10     | CS            |
| 5 | 14 pin Sockets  | .12     | .60     | CS C8414      |
| 1 | 28 pin Socket   | .26     | .26     | CS C8428      |
| 1 | 7805 5V REG     | .40     | .40     | CS 7805T      |
| 1 | 1000mF 16V      | .60     | .60     | CS CEM25-1000 |
| 1 | 100 ohm 1/2W    | 2/.29   | .15     | RS 271-012    |
| 1 | 5 lug tie pt    | 4/1.29  | .32     | RS 271-688    |
| 1 | PC Board        | 3.50    | 3.50    | FAR           |

\$38.95

Remember, if you build the counter you don't need the counter dial which in effect makes the counter cost \$38.95 minus \$9.85 or \$29.10.

**Additional parts if remote counter is built**

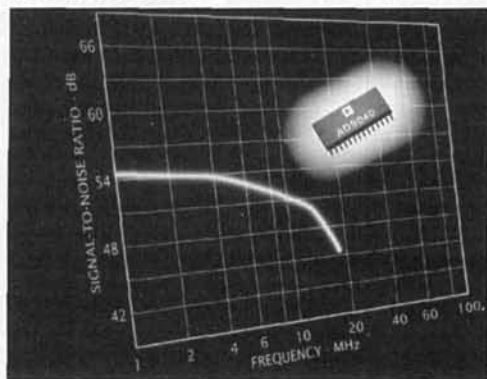
| Quantity     | Part               | Unit Price         | Extended | Source     |
|--------------|--------------------|--------------------|----------|------------|
| 1            | Cabinet            | \$2.19             | \$2.19   | RS 270-231 |
| 1            | Plug cable         | 1.79               | 1.79     | RS 42-2635 |
| 2            | 1mH choke          | purchased on rcvr. | .32      | KA7        |
| 1            | 0.001 $\mu$ F poly | .12                | .12      | CS 23BK210 |
|              |                    |                    | \$4.40   |            |
| Total        |                    |                    | \$43.35  |            |
| SUB CTR DIAL |                    |                    | - 9.85   |            |
|              |                    |                    | \$33.50  |            |

RS = Radio Shack  
 CS = Circuit Specialists  
 KA7 = Dan's Small Parts (formerly KA7QJY Components)  
 AE = All Electronics  
 All prices subject to change.

## PRODUCT INFORMATION

### AD9040 32 Msps, 10-bit, analog-to-digital converter

Analog Devices' AD9040 is a 10-bit, analog-to-digital converter (ADC) with on-board track-and-hold (T/H) amplifier, voltage reference, and timing circuitry. The AD9040 requires an encode signal to achieve sampling rates to 40 Msps. Dynamic specifications are optimized to achieve a typical signal-to-noise ratio (SNR), including harmonics, of 54 dB with a 10.3 MHz analog input sampled at 32 Msps. Applications include professional video equipment, digital scopes, spectrum analyzers, ultrasound imaging, radar, and digital communication receivers.



The AD9040 is CMOS is a complete, -compatible sampling ADC requiring no external circuitry for operation. The high impedance input and full scale input range of 2 V p-p eliminates the need for external buffers in many applications. DC specifications include differential nonlinearity of 1.5 LSB, and integral nonlinearity of 2.0 LSB.

Pricing for the commercial grade AD9040 begins at \$60 (100s), available from stock.

For more information contact: Analog Devices, Inc., 181 Ballardvale Street, Wilmington, MA 01887; or call 617-937-1428 or FAX 617-821-42273.

### New Literature from Analog Devices

Analog Devices now offers a free application note for the AN-242 low-noise microphone preamp with a phantom power option.

The application note describes design and application of a two-IC microphone preamp. A schematic diagram and a table of  $R_G$  values for various gains are included.

For more information about the AN-242 application note, contact Analog Devices, Inc., 181 Ballardvale Street, Wilmington, MA 01887; or call 617-937-1428; or FAX 617-821-4273.

### Philips ECG offers new capacitors and accessories cross reference.

Philips ECG has introduced the new ECG<sup>®</sup> Capacitors and Accessories Cross reference guide.

The publication cross references over 8,000 capacitors and accessories manufacturer's part numbers for 36 competitive brands to the ECG brand replacement part number. Coverage includes aluminum electrolytics, ceramic disk, tantalum, memory back-up, motor run and motor start capacitors.

All ECG products are available through authorized Philips ECG distributors. To locate the nearest distributor, call toll-free, 1-800-526-9354.

# SIMPLIFIED FREQUENCY SYNTHESIZER IC INTERFACING

*BCD thumbwheel switches connected to an EPROM simplify synthesizer/PLL IC interfacing.*

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Many of today's newest, powerful integrated circuits are designed to be used with and interface to microprocessors. Unfortunately, these interfaces are binary in nature and usually a minimum of 8 bits wide. There are times these ICs could be used when the power and complexity of a microprocessor are not needed or desired. One example is an application involving parallel-input synthesizer/PLL ICs. I'll describe a relatively simple approach using Binary-Coded-Decimal (BCD) output thumbwheel switches and Erasable Programmable Read Only Memories (EPROMs) to simplify interfacing. This approach is applied to synthesizers for 222 and 52 MHz.

## Background

One simple way to interface to these ICs, without the complexity of a microprocessor, is to use an array of SPST switches—possibly a dip switch array. This approach is okay for those applications where the settings won't be changed frequently, but isn't practical when changes will be numerous—such as those for

frequency control. It's difficult to remember the 8-bit binary codes for 100 frequency channels (the number of 20 kHz channels in 2 MHz of spectrum)! Many of the original 40 channel CB transceivers used a complex specially designed switch that converted the rotary position of the switch to the specific 8-bit binary codes required by the internal synthesizer/PLL IC, but this approach is not practical for the average experimenter.

You could add keypad/frequency display circuitry, but the complexity would be almost equal to that associated with microprocessor control. My approach, using Binary-Coded-Decimal (BCD) output thumbwheel switches and Erasable Programmable Read Only Memories (EPROMs), is "user friendly" and easy to implement.

## How it works

**Figure 1** is a functional diagram showing how the BCD thumbwheel switch/EPROM works to simplify the interface to a parallel input synthesizer. Separate BCD switches are used for each significant digit in the desired

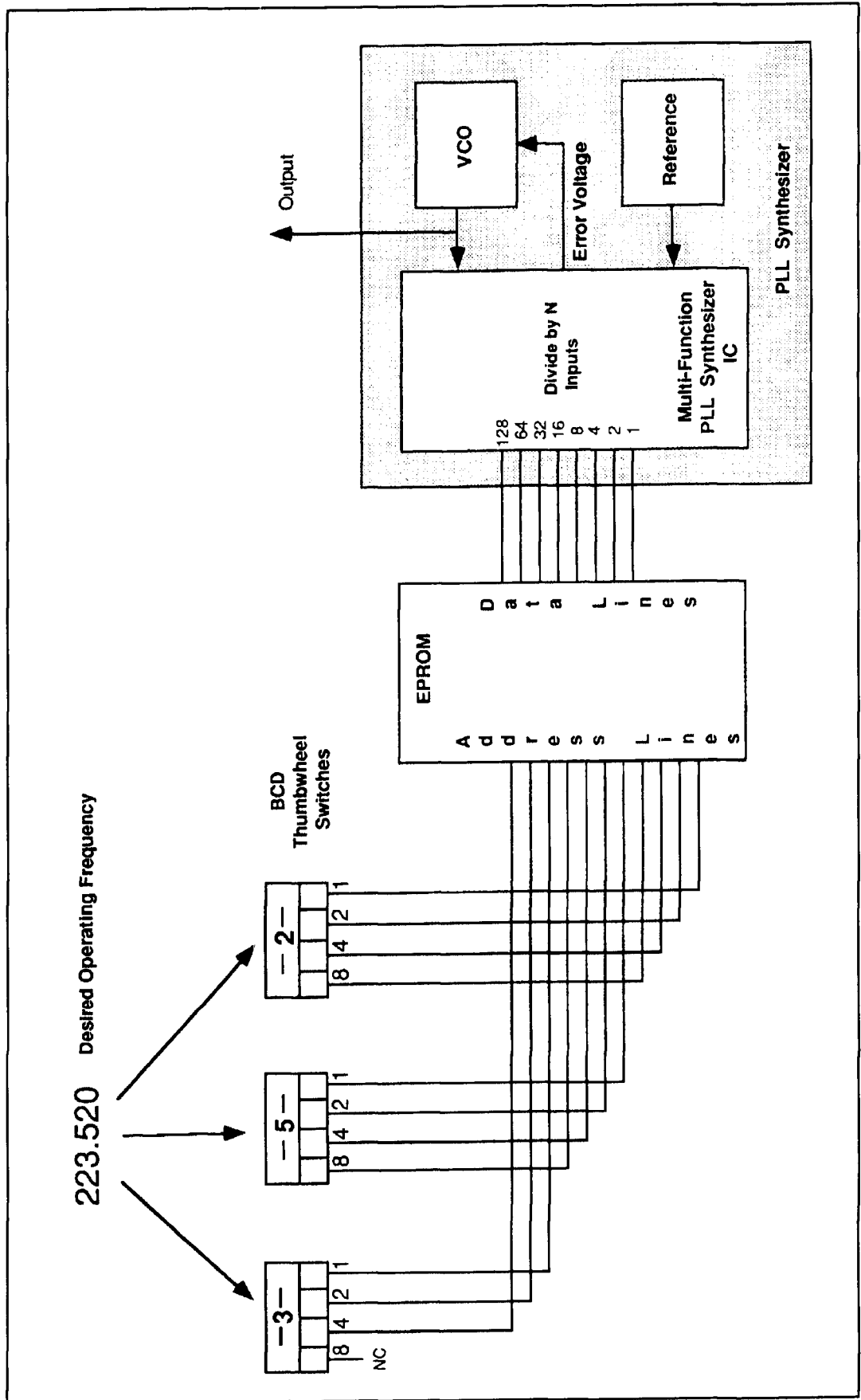


Figure 1. Simplified parallel interface functional diagram.

| Indicated BCD Switch<br>Decimal Number | "C" Terminal<br>Input Level | BCD Output Terminal Logic Levels |   |   |   |
|----------------------------------------|-----------------------------|----------------------------------|---|---|---|
|                                        |                             | 1                                | 2 | 4 | 8 |
| 0                                      | 5                           | 0                                | 0 | 0 | 0 |
| 1                                      | 5                           | 5                                | 0 | 0 | 0 |
| 2                                      | 5                           | 0                                | 5 | 0 | 0 |
| 3                                      | 5                           | 5                                | 5 | 0 | 0 |
| 4                                      | 5                           | 0                                | 0 | 5 | 0 |
| 5                                      | 5                           | 5                                | 0 | 5 | 0 |
| 6                                      | 5                           | 0                                | 5 | 5 | 0 |
| 7                                      | 5                           | 5                                | 5 | 5 | 0 |
| 8                                      | 5                           | 0                                | 0 | 0 | 5 |
| 9                                      | 5                           | 5                                | 0 | 0 | 5 |

Table 1. BCD thumbwheel switch "truth" table.

resulting output frequency. (Not the frequency of the synthesizer, but the final operating frequency of the equipment—either transmit or receive.) Digits that don't change in the frequency, like the first two "2s," in 223.52 aren't included in this technique.

BCD switches display decimal numbers and have outputs in BCD format. The decimal-to-BCD encoding is accomplished internally and mechanically. **Table 1** shows the code table for a BCD switch with +5 volts DC—Logic "1"—connected to the Common terminal.

The outputs of the BCD switches form the address lines for the 2716 EPROM. The EPROM stores, at each address created by the BCD switch outputs, the corresponding binary codes needed for the synthesizer inputs that will provide the desired/indicated frequency.

## Detailed description of the 222-MHz synthesizer

**Figure 2** shows the BCD switch-EPROM approach used with a synthesizer for a 222-MHz transmitter. The synthesizer was described in a previous article<sup>1</sup> and uses a VCO in the 37-MHz range, and a mixing scheme to convert the actual divide-by-N frequency to the 1-MHz range. The PLL IC in this synthesizer requires 8 binary inputs that match the number of data output lines provided by inexpensive EPROMs.

## Synthesizer VCO range and PLL divide-by-N range

Refer to **Figure 2** for the specific situation where 223.52 MHz is the desired transmit frequency. My 222-MHz transmitter uses 18-MHz range crystals with a total frequency multiplication factor of 12, so the output of the synthesizer

must be 223.52/12, or 18.626666 MHz. This corresponds to a synthesizer PLL VCO frequency of 37.25333 MHz and a PLL divide-by-N of 379 (Hex = 17B). The PLL IC has divide-by-N inputs from 1 to 256. Because the divide-by-N range for the required operating range is from 304 to 402 (222.02 MHz to 223.98 MHz), the divide-by-256 programming pin is connected to Logic 1 (+5 volts DC) all the time. With this approach only the IC's 1 to 128 divide-by-N pins need be accessed to change frequency.

## EPROM address lines and stored data

In **Figure 2**, the output of the BCD switches set at 223.52 MHz is a binary 10101001 that forms the 8-bit binary address for the EPROM. For this technique to work properly, the binary equivalent of the required divide-by-N number,  $379 - 256 = 123$  (remember the PLL IC divide-by-N 256 pin is permanently selected), must be stored (programmed) at the EPROM data location addressed by 10101001. The binary equivalent of 123 is 01111011.

That's all there is to it. At each desired operating frequency indicated by the thumbwheel switches, a divide-by-N binary number for the PLL synthesizer is stored at the corresponding EPROM data location. **Table 2** provides a complete listing of Frequency/PLL divide-by-N/EPROM programming for the 222.02 to 223.98 frequency range.

## Using toggle switches and other tricks

**Figure 2** shows three BCD thumbwheel switches that indicate the desired frequency. The MHz BCD switch only has one output line connected—the 1 line—because it's the only

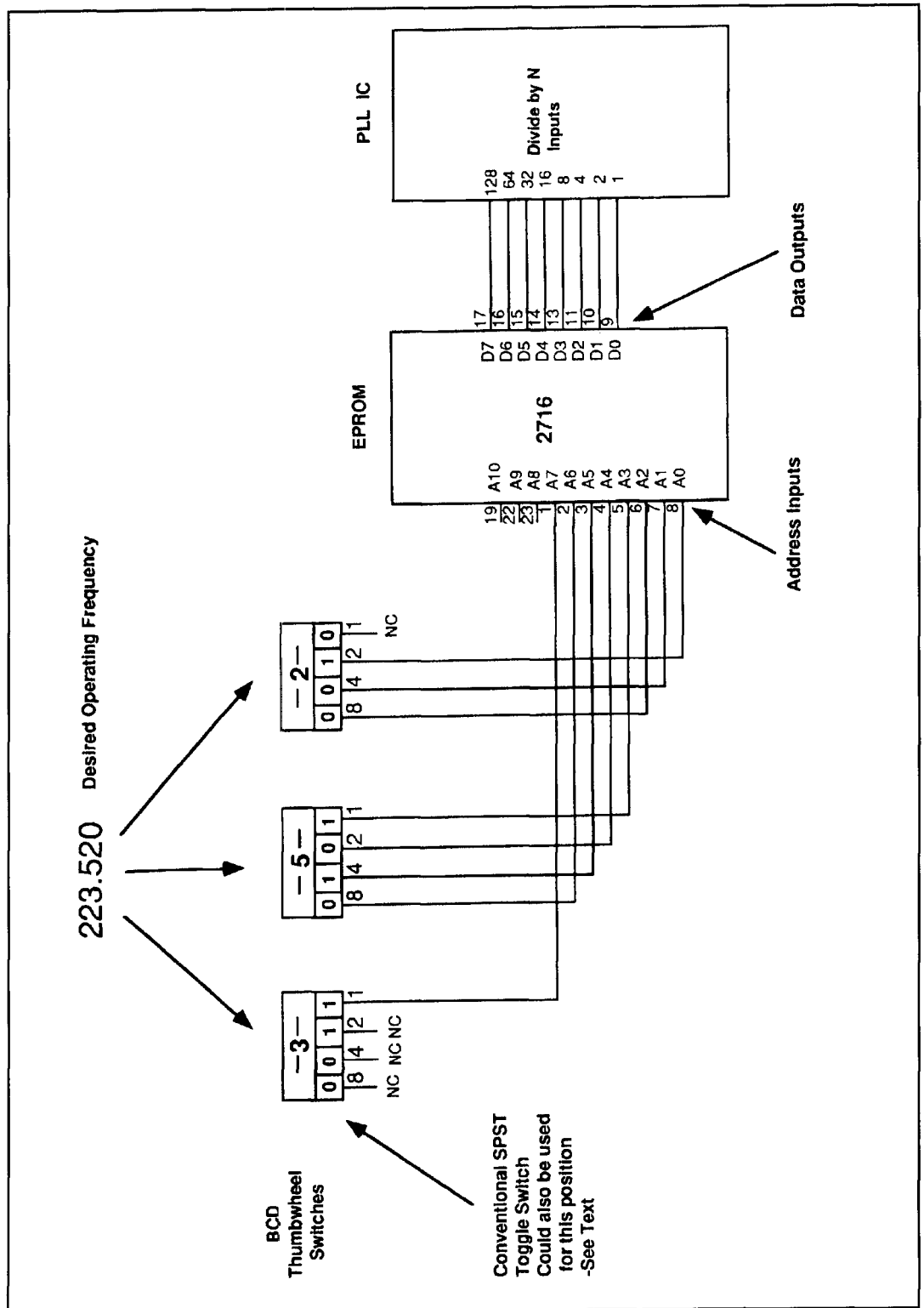


Figure 2. Simplified parallel interface functional diagram for 222-MHz synthesizer PLL IC.

switch output that changes when moving between the indicated decimal 2 and 3. I could have used an SPST toggle switch to select the MHz desired—2 (Off) = Logic “0”, 3 (On) = Logic “1”—but I already had a three gang BCD switch assembly, so I decided to use the third

BCD switch for this position.

You’ll also notice that the “1” output of the 10 kHz BCD switch isn’t used. This is because only 20-kHz (even number) channel steps are programmed. Consequently, the “1” output of this switch never changes, as only even num-

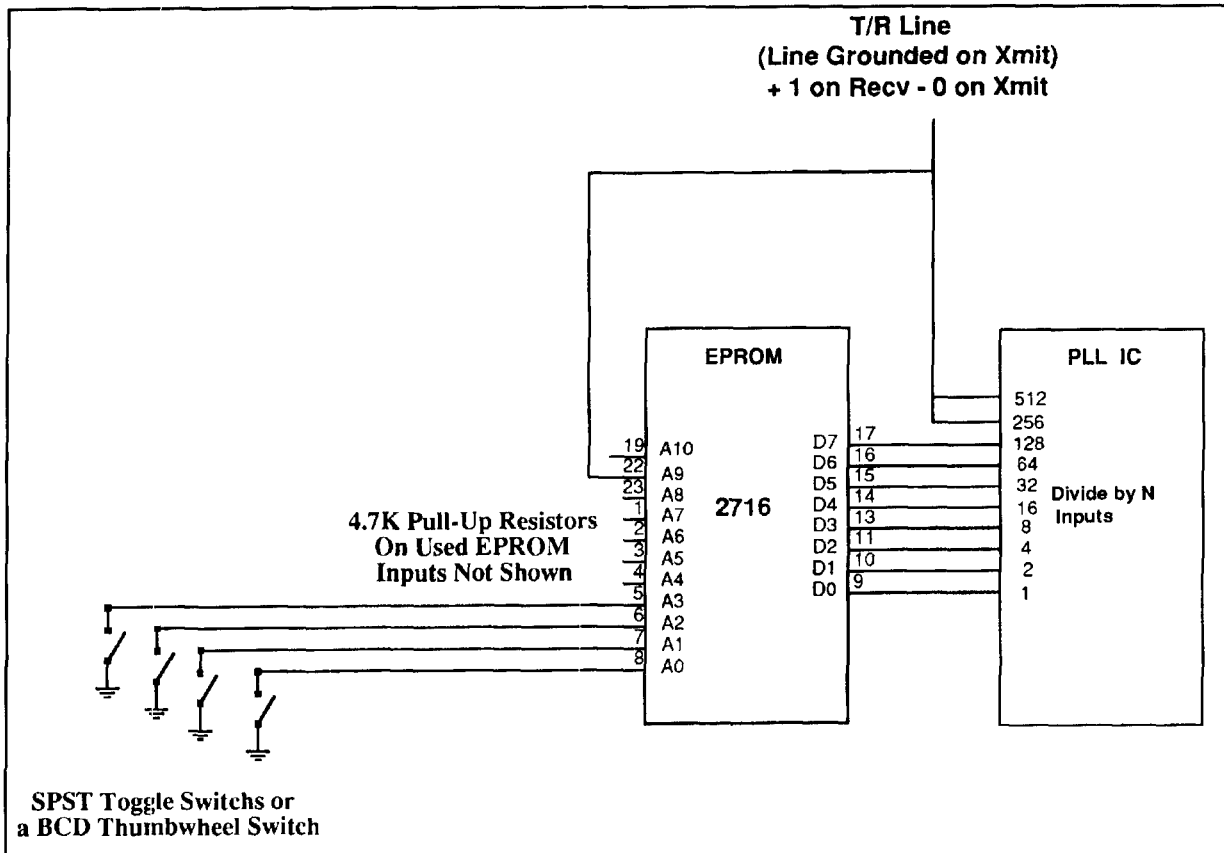


Figure 3. Simple interface for 6-meter synthesizer application.

bers will be selected. If you make a mistake and chose an "odd" channel like 223.53 MHz, you'll get the same output as that selected by the last even number channel—in this case 223.52 MHz.

### Six-meter synthesizer application

Figure 4 is the block diagram of this approach applied to a 6-meter synthesizer. In this application, I combine a synthesizer with a Motorola MC 145151 parallel input PLL synthesizer IC and a used commercial RCA ML-1000 mobile transceiver tuned for 6-meter operation. Unlike the 222-MHz synthesizer just described, the synthesizer in this application is used on both transmit and receive. The synthesizer VCO covers the 26 to 26.5 MHz range on transmit (52.01 to 52.99 MHz) and 29.595 to 30.345 MHz on receive (52.49 to 53.99 MHz).

As in the 222-MHz application, 20-kHz channels are required. With this combination of requirements, the synthesizer reference frequency is 10 kHz and the MC 145151's divide-by-N must be programmed to accommodate divide-by-n ranges of 5201 to 5299 on transmit and 5919 to 6069 on receive. The receiver has a 6.7 MHz IF and uses high side injection.

The PLL IC has divide-by-N select inputs from 1 to 8192. On transmit, the IC's 4096 and 1024 divide-by-N inputs are fixed at Logic 1, and the 1 to 128 divide-by-N inputs are controlled by the output of the EPROM. (The divide-by-N starts at 5120 and increases, depending on the EPROM output.) During receive, the 4096, 1024, 512, and 256 divide-by-N inputs are fixed at Logic 1 and the 1 to 128 divide by inputs are selected by the output of the EPROM. (The divide-by-N starts at 5888 and increases, depending on the EPROM output.)

Because I intended to install the synthesizer and transceiver in the trunk of my car, and due to the limited amount of 6-meter activity, I took a simpler approach to the synthesizer control. Driving this decision was the limited amount of under-dash space available in the car to mount the synthesizer, and the availability of channel selection frequency control wires in the transceiver's control cable. This cable runs from the dash-mounted control head to the transceiver in the trunk.

In Figure 4, you'll notice that an additional address line (A9) is used on the EPROM for T/R selection. This line selects the correct range of divide-by-N outputs for transmit or receive. The difference in address for a transmit



| BCD Switch<br>Dial<br>Freq - Mhz | Output of BCD Switches |         |    |    |   |        |   |   |    | EPROM   |    | PLL      |         | EPROM Data   |         |         |
|----------------------------------|------------------------|---------|----|----|---|--------|---|---|----|---------|----|----------|---------|--------------|---------|---------|
|                                  | MHZ                    | 100 KHZ |    |    |   | 10 KHZ |   |   |    | Address |    | VCO F    | Div / N | Divide / N # |         |         |
|                                  |                        | 1       | 8  | 4  | 2 | 1      | 8 | 4 | 2  | 1       | NC | Dec.     | Hex     | Mhz          | Decimal | Decimal |
|                                  | 128                    | 64      | 32 | 16 | 8 | 4      | 2 | 1 | NC |         |    |          |         |              |         | (-256)  |
| 222.02                           | 0                      | 0       | 0  | 0  | 0 | 0      | 0 | 1 | -  | 1       | 1  | 37.00333 | 304     | 48           | 30      |         |
| 222.04                           | 0                      | 0       | 0  | 0  | 0 | 0      | 1 | 0 | -  | 2       | 2  | 37.00667 | 305     | 49           | 31      |         |
| 222.06                           | 0                      | 0       | 0  | 0  | 0 | 0      | 1 | 1 | -  | 3       | 3  | 37.01000 | 306     | 50           | 32      |         |
| 222.08                           | 0                      | 0       | 0  | 0  | 0 | 1      | 0 | 0 | -  | 4       | 4  | 37.01333 | 307     | 51           | 33      |         |
| 222.10                           | 0                      | 0       | 0  | 0  | 1 | 0      | 0 | 0 | -  | 8       | 8  | 37.01667 | 308     | 52           | 34      |         |
| 222.12                           | 0                      | 0       | 0  | 0  | 1 | 0      | 0 | 1 | -  | 9       | 9  | 37.02000 | 309     | 53           | 35      |         |
| 222.14                           | 0                      | 0       | 0  | 0  | 1 | 0      | 1 | 0 | -  | 10      | A  | 37.02333 | 310     | 54           | 36      |         |
| 222.16                           | 0                      | 0       | 0  | 0  | 1 | 0      | 1 | 1 | -  | 11      | B  | 37.02667 | 311     | 55           | 37      |         |
| 222.18                           | 0                      | 0       | 0  | 0  | 1 | 1      | 0 | 0 | -  | 12      | C  | 37.03000 | 312     | 56           | 38      |         |
| 222.20                           | 0                      | 0       | 0  | 1  | 0 | 0      | 0 | 0 | -  | 16      | 10 | 37.03333 | 313     | 57           | 39      |         |
| 222.22                           | 0                      | 0       | 0  | 1  | 0 | 0      | 0 | 1 | -  | 17      | 11 | 37.03667 | 314     | 58           | 3A      |         |
| 222.24                           | 0                      | 0       | 0  | 1  | 0 | 0      | 1 | 0 | -  | 18      | 12 | 37.04000 | 315     | 59           | 3B      |         |
| 222.26                           | 0                      | 0       | 0  | 1  | 0 | 0      | 1 | 1 | -  | 19      | 13 | 37.04333 | 316     | 60           | 3C      |         |
| 222.28                           | 0                      | 0       | 0  | 1  | 0 | 1      | 0 | 0 | -  | 20      | 14 | 37.04667 | 317     | 61           | 3D      |         |
| 222.30                           | 0                      | 0       | 0  | 1  | 1 | 0      | 0 | 0 | -  | 24      | 18 | 37.05000 | 318     | 62           | 3E      |         |
| 222.32                           | 0                      | 0       | 0  | 1  | 1 | 0      | 0 | 1 | -  | 25      | 19 | 37.05333 | 319     | 63           | 3F      |         |
| 222.34                           | 0                      | 0       | 0  | 1  | 1 | 0      | 1 | 0 | -  | 26      | 1A | 37.05667 | 320     | 64           | 40      |         |
| 222.36                           | 0                      | 0       | 0  | 1  | 1 | 0      | 1 | 1 | -  | 27      | 1B | 37.06000 | 321     | 65           | 41      |         |
| 222.38                           | 0                      | 0       | 0  | 1  | 1 | 1      | 0 | 0 | -  | 28      | 1C | 37.06333 | 322     | 66           | 42      |         |
| 222.40                           | 0                      | 0       | 1  | 0  | 0 | 0      | 0 | 0 | -  | 32      | 20 | 37.06667 | 323     | 67           | 43      |         |
| 222.42                           | 0                      | 0       | 1  | 0  | 0 | 0      | 0 | 1 | -  | 33      | 21 | 37.07000 | 324     | 68           | 44      |         |
| 222.44                           | 0                      | 0       | 1  | 0  | 0 | 0      | 1 | 0 | -  | 34      | 22 | 37.07333 | 325     | 69           | 45      |         |
| 222.46                           | 0                      | 0       | 1  | 0  | 0 | 0      | 1 | 1 | -  | 35      | 23 | 37.07667 | 326     | 70           | 46      |         |
| 222.48                           | 0                      | 0       | 1  | 0  | 0 | 1      | 0 | 0 | -  | 36      | 24 | 37.08000 | 327     | 71           | 47      |         |
| 222.50                           | 0                      | 0       | 1  | 0  | 1 | 0      | 0 | 0 | -  | 40      | 28 | 37.08333 | 328     | 72           | 48      |         |
| 222.52                           | 0                      | 0       | 1  | 0  | 1 | 0      | 0 | 1 | -  | 41      | 29 | 37.08667 | 329     | 73           | 49      |         |
| 222.54                           | 0                      | 0       | 1  | 0  | 1 | 0      | 1 | 0 | -  | 42      | 2A | 37.09000 | 330     | 74           | 4A      |         |
| 222.56                           | 0                      | 0       | 1  | 0  | 1 | 0      | 1 | 1 | -  | 43      | 2B | 37.09333 | 331     | 75           | 4B      |         |
| 222.58                           | 0                      | 0       | 1  | 0  | 1 | 1      | 0 | 0 | -  | 44      | 2C | 37.09667 | 332     | 76           | 4C      |         |
| 222.60                           | 0                      | 0       | 1  | 1  | 0 | 0      | 0 | 0 | -  | 48      | 30 | 37.10000 | 333     | 77           | 4D      |         |
| 222.62                           | 0                      | 0       | 1  | 1  | 0 | 0      | 0 | 1 | -  | 49      | 31 | 37.10333 | 334     | 78           | 4E      |         |
| 222.64                           | 0                      | 0       | 1  | 1  | 0 | 0      | 1 | 0 | -  | 50      | 32 | 37.10667 | 335     | 79           | 4F      |         |
| 222.66                           | 0                      | 0       | 1  | 1  | 0 | 0      | 1 | 1 | -  | 51      | 33 | 37.11000 | 336     | 80           | 50      |         |
| 222.68                           | 0                      | 0       | 1  | 1  | 0 | 1      | 0 | 0 | -  | 52      | 34 | 37.11333 | 337     | 81           | 51      |         |
| 222.70                           | 0                      | 0       | 1  | 1  | 1 | 0      | 0 | 0 | -  | 56      | 38 | 37.11667 | 338     | 82           | 52      |         |
| 222.72                           | 0                      | 0       | 1  | 1  | 1 | 0      | 0 | 1 | -  | 57      | 39 | 37.12000 | 339     | 83           | 53      |         |
| 222.74                           | 0                      | 0       | 1  | 1  | 1 | 0      | 1 | 0 | -  | 58      | 3A | 37.12333 | 340     | 84           | 54      |         |
| 222.76                           | 0                      | 0       | 1  | 1  | 1 | 0      | 1 | 1 | -  | 59      | 3B | 37.12667 | 341     | 85           | 55      |         |
| 222.78                           | 0                      | 0       | 1  | 1  | 1 | 1      | 0 | 0 | -  | 60      | 3C | 37.13000 | 342     | 86           | 56      |         |
| 222.80                           | 0                      | 1       | 0  | 0  | 0 | 0      | 0 | 0 | -  | 64      | 40 | 37.13333 | 343     | 87           | 57      |         |
| 222.82                           | 0                      | 1       | 0  | 0  | 0 | 0      | 0 | 1 | -  | 65      | 41 | 37.13667 | 344     | 88           | 58      |         |
| 222.84                           | 0                      | 1       | 0  | 0  | 0 | 0      | 1 | 0 | -  | 66      | 42 | 37.14000 | 345     | 89           | 59      |         |
| 222.86                           | 0                      | 1       | 0  | 0  | 0 | 0      | 1 | 1 | -  | 67      | 43 | 37.14333 | 346     | 90           | 5A      |         |
| 222.88                           | 0                      | 1       | 0  | 0  | 0 | 1      | 0 | 0 | -  | 68      | 44 | 37.14667 | 347     | 91           | 5B      |         |
| 222.90                           | 0                      | 1       | 0  | 0  | 1 | 0      | 0 | 0 | -  | 72      | 48 | 37.15000 | 348     | 92           | 5C      |         |
| 222.92                           | 0                      | 1       | 0  | 0  | 1 | 0      | 0 | 1 | -  | 73      | 49 | 37.15333 | 349     | 93           | 5D      |         |
| 222.94                           | 0                      | 1       | 0  | 0  | 1 | 0      | 1 | 0 | -  | 74      | 4A | 37.15667 | 350     | 94           | 5E      |         |
| 222.96                           | 0                      | 1       | 0  | 0  | 1 | 0      | 1 | 1 | -  | 75      | 4B | 37.16000 | 351     | 95           | 5F      |         |
| 222.98                           | 0                      | 1       | 0  | 0  | 1 | 1      | 0 | 0 | -  | 76      | 4C | 37.16333 | 352     | 96           | 60      |         |

Table 2. 222-MHz frequency/PLL/divide-by-N/EPROM data.

and receive pair is separated by a single Most-Significant-Bit (MSB) logic line. The transceiver T/R line in the commercial transceiver is used to activate a logic switch that's connected to this address line. This also switches the EPROM fixed divide-by-N inputs described above that change from transmit to receive.

I opted to use four control lines because they

were available in the existing control cable; however, you could use more if you choose.

While the use of four lines limits you to 16 frequencies, this is usually adequate for mobile operation on 6 meters in most areas. The choice of four control lines also lends itself somewhat easily to expanded capabilities like scanning. If you connect the four lines to the EPROM to the

| BCD Switch<br>Dial | Output of BCD Switches |         |    |    |   |        |   |   |    | EPROM   |      | PLL      |            | EPROM Data   |         |     |
|--------------------|------------------------|---------|----|----|---|--------|---|---|----|---------|------|----------|------------|--------------|---------|-----|
|                    | MHZ                    | 100 KHZ |    |    |   | 10 KHZ |   |   |    | Address |      | VCO Frq  | Divide / N | Divide / N # |         |     |
|                    | Freq - Mhz             | 1       | 8  | 4  | 2 | 1      | 8 | 4 | 2  | 1       | Dec. | Hex      | Mhz        | Decimal      | Decimal | Hex |
|                    | 128                    | 64      | 32 | 16 | 8 | 4      | 2 | 1 | NC |         |      |          |            |              | (-256)  |     |
| 223.00             | 1                      | 0       | 0  | 0  | 0 | 0      | 0 | 0 | -  | 128     | 80   | 37.16667 | 353        | 97           | 61      |     |
| 223.02             | 1                      | 0       | 0  | 0  | 0 | 0      | 0 | 1 | -  | 129     | 81   | 37.17000 | 354        | 98           | 62      |     |
| 223.04             | 1                      | 0       | 0  | 0  | 0 | 0      | 1 | 0 | -  | 130     | 82   | 37.17333 | 355        | 99           | 63      |     |
| 223.06             | 1                      | 0       | 0  | 0  | 0 | 0      | 1 | 1 | -  | 131     | 83   | 37.17667 | 356        | 100          | 64      |     |
| 223.08             | 1                      | 0       | 0  | 0  | 0 | 1      | 0 | 0 | -  | 132     | 84   | 37.18000 | 357        | 101          | 65      |     |
| 223.10             | 1                      | 0       | 0  | 0  | 1 | 0      | 0 | 0 | -  | 136     | 88   | 37.18333 | 358        | 102          | 66      |     |
| 223.12             | 1                      | 0       | 0  | 0  | 1 | 0      | 0 | 1 | -  | 137     | 89   | 37.18667 | 359        | 103          | 67      |     |
| 223.14             | 1                      | 0       | 0  | 0  | 1 | 0      | 1 | 0 | -  | 138     | 8A   | 37.19000 | 360        | 104          | 68      |     |
| 223.16             | 1                      | 0       | 0  | 0  | 1 | 0      | 1 | 1 | -  | 139     | 8B   | 37.19333 | 361        | 105          | 69      |     |
| 223.18             | 1                      | 0       | 0  | 0  | 1 | 1      | 0 | 0 | -  | 140     | 8C   | 37.19667 | 362        | 106          | 6A      |     |
| 223.20             | 1                      | 0       | 0  | 1  | 0 | 0      | 0 | 0 | -  | 144     | 90   | 37.20000 | 363        | 107          | 6B      |     |
| 223.22             | 1                      | 0       | 0  | 1  | 0 | 0      | 0 | 1 | -  | 145     | 91   | 37.20333 | 364        | 108          | 6C      |     |
| 223.24             | 1                      | 0       | 0  | 1  | 0 | 0      | 1 | 0 | -  | 146     | 92   | 37.20667 | 365        | 109          | 6D      |     |
| 223.26             | 1                      | 0       | 0  | 1  | 0 | 0      | 1 | 1 | -  | 147     | 93   | 37.21000 | 366        | 110          | 6E      |     |
| 223.28             | 1                      | 0       | 0  | 1  | 0 | 1      | 0 | 0 | -  | 148     | 94   | 37.21333 | 367        | 111          | 6F      |     |
| 223.30             | 1                      | 0       | 0  | 1  | 1 | 0      | 0 | 0 | -  | 152     | 98   | 37.21667 | 368        | 112          | 70      |     |
| 223.32             | 1                      | 0       | 0  | 1  | 1 | 0      | 0 | 1 | -  | 153     | 99   | 37.22000 | 369        | 113          | 71      |     |
| 223.34             | 1                      | 0       | 0  | 1  | 1 | 0      | 1 | 0 | -  | 154     | 9A   | 37.22333 | 370        | 114          | 72      |     |
| 223.36             | 1                      | 0       | 0  | 1  | 1 | 0      | 1 | 1 | -  | 155     | 9B   | 37.22667 | 371        | 115          | 73      |     |
| 223.38             | 1                      | 0       | 0  | 1  | 1 | 1      | 0 | 0 | -  | 156     | 9C   | 37.23000 | 372        | 116          | 74      |     |
| 223.40             | 1                      | 0       | 1  | 0  | 0 | 0      | 0 | 0 | -  | 160     | A0   | 37.23333 | 373        | 117          | 75      |     |
| 223.42             | 1                      | 0       | 1  | 0  | 0 | 0      | 0 | 1 | -  | 161     | A1   | 37.23667 | 374        | 118          | 76      |     |
| 223.44             | 1                      | 0       | 1  | 0  | 0 | 0      | 1 | 0 | -  | 162     | A2   | 37.24000 | 375        | 119          | 77      |     |
| 223.46             | 1                      | 0       | 1  | 0  | 0 | 0      | 1 | 1 | -  | 163     | A3   | 37.24333 | 376        | 120          | 78      |     |
| 223.48             | 1                      | 0       | 1  | 0  | 0 | 1      | 0 | 0 | -  | 164     | A4   | 37.24667 | 377        | 121          | 79      |     |
| 223.50             | 1                      | 0       | 1  | 0  | 1 | 0      | 0 | 0 | -  | 168     | A8   | 37.25000 | 378        | 122          | 7A      |     |
| 223.52             | 1                      | 0       | 1  | 0  | 1 | 0      | 0 | 1 | -  | 169     | A9   | 37.25333 | 379        | 123          | 7B      |     |
| 223.54             | 1                      | 0       | 1  | 0  | 1 | 0      | 1 | 0 | -  | 170     | AA   | 37.25667 | 380        | 124          | 7C      |     |
| 223.56             | 1                      | 0       | 1  | 0  | 1 | 0      | 1 | 1 | -  | 171     | AB   | 37.26000 | 381        | 125          | 7D      |     |
| 223.58             | 1                      | 0       | 1  | 0  | 1 | 1      | 0 | 0 | -  | 172     | AC   | 37.26333 | 382        | 126          | 7E      |     |
| 223.60             | 1                      | 0       | 1  | 1  | 0 | 0      | 0 | 0 | -  | 176     | B0   | 37.26667 | 383        | 127          | 7F      |     |
| 223.62             | 1                      | 0       | 1  | 1  | 0 | 0      | 0 | 1 | -  | 177     | B1   | 37.27000 | 384        | 128          | 80      |     |
| 223.64             | 1                      | 0       | 1  | 1  | 0 | 0      | 1 | 0 | -  | 178     | B2   | 37.27333 | 385        | 129          | 81      |     |
| 223.66             | 1                      | 0       | 1  | 1  | 0 | 0      | 1 | 1 | -  | 179     | B3   | 37.27667 | 386        | 130          | 82      |     |
| 223.68             | 1                      | 0       | 1  | 1  | 0 | 1      | 0 | 0 | -  | 180     | B4   | 37.28000 | 387        | 131          | 83      |     |
| 223.70             | 1                      | 0       | 1  | 1  | 1 | 0      | 0 | 0 | -  | 184     | B8   | 37.28333 | 388        | 132          | 84      |     |
| 223.72             | 1                      | 0       | 1  | 1  | 1 | 0      | 0 | 1 | -  | 185     | B9   | 37.28667 | 389        | 133          | 85      |     |
| 223.74             | 1                      | 0       | 1  | 1  | 1 | 0      | 1 | 0 | -  | 186     | BA   | 37.29000 | 390        | 134          | 86      |     |
| 223.76             | 1                      | 0       | 1  | 1  | 1 | 0      | 1 | 1 | -  | 187     | BB   | 37.29333 | 391        | 135          | 87      |     |
| 223.78             | 1                      | 0       | 1  | 1  | 1 | 1      | 0 | 0 | -  | 188     | BC   | 37.29667 | 392        | 136          | 88      |     |
| 223.80             | 1                      | 1       | 0  | 0  | 0 | 0      | 0 | 0 | -  | 192     | C0   | 37.30000 | 393        | 137          | 89      |     |
| 223.82             | 1                      | 1       | 0  | 0  | 0 | 0      | 0 | 1 | -  | 193     | C1   | 37.30333 | 394        | 138          | 8A      |     |
| 223.84             | 1                      | 1       | 0  | 0  | 0 | 0      | 1 | 0 | -  | 194     | C2   | 37.30667 | 395        | 139          | 8B      |     |
| 223.86             | 1                      | 1       | 0  | 0  | 0 | 0      | 1 | 1 | -  | 195     | C3   | 37.31000 | 396        | 140          | 8C      |     |
| 223.88             | 1                      | 1       | 0  | 0  | 0 | 1      | 0 | 0 | -  | 196     | C4   | 37.31333 | 397        | 141          | 8D      |     |
| 223.90             | 1                      | 1       | 0  | 0  | 1 | 0      | 0 | 0 | -  | 200     | C8   | 37.31667 | 398        | 142          | 8E      |     |
| 223.92             | 1                      | 1       | 0  | 0  | 1 | 0      | 0 | 1 | -  | 201     | C9   | 37.32000 | 399        | 143          | 8F      |     |
| 223.94             | 1                      | 1       | 0  | 0  | 1 | 0      | 1 | 0 | -  | 202     | CA   | 37.32333 | 400        | 144          | 90      |     |
| 223.96             | 1                      | 1       | 0  | 0  | 1 | 0      | 1 | 1 | -  | 203     | CB   | 37.32667 | 401        | 145          | 91      |     |
| 223.98             | 1                      | 1       | 0  | 0  | 1 | 1      | 0 | 0 | -  | 204     | CC   | 37.33000 | 402        | 146          | 92      |     |

output of a binary counter such as a 74193, or equivalent, which is driven by an oscillator gated by the squelch signal from the receiver, you'll have a scanning receiver. These same four lines could also drive a 7-segment decoder-driver/display that would indicate what channel was active.

**Table 3** is a list of Frequency/PLL divide-

by-N/EPROM data for the 6-meter synthesizer application just described.

### EPROM selection

I used EPROMs instead of PROMs—one-time Programmable Read Only Memories—for these applications because they allow for the

| Match-XMIT | T/R | Output of BCD Switches |         |    |    |    |   |        |   |   |     | EPROM |          | PLL      |         | EPROM Data |              |         |
|------------|-----|------------------------|---------|----|----|----|---|--------|---|---|-----|-------|----------|----------|---------|------------|--------------|---------|
|            |     | MHZ                    | 100 KHZ |    |    |    |   | 10 KHZ |   |   |     |       | Address  |          | VCO Frq | Divide / N | Divide / N # |         |
|            |     |                        | T=1     | 1  | 8  | 4  | 2 | 1      | 8 | 4 | 2   | 1     | NC       | Dec.     | Hex     | Mhz        | Decimal      | Decimal |
|            |     | 128                    | 128     | 64 | 32 | 16 | 8 | 4      | 2 | 1 | NC  |       |          |          |         | (-5120)    |              |         |
| 52.01      | 1   | 1                      | 0       | 0  | 0  | 0  | 0 | 0      | 0 | 0 | -   | 384   | 180      | 26.00500 | 5201    | 81         | 51           |         |
| 52.03      | 1   | 1                      | 0       | 0  | 0  | 0  | 0 | 0      | 0 | 1 | -   | 385   | 181      | 26.01500 | 5203    | 83         | 53           |         |
| 52.05      | 1   | 1                      | 0       | 0  | 0  | 0  | 0 | 0      | 1 | 0 | -   | 386   | 182      | 26.02500 | 5205    | 85         | 55           |         |
| 52.07      | 1   | 1                      | 0       | 0  | 0  | 0  | 0 | 1      | 1 | - | 387 | 183   | 26.03500 | 5207     | 87      | 57         |              |         |
| 52.09      | 1   | 1                      | 0       | 0  | 0  | 0  | 1 | 0      | 0 | - | 388 | 184   | 26.04500 | 5209     | 89      | 59         |              |         |
| 52.11      | 1   | 1                      | 0       | 0  | 0  | 1  | 0 | 0      | 0 | - | 392 | 188   | 26.05500 | 5211     | 91      | 5B         |              |         |
| 52.13      | 1   | 1                      | 0       | 0  | 0  | 1  | 0 | 0      | 1 | - | 393 | 189   | 26.06500 | 5213     | 93      | 5D         |              |         |
| 52.15      | 1   | 1                      | 0       | 0  | 0  | 1  | 0 | 1      | 0 | - | 394 | 18A   | 26.07500 | 5215     | 95      | 5F         |              |         |
| 52.17      | 1   | 1                      | 0       | 0  | 0  | 1  | 0 | 1      | 1 | - | 395 | 18B   | 26.08500 | 5217     | 97      | 61         |              |         |
| 52.19      | 1   | 1                      | 0       | 0  | 0  | 1  | 1 | 0      | 0 | - | 396 | 18C   | 26.09500 | 5219     | 99      | 63         |              |         |
| 52.21      | 1   | 1                      | 0       | 0  | 1  | 0  | 0 | 0      | 0 | - | 400 | 190   | 26.10500 | 5221     | 101     | 65         |              |         |
| 52.23      | 1   | 1                      | 0       | 0  | 1  | 0  | 0 | 0      | 1 | - | 401 | 191   | 26.11500 | 5223     | 103     | 67         |              |         |
| 52.25      | 1   | 1                      | 0       | 0  | 1  | 0  | 0 | 1      | 0 | - | 402 | 192   | 26.12500 | 5225     | 105     | 69         |              |         |
| 52.27      | 1   | 1                      | 0       | 0  | 1  | 0  | 0 | 1      | 1 | - | 403 | 193   | 26.13500 | 5227     | 107     | 6B         |              |         |
| 52.29      | 1   | 1                      | 0       | 0  | 1  | 0  | 1 | 0      | 0 | - | 404 | 194   | 26.14500 | 5229     | 109     | 6D         |              |         |
| 52.31      | 1   | 1                      | 0       | 0  | 1  | 1  | 0 | 0      | 0 | - | 408 | 198   | 26.15500 | 5231     | 111     | 6F         |              |         |
| 52.33      | 1   | 1                      | 0       | 0  | 1  | 1  | 0 | 0      | 1 | - | 409 | 199   | 26.16500 | 5233     | 113     | 71         |              |         |
| 52.35      | 1   | 1                      | 0       | 0  | 1  | 1  | 0 | 1      | 0 | - | 410 | 19A   | 26.17500 | 5235     | 115     | 73         |              |         |
| 52.37      | 1   | 1                      | 0       | 0  | 1  | 1  | 0 | 1      | 1 | - | 411 | 19B   | 26.18500 | 5237     | 117     | 75         |              |         |
| 52.39      | 1   | 1                      | 0       | 0  | 1  | 1  | 1 | 0      | 0 | - | 412 | 19C   | 26.19500 | 5239     | 119     | 77         |              |         |
| 52.41      | 1   | 1                      | 0       | 1  | 0  | 0  | 0 | 0      | 0 | - | 416 | 1A0   | 26.20500 | 5241     | 121     | 79         |              |         |
| 52.43      | 1   | 1                      | 0       | 1  | 0  | 0  | 0 | 0      | 1 | - | 417 | 1A1   | 26.21500 | 5243     | 123     | 7B         |              |         |
| 52.45      | 1   | 1                      | 0       | 1  | 0  | 0  | 0 | 1      | 0 | - | 418 | 1A2   | 26.22500 | 5245     | 125     | 7D         |              |         |
| 52.47      | 1   | 1                      | 0       | 1  | 0  | 0  | 0 | 1      | 1 | - | 419 | 1A3   | 26.23500 | 5247     | 127     | 7F         |              |         |
| 52.49      | 1   | 1                      | 0       | 1  | 0  | 0  | 1 | 0      | 0 | - | 420 | 1A4   | 26.24500 | 5249     | 129     | 81         |              |         |
| 52.51      | 1   | 1                      | 0       | 1  | 0  | 1  | 0 | 0      | 0 | - | 424 | 1A8   | 26.25500 | 5251     | 131     | 83         |              |         |
| 52.53      | 1   | 1                      | 0       | 1  | 0  | 1  | 0 | 0      | 1 | - | 425 | 1A9   | 26.26500 | 5253     | 133     | 85         |              |         |
| 52.55      | 1   | 1                      | 0       | 1  | 0  | 1  | 0 | 1      | 0 | - | 426 | 1AA   | 26.27500 | 5255     | 135     | 87         |              |         |
| 52.57      | 1   | 1                      | 0       | 1  | 0  | 1  | 0 | 1      | 1 | - | 427 | 1AB   | 26.28500 | 5257     | 137     | 89         |              |         |
| 52.59      | 1   | 1                      | 0       | 1  | 0  | 1  | 1 | 0      | 0 | - | 428 | 1AC   | 26.29500 | 5259     | 139     | 8B         |              |         |
| 52.61      | 1   | 1                      | 0       | 1  | 1  | 0  | 0 | 0      | 0 | - | 432 | 1B0   | 26.30500 | 5261     | 141     | 8D         |              |         |
| 52.63      | 1   | 1                      | 0       | 1  | 1  | 0  | 0 | 0      | 1 | - | 433 | 1B1   | 26.31500 | 5263     | 143     | 8F         |              |         |
| 52.65      | 1   | 1                      | 0       | 1  | 1  | 0  | 0 | 1      | 0 | - | 434 | 1B2   | 26.32500 | 5265     | 145     | 91         |              |         |
| 52.67      | 1   | 1                      | 0       | 1  | 1  | 0  | 0 | 1      | 1 | - | 435 | 1B3   | 26.33500 | 5267     | 147     | 93         |              |         |
| 52.69      | 1   | 1                      | 0       | 1  | 1  | 0  | 1 | 0      | 0 | - | 436 | 1B4   | 26.34500 | 5269     | 149     | 95         |              |         |
| 52.71      | 1   | 1                      | 0       | 1  | 1  | 1  | 0 | 0      | 0 | - | 440 | 1B8   | 26.35500 | 5271     | 151     | 97         |              |         |
| 52.73      | 1   | 1                      | 0       | 1  | 1  | 1  | 0 | 0      | 1 | - | 441 | 1B9   | 26.36500 | 5273     | 153     | 99         |              |         |
| 52.75      | 1   | 1                      | 0       | 1  | 1  | 1  | 0 | 1      | 0 | - | 442 | 1BA   | 26.37500 | 5275     | 155     | 9B         |              |         |
| 52.77      | 1   | 1                      | 0       | 1  | 1  | 1  | 0 | 1      | 1 | - | 443 | 1BB   | 26.38500 | 5277     | 157     | 9D         |              |         |
| 52.79      | 1   | 1                      | 0       | 1  | 1  | 1  | 1 | 0      | 0 | - | 444 | 1BC   | 26.39500 | 5279     | 159     | 9F         |              |         |
| 52.81      | 1   | 1                      | 1       | 0  | 0  | 0  | 0 | 0      | 0 | - | 448 | 1C0   | 26.40500 | 5281     | 161     | A1         |              |         |
| 52.83      | 1   | 1                      | 1       | 0  | 0  | 0  | 0 | 0      | 1 | - | 449 | 1C1   | 26.41500 | 5283     | 163     | A3         |              |         |
| 52.85      | 1   | 1                      | 1       | 0  | 0  | 0  | 0 | 1      | 0 | - | 450 | 1C2   | 26.42500 | 5285     | 165     | A5         |              |         |
| 52.87      | 1   | 1                      | 1       | 0  | 0  | 0  | 0 | 1      | 1 | - | 451 | 1C3   | 26.43500 | 5287     | 167     | A7         |              |         |
| 52.89      | 1   | 1                      | 1       | 0  | 0  | 0  | 1 | 0      | 0 | - | 452 | 1C4   | 26.44500 | 5289     | 169     | A9         |              |         |
| 52.91      | 1   | 1                      | 1       | 0  | 0  | 1  | 0 | 0      | 0 | - | 456 | 1C8   | 26.45500 | 5291     | 171     | AB         |              |         |
| 52.93      | 1   | 1                      | 1       | 0  | 0  | 1  | 0 | 0      | 1 | - | 457 | 1C9   | 26.46500 | 5293     | 173     | AD         |              |         |
| 52.95      | 1   | 1                      | 1       | 0  | 0  | 1  | 0 | 1      | 0 | - | 458 | 1CA   | 26.47500 | 5295     | 175     | AF         |              |         |
| 52.97      | 1   | 1                      | 1       | 0  | 0  | 1  | 0 | 1      | 1 | - | 459 | 1CB   | 26.48500 | 5297     | 177     | B1         |              |         |
| 52.99      | 1   | 1                      | 1       | 0  | 0  | 1  | 1 | 0      | 0 | - | 460 | 1CC   | 26.49500 | 5299     | 179     | B3         |              |         |

Table 3. Six-meter synthesizer/PLL divide-by-N/EPROM data.

correction of programming errors. You could use PROMS if desired, as long as you make the appropriate changes in circuitry.

For the applications described in this article, I chose 2716 EPROMs because of circuit address and data line requirements. The number of available 2716 address lines (11) exceeds the total number of needed BCD output switch lines (9), and the number of data output lines (8) matches the PLL synthesizer IC programming line requirements. The 2716, while no longer state-of-the-art, is easy to use and has simple programming requirements that allow it

to be programmed by home-built programmers. It's available from many suppliers.

## EPROM programming

As mentioned before, the 2716 has been around for years and many articles have been written about programmers. Two are listed in the references. I believe the article in **Reference 5**, although directed at Electrically-Erasable Programmable Read-Only-Memories (EEPROMs), could be easily modified for

| Dial       | T/R | MHZ |    |    |    |   |   | 100 KHZ |   |    |    | 10 KHZ |     |          |         | Address |     | VCO Frq | Divide / N | Divide / N # |  |
|------------|-----|-----|----|----|----|---|---|---------|---|----|----|--------|-----|----------|---------|---------|-----|---------|------------|--------------|--|
| Freq - Mhz | R=0 | 1   | 8  | 4  | 2  | 1 | 8 | 4       | 2 | 1  | NC | Dec.   | Hex | Mhz      | Decimal | Decimal | Hex |         |            |              |  |
|            | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2       | 1 | NC |    |        |     |          |         |         |     |         |            |              |  |
| 53.01      | 0   | 0   | 0  | 0  | 0  | 0 | 0 | 0       | 0 | 1  | -  | 1      | 1   | 29.85500 | 5971    | 83      | 53  |         |            |              |  |
| 53.03      | 0   | 0   | 0  | 0  | 0  | 0 | 0 | 0       | 0 | 1  | 0  | 2      | 2   | 29.86500 | 5973    | 85      | 55  |         |            |              |  |
| 53.05      | 0   | 0   | 0  | 0  | 0  | 0 | 0 | 0       | 0 | 1  | 1  | 3      | 3   | 29.87500 | 5975    | 87      | 57  |         |            |              |  |
| 53.07      | 0   | 0   | 0  | 0  | 0  | 0 | 1 | 0       | 0 | 0  | -  | 4      | 4   | 29.88500 | 5977    | 89      | 59  |         |            |              |  |
| 53.09      | 0   | 0   | 0  | 0  | 0  | 1 | 0 | 0       | 0 | 0  | -  | 8      | 8   | 29.89500 | 5979    | 91      | 5B  |         |            |              |  |
| 53.11      | 0   | 0   | 0  | 0  | 0  | 1 | 0 | 0       | 1 | 0  | -  | 9      | 9   | 29.90500 | 5981    | 93      | 5D  |         |            |              |  |
| 53.13      | 0   | 0   | 0  | 0  | 0  | 1 | 0 | 1       | 0 | 0  | -  | 10     | A   | 29.91500 | 5983    | 95      | 5F  |         |            |              |  |
| 53.15      | 0   | 0   | 0  | 0  | 0  | 1 | 0 | 1       | 1 | 0  | -  | 11     | B   | 29.92500 | 5985    | 97      | 61  |         |            |              |  |
| 53.17      | 0   | 0   | 0  | 0  | 0  | 1 | 1 | 0       | 0 | 0  | -  | 12     | C   | 29.93500 | 5987    | 99      | 63  |         |            |              |  |
| 53.19      | 0   | 0   | 0  | 0  | 1  | 0 | 0 | 0       | 0 | 0  | -  | 16     | 10  | 29.94500 | 5989    | 101     | 65  |         |            |              |  |
| 53.21      | 0   | 0   | 0  | 0  | 1  | 0 | 0 | 0       | 0 | 1  | -  | 17     | 11  | 29.95500 | 5991    | 103     | 67  |         |            |              |  |
| 53.23      | 0   | 0   | 0  | 0  | 1  | 0 | 0 | 1       | 0 | 0  | -  | 18     | 12  | 29.96500 | 5993    | 105     | 69  |         |            |              |  |
| 53.25      | 0   | 0   | 0  | 0  | 1  | 0 | 0 | 1       | 1 | 0  | -  | 19     | 13  | 29.97500 | 5995    | 107     | 6B  |         |            |              |  |
| 53.27      | 0   | 0   | 0  | 0  | 1  | 0 | 1 | 0       | 0 | 0  | -  | 20     | 14  | 29.98500 | 5997    | 109     | 6D  |         |            |              |  |
| 53.29      | 0   | 0   | 0  | 0  | 1  | 1 | 0 | 0       | 0 | 0  | -  | 24     | 18  | 29.99500 | 5999    | 111     | 6F  |         |            |              |  |
| 53.31      | 0   | 0   | 0  | 0  | 1  | 1 | 0 | 0       | 1 | 0  | -  | 25     | 19  | 30.00500 | 6001    | 113     | 71  |         |            |              |  |
| 53.33      | 0   | 0   | 0  | 0  | 1  | 1 | 0 | 1       | 0 | 0  | -  | 26     | 1A  | 30.01500 | 6003    | 115     | 73  |         |            |              |  |
| 53.35      | 0   | 0   | 0  | 0  | 1  | 1 | 0 | 1       | 1 | 0  | -  | 27     | 1B  | 30.02500 | 6005    | 117     | 75  |         |            |              |  |
| 53.37      | 0   | 0   | 0  | 0  | 1  | 1 | 1 | 0       | 0 | 0  | -  | 28     | 1C  | 30.03500 | 6007    | 119     | 77  |         |            |              |  |
| 53.39      | 0   | 0   | 0  | 1  | 0  | 0 | 0 | 0       | 0 | 0  | -  | 32     | 20  | 30.04500 | 6009    | 121     | 79  |         |            |              |  |
| 53.41      | 0   | 0   | 0  | 1  | 0  | 0 | 0 | 0       | 1 | 0  | -  | 33     | 21  | 30.05500 | 6011    | 123     | 7B  |         |            |              |  |
| 53.43      | 0   | 0   | 0  | 1  | 0  | 0 | 0 | 1       | 0 | 0  | -  | 34     | 22  | 30.06500 | 6013    | 125     | 7D  |         |            |              |  |
| 53.45      | 0   | 0   | 0  | 1  | 0  | 0 | 0 | 1       | 1 | 0  | -  | 35     | 23  | 30.07500 | 6015    | 127     | 7F  |         |            |              |  |
| 53.47      | 0   | 0   | 0  | 1  | 0  | 0 | 1 | 0       | 0 | 0  | -  | 36     | 24  | 30.08500 | 6017    | 129     | 81  |         |            |              |  |
| 53.49      | 0   | 0   | 0  | 1  | 0  | 1 | 0 | 0       | 0 | 0  | -  | 40     | 28  | 30.09500 | 6019    | 131     | 83  |         |            |              |  |
| 53.51      | 0   | 0   | 0  | 1  | 0  | 1 | 0 | 0       | 1 | 0  | -  | 41     | 29  | 30.10500 | 6021    | 133     | 85  |         |            |              |  |
| 53.53      | 0   | 0   | 0  | 1  | 0  | 1 | 0 | 1       | 0 | 0  | -  | 42     | 2A  | 30.11500 | 6023    | 135     | 87  |         |            |              |  |
| 53.55      | 0   | 0   | 0  | 1  | 0  | 1 | 0 | 1       | 1 | 0  | -  | 43     | 2B  | 30.12500 | 6025    | 137     | 89  |         |            |              |  |
| 53.57      | 0   | 0   | 0  | 1  | 0  | 1 | 1 | 0       | 0 | 0  | -  | 44     | 2C  | 30.13500 | 6027    | 139     | 8B  |         |            |              |  |
| 53.59      | 0   | 0   | 0  | 1  | 1  | 0 | 0 | 0       | 0 | 0  | -  | 48     | 30  | 30.14500 | 6029    | 141     | 8D  |         |            |              |  |
| 53.61      | 0   | 0   | 0  | 1  | 1  | 0 | 0 | 0       | 1 | 0  | -  | 49     | 31  | 30.15500 | 6031    | 143     | 8F  |         |            |              |  |
| 53.63      | 0   | 0   | 0  | 1  | 1  | 0 | 0 | 1       | 0 | 0  | -  | 50     | 32  | 30.16500 | 6033    | 145     | 91  |         |            |              |  |
| 53.65      | 0   | 0   | 0  | 1  | 1  | 0 | 0 | 1       | 1 | 0  | -  | 51     | 33  | 30.17500 | 6035    | 147     | 93  |         |            |              |  |
| 53.67      | 0   | 0   | 0  | 1  | 1  | 0 | 1 | 0       | 0 | 0  | -  | 52     | 34  | 30.18500 | 6037    | 149     | 95  |         |            |              |  |
| 53.69      | 0   | 0   | 0  | 1  | 1  | 1 | 0 | 0       | 0 | 0  | -  | 56     | 38  | 30.19500 | 6039    | 151     | 97  |         |            |              |  |
| 53.71      | 0   | 0   | 0  | 1  | 1  | 1 | 0 | 0       | 1 | 0  | -  | 57     | 39  | 30.20500 | 6041    | 153     | 99  |         |            |              |  |
| 53.73      | 0   | 0   | 0  | 1  | 1  | 1 | 0 | 1       | 0 | 0  | -  | 58     | 3A  | 30.21500 | 6043    | 155     | 9B  |         |            |              |  |
| 53.75      | 0   | 0   | 0  | 1  | 1  | 1 | 0 | 1       | 1 | 0  | -  | 59     | 3B  | 30.22500 | 6045    | 157     | 9D  |         |            |              |  |
| 53.77      | 0   | 0   | 0  | 1  | 1  | 1 | 1 | 0       | 0 | 0  | -  | 60     | 3C  | 30.23500 | 6047    | 159     | 9F  |         |            |              |  |
| 53.79      | 0   | 0   | 1  | 0  | 0  | 0 | 0 | 0       | 0 | 0  | -  | 64     | 40  | 30.24500 | 6049    | 161     | A1  |         |            |              |  |
| 53.81      | 0   | 0   | 1  | 0  | 0  | 0 | 0 | 0       | 1 | 0  | -  | 65     | 41  | 30.25500 | 6051    | 163     | A3  |         |            |              |  |
| 53.83      | 0   | 0   | 1  | 0  | 0  | 0 | 0 | 1       | 0 | 0  | -  | 66     | 42  | 30.26500 | 6053    | 165     | A5  |         |            |              |  |
| 53.85      | 0   | 0   | 1  | 0  | 0  | 0 | 0 | 1       | 1 | 0  | -  | 67     | 43  | 30.27500 | 6055    | 167     | A7  |         |            |              |  |
| 53.87      | 0   | 0   | 1  | 0  | 0  | 0 | 1 | 0       | 0 | 0  | -  | 68     | 44  | 30.28500 | 6057    | 169     | A9  |         |            |              |  |
| 53.89      | 0   | 0   | 1  | 0  | 0  | 1 | 0 | 0       | 0 | 0  | -  | 72     | 48  | 30.29500 | 6059    | 171     | AB  |         |            |              |  |
| 53.91      | 0   | 0   | 1  | 0  | 0  | 1 | 0 | 0       | 1 | 0  | -  | 73     | 49  | 30.30500 | 6061    | 173     | AD  |         |            |              |  |
| 53.93      | 0   | 0   | 1  | 0  | 0  | 1 | 0 | 1       | 0 | 0  | -  | 74     | 4A  | 30.31500 | 6063    | 175     | AF  |         |            |              |  |
| 53.95      | 0   | 0   | 1  | 0  | 0  | 1 | 0 | 1       | 1 | 0  | -  | 75     | 4B  | 30.32500 | 6065    | 177     | B1  |         |            |              |  |
| 53.97      | 0   | 0   | 1  | 0  | 0  | 1 | 1 | 0       | 0 | 0  | -  | 76     | 4C  | 30.33500 | 6067    | 179     | B3  |         |            |              |  |
| 53.99      | 0   | 0   | 1  | 0  | 0  | 1 | 1 | 0       | 0 | 0  | -  | 76     | 4C  | 30.34500 | 6069    | 181     | B5  |         |            |              |  |

EPROM programming by changing the programmer parameters for EPROM operation. (By the way, there's no reason why you can't use EEPROMs in this application in place of EPROMs; however, EPROMs are more readily available and less expensive.) The 2716 has been used in commercial two-way radio synthesizers—so programming capability exists in many two-way radio shops. Read on to learn about the EPROM programming process.

When the 2716 is completely erased all bits will be at a "1" level (output high). During erasure, all bits are erased at once—it's not possi-

ble to erase selected bits. The 2716 is programmed by placing "0"s into the desired locations. This is done 8 bits (a byte) at a time. Data associated with random addresses may be programmed in any sequence. The 8 bits associated with an address location are programmed with a single program pulse applied to the chip enable pin. The following programming information is from the *National MM27116 National Data Sheet*.<sup>2</sup>

"All input voltage levels, including the program pulse and chip enable are TTL compatible. The programming sequence is: With VPP

## Hexadecimal and Binary Numbers

A *binary* number is a sequence of zeros or ones with the place representing multiple values of 2, as opposed to the decimal system. For example the binary number 1111 is not equal to one thousand one hundred eleven, but  $(1 \times 1) + (1 \times 2) + (1 \times 4) + (1 \times 8)$ , or decimal 15. Eight-bit binary numbers are cumbersome to work with so they are often changed into 2-digit hexadecimal numbers. Hex numbers use the 10 ordinary (decimal) numerals to represent 0 through 9, and the capital letters A through F to represent 10 through 15. Each hex digit represents four binary digits:

| Hex | Binary | Hex | Binary | Hex | Binary | Hex | Binary |
|-----|--------|-----|--------|-----|--------|-----|--------|
| 0   | 0000   | 4   | 0100   | 8   | 1000   | C   | 1100   |
| 1   | 0010   | 5   | 0101   | 9   | 1001   | D   | 1101   |
| 2   | 0010   | 6   | 0110   | A   | 1010   | F   | 1110   |
| 3   | 0011   | 7   | 0111   | B   | 1011   | F   | 1111   |

Thus to convert an eight-bit binary number into a two-digit hex number, simply replace the first four bits with the corresponding hex digit and the last four bits with the corresponding hex digit. As an example, 00011010 split into two 4-bit binary numbers is 1010, which converts to a hex A, and 0001, which converts to a hex 1. Therefore 00011010 is equal to 1A in hex.

To avoid confusion, hexadecimal numbers are often designated by preceding the digits with a dollar sign (\$); for example:

\$1A to indicate that they are hex.

= 25V, VCC = 5V, OE = VIH and CE/PGM = VIL, an address is selected and the desired data word is applied to the output pins. (VIL = "0" and VIH = "1" for both address and data.) After the address and data signals are stable, the program pin is pulsed from VIL to VIH with a pulse width between 45 ms and 55 ms. Multiple pulses are not needed, but will not cause device damage. No pins should be left open. A high level (VIH or higher) *must not* be maintained longer than  $tpW(MAX)$  on the program pin during programming."

It's important to note that multiple pulses won't damage the EPROM. Fifty millisecond pulses can be derived easily from 60 Hz with a divide-by 3-circuit. This can simplify the construction of a homebrew programmer and minimize concerns about obtaining the right programming pulse width.

Many EPROM programmers have a hex editor mode that greatly simplifies the programming process (see the sidebar, "Hexadecimal and Binary Numbers," for details). **Tables 2** and **3** include hex equivalent numbers.

### EPROM erasing

EPROMs are erased by exposing the surface under the transparent window on the chip to high-intensity ultraviolet light. Consequently, I recommend that you *do not* expose programmed 2716s to direct sunlight. The UV content of sunlight may cause a partial erasure

of some bits. Again quoting from the National data sheet on EPROM erasure:

"An ultraviolet source of 2537 Å, yielding a total integrated dosage of 15 watt-seconds/cm<sup>2</sup>, is required. This will erase the part in approximately 15 to 20 minutes if a UV lamp with a 12,000 μW/cm<sup>2</sup> power rating is used. The 2716 to be erased should be placed 1 inch away from the lamp and no filters should be used."

For those interested in doing their own EPROM erasing, UV erasers are available from many sources—usually in the \$40 to \$50 range.

### Summary

This article has described a way to simplify interfacing to parallel input synthesizer integrated circuits without the added complexity of a microprocessor. BCD thumbwheel switches connected to an EPROM provide the conversion from the easy-to-use decimal "world" we're all familiar with to the more complex binary "world" used by the parallel input ICs.

### REFERENCES

1. J. Robert Witmer, W3RW, "Modifying a CB-Board Synthesizer for Amateur Use," *QST*, March 1983, pages 20-24.
2. *National Semiconductor MM2716 EPROM Data Sheet*, November 1979.
3. G. Palmer, "PROM Programmer/Reader and Utility Software for 2708 and 2716 PROMS," *QEX*, February 1983, pages 3-9.
4. C.A. Eubanks, N3CA, "2716 EPROM Programmer," *Ham Radio*, April 1982, pages 32-36.
5. G. Swindell, "Simple EEPROM Programmer," *Ham Radio*, January 1990.

# DOUBLE RESONANT ANTENNAS WITH LOADING REACTORS

## *The unknown possibilities of trap antennas*

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**T**rap antennas, familiar to the many amateurs who operate on several bands from locations with limited area, have proven their usefulness over the years. However, I've found that they are poorly understood. In reexamining trap antenna basics, I found they have unknown possibilities. While trap antennas for three or more bands are in common use, I will deal only with dual-band versions because one cannot expect to understand multi-band types until he first understands the dual-band models.

While my main objective is to gain understanding, I have developed several practical designs. The first part of this article gives data on some antennas you can build without doing elaborate calculations or reading the rest of the information contained here. Part II presents general trap antenna principles and part III contains my conclusions.

One of the most important bits of information I've acquired is that once you have selected lower and upper resonant frequencies, FL and FU, and the dimensions, antennas belong to one of four types. I have found that, for an antenna to be capable of having a double resonance, it must have at least one natural resonance or anti-resonance at a frequency between the desired frequencies FL and FU. (See part II for detailed explanations of these statements.)

**Type 1.** With Type 1 antennas you can always produce double resonance by inserting properly selected *parallel* L-C circuits—the familiar type. Antennas of this kind require

positive (inductive) reactances at FL and negative (capacitive) ones at FU.

**Type 2.** With Type 2 antennas you can always produce a double resonance with *series* L-C circuits. This antenna type requires the reverse of Type 1, a negative reactance at FL and a positive one at FU.

**Type 3.** With Type 3 antennas you can produce double resonance with *either* parallel or series circuits. These are antennas where the required reactances are of the same sign, but the reactances at FU are larger, or less negative, than those at FL.

**Type 4.** With Type 4 antennas you *cannot* produce double resonance with either type of circuit. In these antennas the required reactances are of the same sign, but the reactance at FU is smaller.

Handbooks generally explain the operation of a trap antenna by repeating the argument contained in early articles.<sup>1,2</sup> There are parallel L-C circuits placed along a dipole antenna symmetrically about the center feed point. The resonant frequencies of each pair coincides with one of the desired resonances of the antenna. At one of these frequencies, one pair of L-C circuits has a very high impedance and, in effect, disconnects the outer portions of the antenna while the others act approximately as short circuits. The positions of the traps, then, are such that the distances between them are equal to the half-wave lengths corresponding to the resonant frequencies. The antenna acts as a half-

wave dipole at each resonant frequency.

This picture is easy to understand and suggests the way to build a multi-band antenna. In part II, I'll review this argument in detail—pointing out inconsistencies that lead to some undesirable features. Many commercially made antennas don't conform with this design. According to the accepted theory of operation, the traps of a three-band dipole should be separated. While some existing antennas fit this description, many have two traps at a single location in a single structure. Obviously, then, this description does not hold, and therefore, the outer portions are not “disconnected” at the resonant frequencies. The proper explanation is that the L-C circuits produce resonance at the desired frequencies by tuning out whatever reactance is present.

I will call these L-C circuits “resonators,” and use the word “trap” only when the antenna in question closely conforms with the traditional explanation.

In an earlier article, I made an attempt to understand these antennas;<sup>3</sup> however, partly due to the cumbersome calculation method I used, I could not compute most of the properties of the antennas, and didn't see the big picture. (In that article, I called the “trap” design the “classic” one.) Since then I have developed the program ONETWORES,<sup>4</sup> which provides information on all properties of interest except frequency response. That, I must still determine by experiment. Part II contains many results obtained using ONETWORES.

## Part I: practical antennas

**Table 1** lists the properties of six antennas you can build. (In a sense there are only four because A and B are the same, with the exception of their resonators. Antennas E and F are also alike in the same way.) You may be confused by the fact that five of the antennas are for the same frequencies, 14.2 and 28.4 MHz. This information is even more useful because many of our other bands have the frequency ratio  $F_U/F_L = 2$ , and you can scale these data. For example, if you build antennas with four times the dimensions, and inductances and capacitances four times as large, you have the specifications of an antenna for 3.505 and 7.1 MHz. However, the one you would choose for use at 14 to 28 MHz may not be the best one for scaling to 3.5 MHz. Also, you might not want a frequency ratio of exactly 2. These are questions I discuss later.

In **Table 1**, as in the rest of the article, unless specifically stated otherwise, dimensions in wavelengths are always given in terms of the wavelength corresponding to the upper frequency,  $F_U$ . In order to make **Table 1** reason-

ably small, I have had to leave out some information that is of interest, and which is given by my computer program. However, the things I've left out are things you can calculate from the items given using a calculator. The table doesn't provide the inductance values, but you can calculate them from the resonant frequency,  $F_0$ , and the capacitance by the standard formula. Later, when I discuss the individual antennas, I give the inductances and, in some cases, the winding data. You can also determine the efficiency and directivity quite easily. I remind you that the gain, as a ratio, is the product of the efficiency and the directivity, or, in dB is equal to their sum. The efficiency, as a ratio, is the radiation resistance divided by the total resistance. As an example, look at the 14-MHz data for antenna B. The efficiency is  $39.0/45.6 = 0.86$  or 86 percent. In dB, this is  $-0.68$ . The directivity in dB is then found by subtracting this number from  $-0.92$ , which gives you  $-0.24$  dB.

## Construction and measurements

All of these antennas use no. 14 wire. When I have suitable high-voltage ceramic or mica capacitors, I use them. In other cases, I use ceramic or silver mica capacitors with pigtailed with at least 500 volts rating in series or series-parallel, so I have a voltage rating of at least 1,000 volts. The inductors are wound on homemade compression-type plastic insulators of the type described in my article on  $5/4$ -wavelength dipoles.<sup>5</sup> As that article shows, these dipoles have a distributed shunt capacitance of about 1 pF, which can be ignored in most cases. I assume a power output of 100 watts (“bare-foot”). If you plan to use higher power, you must use components with higher ratings.

My antennas were mounted horizontally about 20 feet above ground. They were fed with about 30 feet of RG-58/U foam coax. A few feet of coax at the antenna were coiled up to act as a balun. I haven't adjusted the SWR data plotted in **Figures 1** through **6** for the effects of the cable, but the corrections are small due to the shortness of the line. At 28 MHz, a SWR of 2 at the input of the line corresponds to 2.22 at the antenna; one of 2.5 at the input corresponds to 2.9 at the antenna. At lower frequencies, the effects are smaller.

One reason why I have made no correction is because of the uncertainty in the calibration of the equipment used to make my measurements. The values plotted are those obtained with a Daiwa CN-410 M crossed needle instrument, which gives the most pessimistic values (i.e., highest readings) of the three instruments I have used. I also have a Heathkit HM-15 and the SWR detector built into an Argonaut 505



| Length<br>WL<br>feet                                                                                                                                                                                                                                                                                                                                                                        | Sep.<br>WL<br>feet | XL<br>ohms | RL<br>ohms | GL<br>dB | XU<br>ohms | RU<br>ohms | GU<br>dB | F0<br>MHz | CAP<br>pF |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|------------|------------|----------|------------|------------|----------|-----------|-----------|
| <b>18.118 to 24.94 MHz</b>                                                                                                                                                                                                                                                                                                                                                                  |                    |            |            |          |            |            |          |           |           |
| <b>Antenna A</b>                                                                                                                                                                                                                                                                                                                                                                            |                    |            |            |          |            |            |          |           |           |
| 0.59                                                                                                                                                                                                                                                                                                                                                                                        | 0.27               | +211       | 58, 64     | -0.47    | -231       | 87, 91     | -0.11    | 21.4      | 105 P     |
| 22.0                                                                                                                                                                                                                                                                                                                                                                                        | 10.4               |            | 63         |          |            | 90         |          | 21.4      | 100 P     |
| <b>14.2 to 28.4 MHz</b>                                                                                                                                                                                                                                                                                                                                                                     |                    |            |            |          |            |            |          |           |           |
| <b>Antenna B</b>                                                                                                                                                                                                                                                                                                                                                                            |                    |            |            |          |            |            |          |           |           |
| 0.67                                                                                                                                                                                                                                                                                                                                                                                        | 0.3                | +527       | 39, 46     | -0.92    | -457       | 97, 100    | +0.07    | 19.6      | 23.5 P    |
| 22.0                                                                                                                                                                                                                                                                                                                                                                                        | 10.4               |            | 28         |          |            | 115        |          | 20        | 23.5 P    |
| <b>Antenna C</b>                                                                                                                                                                                                                                                                                                                                                                            |                    |            |            |          |            |            |          |           |           |
| 0.8                                                                                                                                                                                                                                                                                                                                                                                         | 0.4                | +324       | 54, 56     | -0.33    | -1.4 k     | 94, 99     | +0.02    | 24.7      | 16.9 P    |
| 26.4                                                                                                                                                                                                                                                                                                                                                                                        | 13.3               |            | 56         |          |            | 93         |          | 24.6      | 17.7 P    |
| <b>Antenna D</b>                                                                                                                                                                                                                                                                                                                                                                            |                    |            |            |          |            |            |          |           |           |
| 0.95                                                                                                                                                                                                                                                                                                                                                                                        | 0.5                | +85        | 69, 69     | -0.11    | -16 k      | 73, 73     | -0.09    | 28.4      | 44.0 P    |
| 31.3                                                                                                                                                                                                                                                                                                                                                                                        | 16.6               |            | 56         |          |            | 90         |          | 28.8      | 25 P      |
| <b>Antenna E</b>                                                                                                                                                                                                                                                                                                                                                                            |                    |            |            |          |            |            |          |           |           |
| 0.95                                                                                                                                                                                                                                                                                                                                                                                        | 0.6                | +127       | 70, 70     | -0.10    | +1.8 k     | 52, 67     | +0.30    | 30.1      | 25.1 P    |
| 31.3                                                                                                                                                                                                                                                                                                                                                                                        | 20.7               |            | 55         |          |            | 83         |          | 29.6      | 25 P      |
| <b>Antenna F</b>                                                                                                                                                                                                                                                                                                                                                                            |                    |            |            |          |            |            |          |           |           |
| 0.95                                                                                                                                                                                                                                                                                                                                                                                        | 0.6                | +127       | 70, 73     | -0.31    | +1.8 k     | 52, 53     | +1.28    | 13.4      | 10.9 S    |
| 31.3                                                                                                                                                                                                                                                                                                                                                                                        | 20.7               |            | 75         |          |            | 58         |          | 11.8      | 41.5 S    |
| <b>Notes:</b>                                                                                                                                                                                                                                                                                                                                                                               |                    |            |            |          |            |            |          |           |           |
| For each antenna there are two lines. The first one contains numbers calculated (with inductor Q = 200). The second contains experimental data.                                                                                                                                                                                                                                             |                    |            |            |          |            |            |          |           |           |
| The dimensions in the first two columns in the first lines, in wavelengths (WL), are design objectives. Those in the second lines, in feet, in some cases have been adjusted slightly to bring the resonances to the desired frequencies. The conversion from wavelengths to feet involves end corrections that are somewhat uncertain (see Reference 4).                                   |                    |            |            |          |            |            |          |           |           |
| R denotes the resistance at the input to the dipole. The L is for the lower frequency (18.118 or 14.2 MHz), and U is for the upper frequency (24.94 or 28.4 MHz).                                                                                                                                                                                                                           |                    |            |            |          |            |            |          |           |           |
| Two values of calculated resistance are cited in each case. The ones on the left are the radiation resistances; the ones on the right include the losses in the inductors. The resistances in the second lines have been obtained by taking the characteristic impedance Z0 = 50 ohms and multiplying or dividing it by the minimum SWRs, as is more consistent with the calculated values. |                    |            |            |          |            |            |          |           |           |
| G is the gain. X denotes the reactance that must be supplied by the resonators to produce resonance. F0 is the resonant frequency of the L-C circuits when disconnected from the antenna. CAP denotes their capacitances.                                                                                                                                                                   |                    |            |            |          |            |            |          |           |           |

**Table 1. Dual-band dipole data.**

transceiver. All three read almost exactly 1.0 when connected to a 50-ohm dummy load, but otherwise they disagree. Furthermore, the Heathkit reading depends upon the power level.

As a check on the Daiwa instrument, I mea-

sured the SWRs of half-wave dipoles at 14, 21, and 28 MHz in the same location as that of my double-resonant antennas. The values were 1.4, 1.45, and 1.25, respectively. Such antennas in free space have radiation resistances of 73

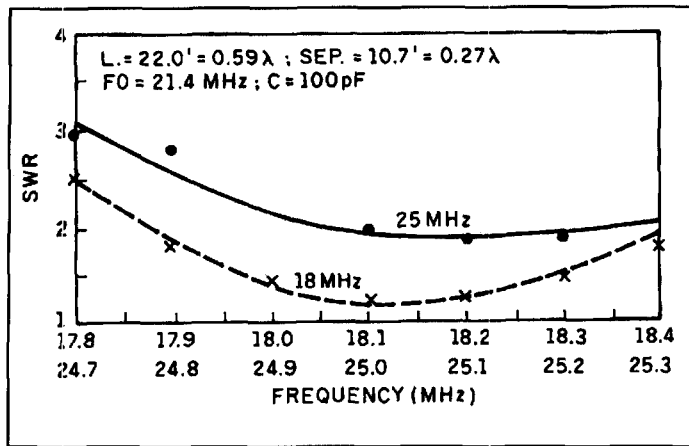


Figure 1. SWR as a function of frequency for antenna A (see Table 1).

ohms, which would give a SWR of 1.45. Therefore, effects of the ground on the SWR appear to be unimportant.

### Comments upon individual antennas

**Antennas A and B.** See Figures 1 and 2 for plots of the SWRs versus frequency. The total length was chosen to be the geometrical average of the lengths of half-wave dipoles for the design frequencies of 18.118 and 24.94 MHz.

In a previous article,<sup>3</sup> I wanted to show that it was possible to design a double-resonant antenna that conformed to a design very different from the well-known trap design. To demonstrate this hypothesis experimentally, I built antennas configured so the reactances at the two design frequencies, FL and FU, are ideally equal in magnitude, but of opposite sign. I

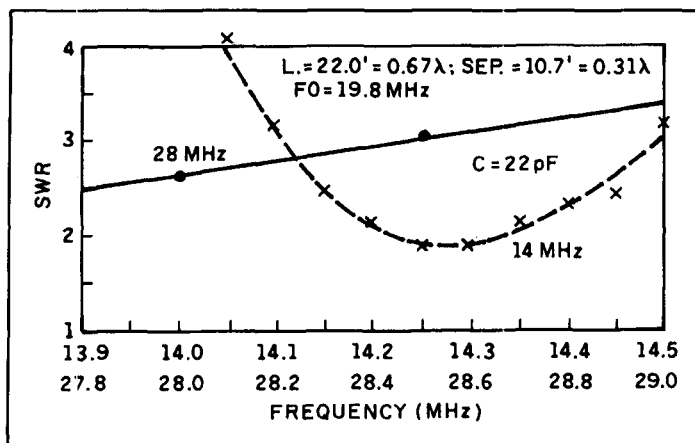


Figure 2. SWR as a function of frequency for antenna B (see Table 1). Antennas A and B have the same dimensions but different resonators. The graph shows only two experimental points for 28 MHz; however, I took three others far outside the frequency range of this plot, and all five lie close to the same straight line.

called this the “symmetrical” design. With the cumbersome computer methods I used then, I could demonstrate only the theoretical justification for the existence of such antennas, but I could not evaluate their properties. Now with my present program I can do so. It appeared likely that if I chose the lengths in the way described here, I would have ones that nearly conform with this design. At the same time, I would formulate the calculations in a convenient way. The reactance values for antennas A and B shown in Table 1 do indeed approximately conform with this design.

By accident, the length coincides with that of a half-wave dipole for 21.2 MHz. The antenna can be used on that frequency by shorting out the resonators, whose frequency by further coincidence is 21 MHz. The positions of resonators were chosen because the computer program gave, for both antennas A and B, reasonable values for the capacitors and for the same positions: 100 pF for A and 23.5 pF for B.

Note that the resonators for antennas A and B have almost the same frequency. Therefore, the main difference between them is the L/C ratio: a high L/C ratio goes with a higher FU/FL ratio. (Later I found the opposite to be true with series L-C resonators.) These are very useful things to remember. If you are working with a new antenna and the resonances are not where you want them to be, calculate the measured FU/FL ratio. Change the resonant frequency of the L-C, and do it in such a way as to change the L/C ratio in the right direction; that is, this observation tells you whether to change L or C.

The inductors of antenna A (18.118 to 24.94 MHz) have 7 turns of no. 14 wire with an inner diameter of 1/2 inch and a length of 1 inch (0.55 μH). They are self-supporting. Those for B (14.2-28.4 MHz) have 12 turns of no. 18 plastic coated wire on 1 inch forms. The end turns are spread slightly (2.66 μH).

**Antenna C.** See Figure 3 for a plot of SWR versus frequency. The total length is longer than B, but less than that of a “trap” antenna. The inductors have 15 turns of no. 18 enamel wire close wound on a 3/4-inch form (2.36 μH).

**Antenna D.** See Figure 4 for a plot of SWR versus frequency. This conforms with the “trap” or “classic” design as close as is practical. Traditionally, the total length should be equal to the half wavelength at FL, which in this case would be 1.0 FU wavelengths. However at FL, as discussed in Part II, the resonator in practice produces a small inductive reactance rather than the ideal short circuit. To compensate, the total length must be reduced slightly. In this case, it is 0.95. There is a discrepancy between the theoretical and experimental values of the resonator capacitances. As explained in Part II, this design has an instabil-

ity which causes a small error in the length to cause a larger change in the capacitance. Such an error might be caused by the end correction. The required inductance is 1.22  $\mu\text{H}$ .

**Antennas E and F.** See Figures 5 and 6 for plots of the SWRs versus frequency. To my knowledge, no one has built a double-resonant antenna with a resonator separation of more than 0.5 wavelengths. I decided to try 0.6 on the computer, and I received a pleasant surprise. For one thing, I discovered that the reactances are those of a Type 3 antenna, with which the use of either series or parallel L-C circuits can produce double resonance. Antenna E uses parallel circuits, while F uses series circuits. I also found that radiation resistances aren't far from 50 ohms. Therefore it is possible to get fairly good impedance matches at both frequencies. However, partly because of different coil losses, they have different frequency responses and gains. The series configuration does have one disturbing feature: the discrepancy between the theoretical and experimental values of the resonator capacitances. Some of this is due to the distributed capacitance of the insulator—about 1 pF. In the parallel case, this is fairly small compared to a capacitance of 25 pF, and you can neglect it with fair conscience. However, the 1 pF insulator has a reactance of about  $-5 \text{ k}$  at 28 MHz, which is appreciable compared to the desired reactance of 1.8 k. Furthermore, calculations show that, with the series connection, it is somewhat sensitive: small changes in the length cause large changes in the capacitances and the resonant frequencies of the L-C circuits. End corrections can be sources of such errors. As a check, I inserted inductors alone to make this a single-band 28-MHz antenna. The required inductances were about 600 ohms instead of the 1.8 k predicted by the theory. This is the only case where I have observed a serious discrepancy between theory and experiment. The inductors for the series configuration F have 12 turns of no. 20 plastic insulated wire on 1.25-inch diameter forms (4.23  $\mu\text{H}$ ), while the parallel configuration E needs inductors of 1.16  $\mu\text{H}$ .

## Selecting a 14 to 28-MHz antenna

Which of these antennas would you choose to use? The answer depends on what you want to do. The features you should consider are impedance match, bandwidth, directivity, and gain. You should consider which band's performance you would prefer to emphasize.

The impedance match question is important if you expect to have a long transmission line.

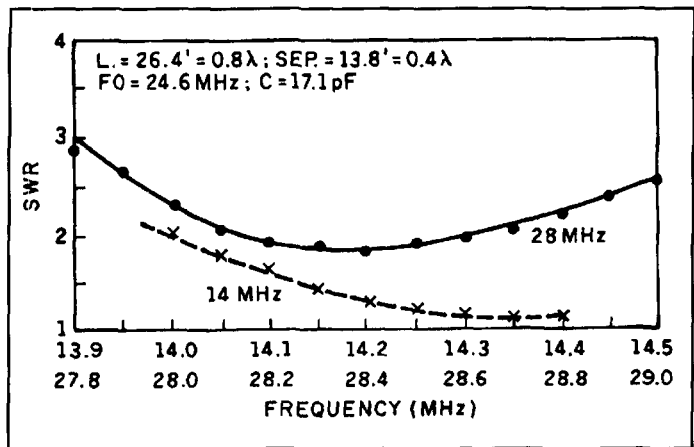


Figure 3. SWR as a function of frequency for antenna C (see Table 1).

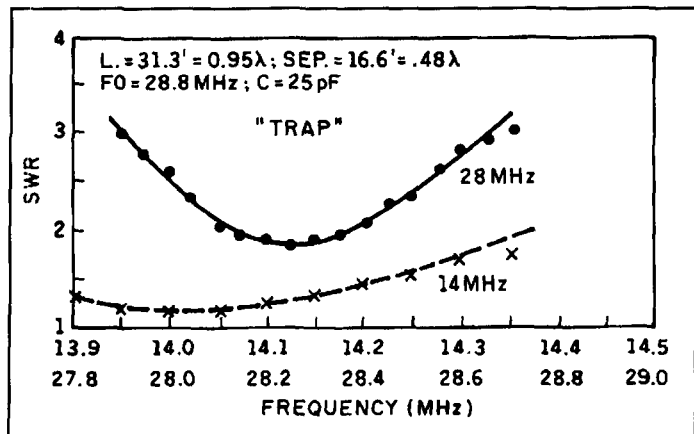


Figure 4. SWR as a function of frequency for antenna D, which closely conforms with the "trap" design (see Table 1).

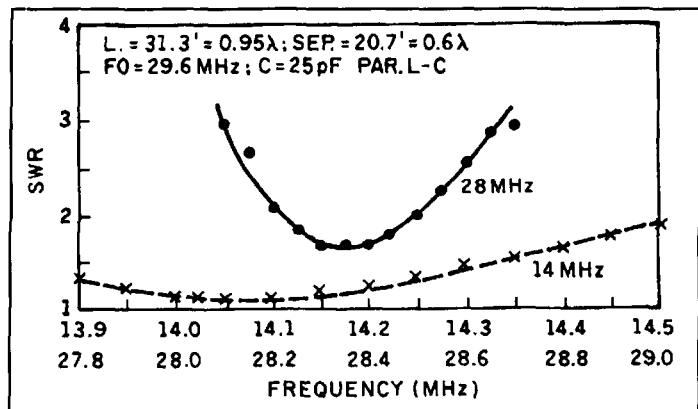


Figure 5. SWR as a function of frequency for antenna E (see Table 1).

With a tuner, line losses are low even with lines up to 50 feet and with a SWR as high as 3. However if you are building an antenna for portable use, you may not wish to take along an antenna tuner; in this situation, designs with low SWRs are better.

**Antennas E and F** have small amounts of gain and directivity relative to the others. If you

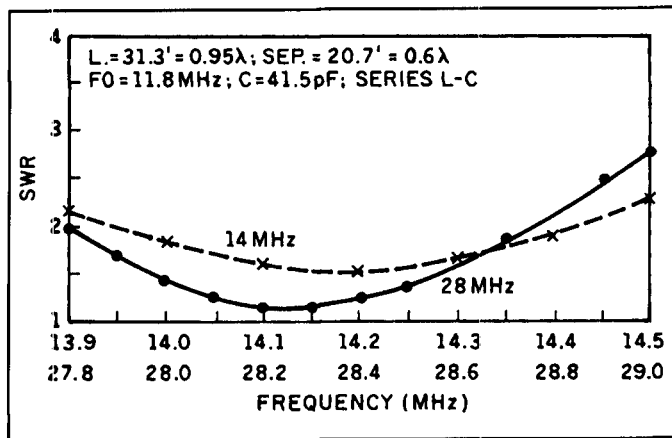


Figure 6. SWR as a function of frequency for antenna F (see Table 1). Antennas E and F have the same dimensions but E has parallel L-C resonators while F has series ones.

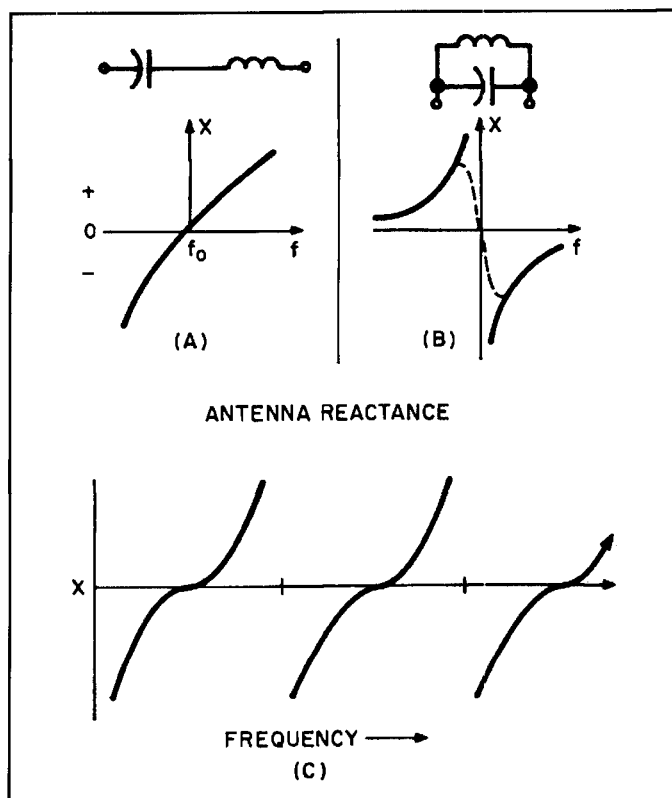


Figure 7. Sketches (not to scale) for reactance as a function of frequency for (A) a series L-C circuit, (B) a parallel L-C circuit, and (C) a center-fed dipole antenna.

can rotate the dipole, or mount it in a direction you wish to favor, you might prefer to use one of these.

If you are choosing an antenna for 14 and 28 MHz, you'd probably prefer a design that gives a broad response at 28 MHz, because that band is the wider one. If you are choosing a design for scaling to 3.5 and 7 MHz, you would choose one that has a wider response on 14

MHz because then the lower frequency band, 3.5 MHz, is the wider one.

## Some useful vertical Type 2 antennas

Antennas A through D are of Type 1; E and F are of Type 3. Do any Type 2 antennas exist? Yes, but first I'll tell you what I learned from my computer program. I found that I obtained reasonable values for inductances and capacitances only when the frequency ratio  $F_U/F_L$  is about 2.5. Even then, the radiation resistances are high, making it hard to get an impedance match to 50 ohms. However, radiation resistances of vertical antennas are one half those of corresponding horizontal ones. In an inconspicuous note, which deserves more attention, Carr<sup>6</sup> has published the design of dual-band verticals that are indeed Type 2 antennas. Previously, Reh<sup>7</sup> had shown that antennas that were approximately quarter-wave verticals on 7 and 10 MHz can be used as 5/8-wavelength antennas on 18 and 24 MHz, respectively. However, Reh used plug-in loading reactors on each band. Carr showed that these can be replaced by series L-C circuits with automatic dual-band operation.

For your convenience, I quote the parameters of their antennas: (1) for 10 to 24 MHz, length = 23'5",  $L = 1.18 \mu\text{H}$ , and  $C = 209 \text{ pF}$ ; (2) for 7 to 18 MHz, length = 32'3",  $L = 1.62 \mu\text{H}$ , and  $C = 301 \text{ pF}$ .

I have built antennas similar to these, but with slightly different parameters and used them successfully for about three years.

## Part II: Understanding the different antenna types Reactance properties of L-C circuits

To understand why the Type 1 through Type 4 situations exist, you must know how the reactances of L-C circuits and antennas vary with frequency. **Figure 7A** shows such a plot for a series L-C circuit. Note that at low frequencies it has large negative (capacitive) values, then rises to zero at resonance, and then continues to rise to infinity.

The behavior of a parallel L-C circuit, as shown in **Figure 7B** is more complicated. The solid lines show the situation when there are no losses. The reactance starts at zero, and then as the frequency approaches resonance (in this case, often called "anti-resonance"), it increases to large positive (inductive) values. Then it suddenly snaps to very large negative values

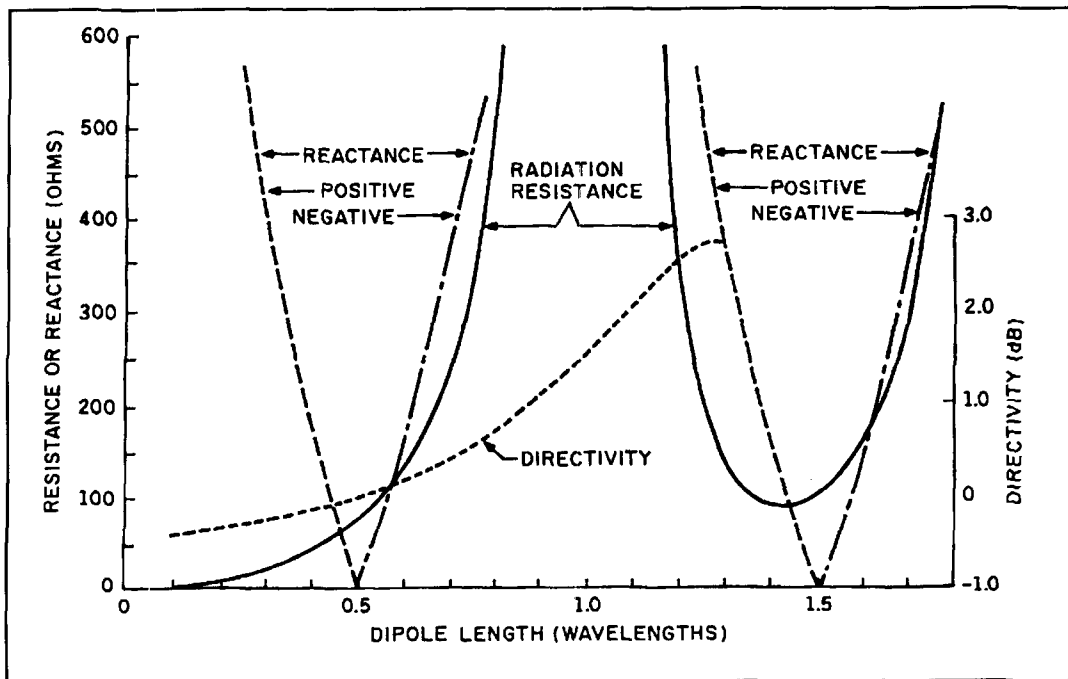


Figure 8. Plot of the properties of a center-fed dipole with resonating reactors at the feed point as a function of length, as calculated by ONETWORES.

and increases to zero. When losses are present, the behavior around the center of the graph follows the dotted curve: very large positive and negative values are not attained. The frequency separation between the peaks A and B is approximately resonant frequency divided by the Q of the circuit, which in practice, is 100 or more. If the resonant frequency is 28 MHz, the separation A-B is only 280 kHz or less. You aren't likely to build a double-resonant antenna with an FL and FU average near 28 MHz and a difference between them this small. Therefore, for present purposes the dotted portion is of no interest. We can say that reactance always increases with frequency except for the sudden jump from large positive to large negative values at anti-resonance.

Figure 7C illustrates how the reactance of a center-fed dipole varies with frequency under the hypothesis that it has no losses. (This, of course, is a contradiction because the primary purpose of an antenna is to have losses by radiation.) Qualitatively near the fundamental and odd harmonics, when the length corresponds to odd numbers of half wavelengths, the curve resembles that of a series L-C circuit, while near the even harmonics it resembles that of a parallel one. Losses again restrict the reactance to moderately low values, as with the dotted curve in Figure 7C. You can think of the anti-resonances as dividing the curve into "branches." Within each branch, reactance increases with frequency.

I define resonance as the situation in which

the total reactance at a point is zero; that is, if you cut the antenna at that point, the reactances looking to the left and right are equal but opposite in sign. If they are not naturally equal, you can create resonance by inserting a loading reactor of opposite sign to that of their differences. I assume the axiom that if you establish a state of zero reactance at one point, it is true at all points.

By examining the shape of these curves, you can see why there are four types of situations, and you can see the simple cases when they occur. It is clear from Figure 7C that the reactances at FL and FU may be either positive or negative.

In a situation where XL(1) for FL is negative and XL(2) for FU is positive (which I abbreviate as -+), the loading reactors must be of opposite signs, or +- , which conform with the properties of the parallel L-C circuit (Type 1). In the simplest case, if FH is the frequency of the fundamental, when the antenna is a half-wavelength long, FH must be greater than FL and less than FU.

On the other hand, in the +- case for the antenna, the resonator must have the -+ properties of series L-C circuits (Type 2). Study of Figure 7C reveals that the shortest Type 2 antenna is obtained when the length of the antenna is slightly greater than a half wave, but shorter than a full wavelength for FL and slightly longer than a wavelength for FU.

Consider what happens when the antenna reactances are the same sign at FL and FU, ++

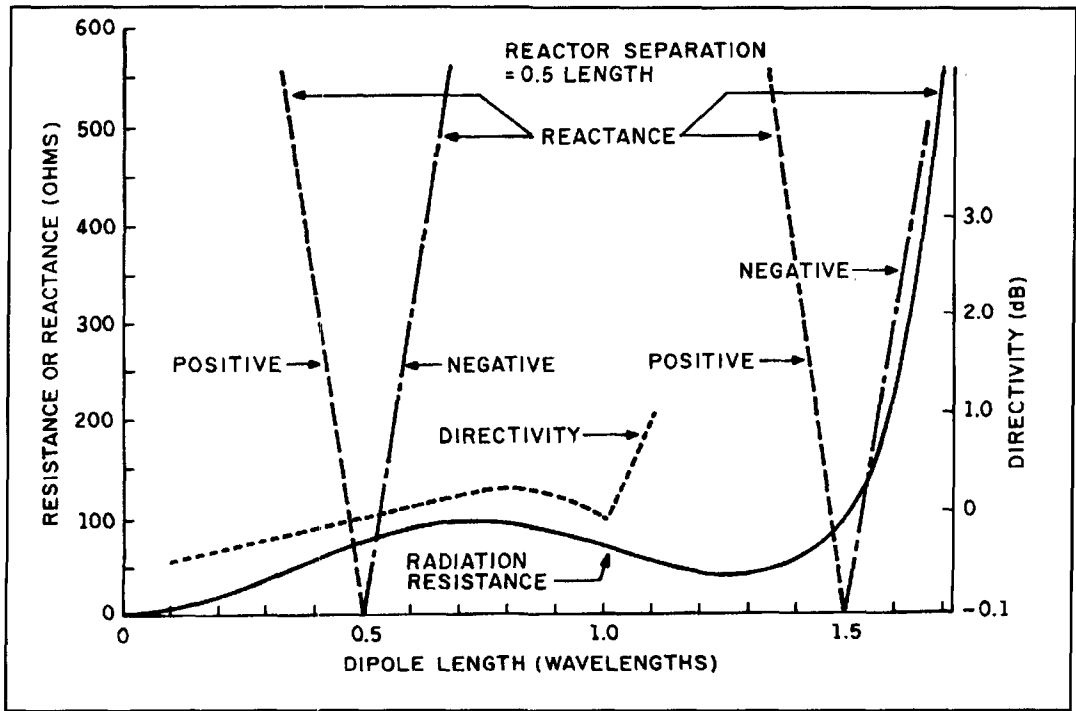


Figure 9. Plot of the properties of a center-loaded dipole with resonating reactors halfway between the center and the ends as a function of length, as calculated by ONETWORES.

or --. If the reactance at FU is larger or less negative, it requires a circuit whose reactance increases with frequency. One half of either **Figure 7 A** or **B** displays such a property. Therefore, either a parallel or a series circuit

can work (Type 3). But the requirement that the reactance of an L-C circuit increase with frequency prevents either one from satisfying the requirements of an antenna that requires a smaller reactance at FU (Type 4).

The shortest antenna with reactances of the same sign is one where FU and FL are both lower than the fundamental resonant frequency FH, whose half wavelength coincides with the length of the antenna. In looking at **Figure 7A**, note that the reactances change from a more negative to a less negative value—requiring a resonator whose reactance decreases from a more positive to a less positive value. However, neither the series nor parallel L-C circuit can satisfy this requirement. Therefore, this is a Type 4 situation.

Another situation that has reactance of the same sign occurs when FL is lower than the fundamental frequency of the antenna, for which it is a half wavelength long and FU is greater than that for which it is a full wavelength long. Whether the situation is Type 3 or Type 4 depends on the numerical values.

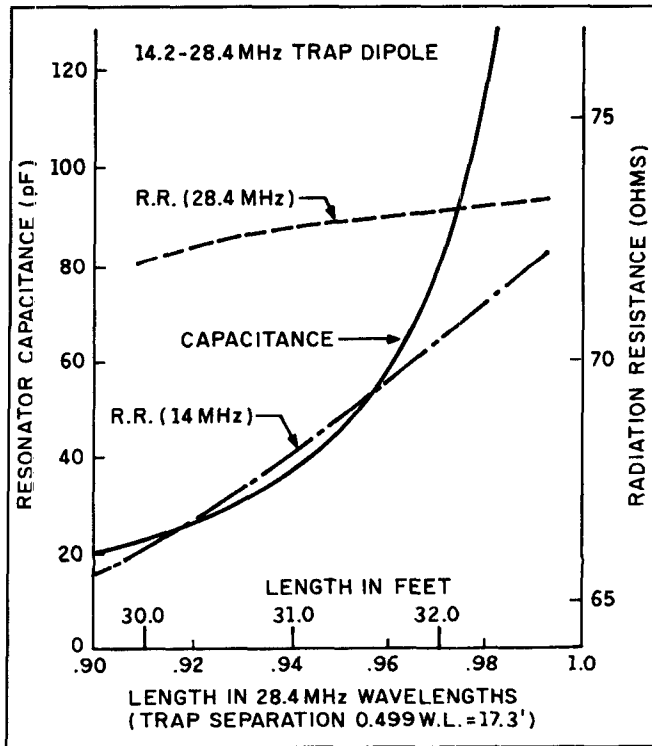


Figure 10. Properties of a 14 to 28-MHz "trap" dipole as a function of length, as calculated by ONETWORES.

## Computer study of single-band dipoles

**Figure 8** is a graph corresponding to **Figure 7C** based upon computer calculations. To improve graphical accuracy I have plotted both negative and positive reactances upward, but

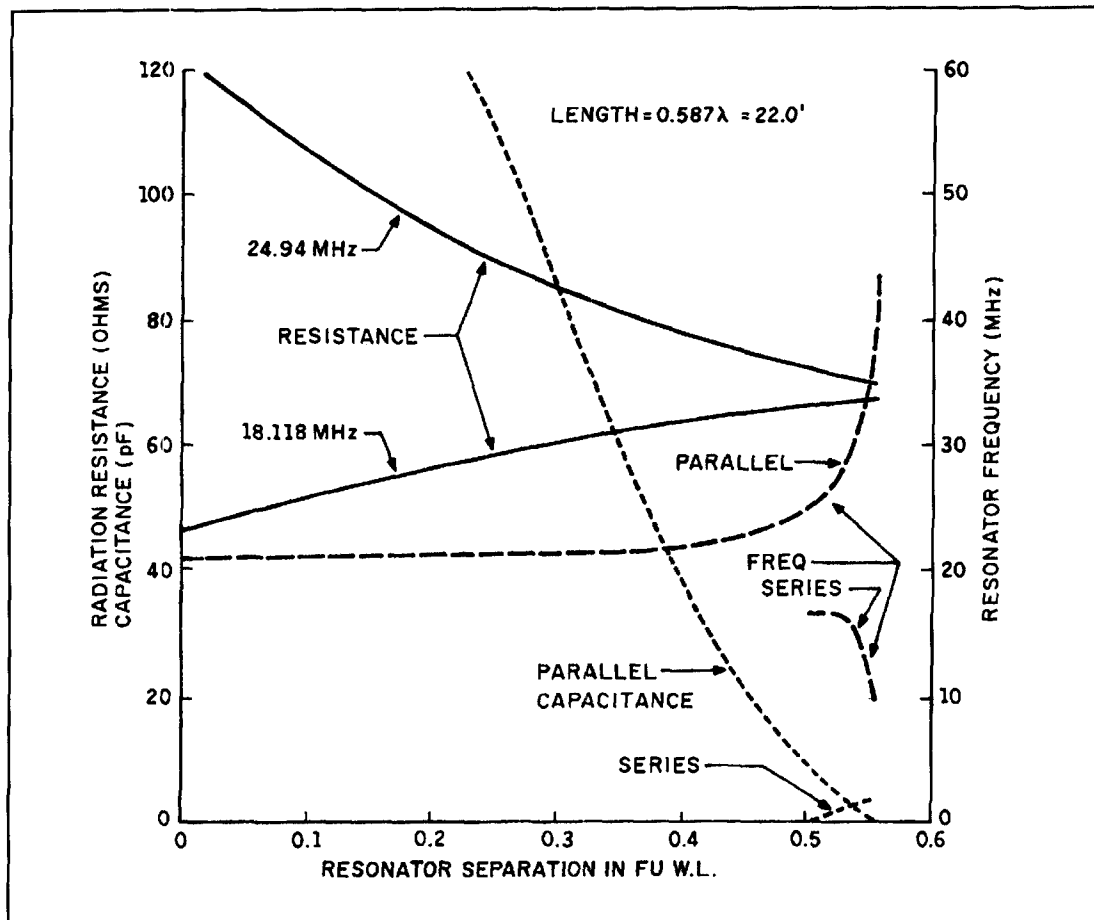


Figure 11. Properties of 18 to 24-MHz antenna A as a function of resonator separation, as calculated by ONETWOES.

have distinguished between them by the type of line. It is assumed that the dipole is in free space. The reactances plotted here are those that must be supplied to either side of the antenna to produce resonance. Therefore, the signs are opposite from those in **Figure 7C**, and the magnitudes are one half the actual antenna reactances. Here the horizontal coordinate represents length rather than frequency.

Also plotted are the radiation resistance and directivity. One check on the accuracy of the program is that the radiation resistances agree with **Reference 8** to the degree of accuracy with which I can read the graph it contains. The radiation resistance for short lengths is approximately proportional to the square of the length. At one half wavelength it is 73 ohms. It rises to high values at one wavelength and then falls, reaching a minimum near 1.5 wavelength. At short lengths, the directivity rises slowly through negative values to 0 dB at a half wavelength, reaching a maximum of 2.65 dB at 1.25 wavelength. The radiation pattern has a maximum at right angles to the antenna up to a length of 1.3 wavelength. Above 1.0 wavelength it has a secondary maximum. Above

1.30 wavelength, the principal maximum starts to split in two. For that reason, I have ended the directivity curve here, although the antenna continues to have a directivity greater than 0 dB.

**Figure 8** represents a special case that occurs when the loading reactors are placed at the center. You can place them at any other place you choose, but the values of the reactances you need are different, and the current distributions are different. Therefore all the other properties change. For example, you can place the loading reactors halfway between the center and the ends. **Figure 9** shows the corresponding graphs. The most dramatic difference from **Figure 8** is the performance near 1.0 wavelength, where the radiation resistance has gone from very high values to low ones. In fact, near 1.0 wavelength one can get a good impedance match to 50 ohms on both frequencies. The gain has dropped to a minimum at 1.0 wavelength. Again, I have stopped the gain curve when the principal maximum ceases to be at 90 degrees to the antenna.

A principle problem in the design of a loaded dipole is finding the reactor positions that provide the best compromise in their properties.



Let's use the computer program ONETWORES to study dual-band antennas, starting with a review of the "trap" antenna.

## Computer study of the "trap" or "classic" antenna

**Figure 10** is a plot of various "trap" antenna quantities for 14.2 to 28.4 MHz as a function of length, as calculated by the computer. The resonators, according to this design, are 0.5 wavelength apart. At FL the resonators don't constitute true short circuits, as is usually assumed, but, with reference to **Figure 7B**, low inductive reactances. Therefore, in accordance with **Figure 7C**, the length must be reduced slightly to compensate. A graph of the computed resonator frequencies would be a horizontal line at very near to 28.4 MHz, as expected. However, as the length changes the necessary L/C ratio changes. The steep slope, near a length of 0.99, implies a condition of instability: a small error in one of the parameters causes a big change in performance. Such a small error might not lie in the design, but be due to some environmental effect like moisture or a change in location. This instability is connected with the fact that if the length exceeds 1.0 by a small amount, the situation becomes a Type 4, and double resonance cannot be obtained. Therefore this situation must be avoided, and in practice the length should not exceed 0.95 FU wavelengths.

In general, the radiation resistances for the two frequencies aren't equal, but as the length approaches 1.0, they both approach 73 ohms—that of a half-wave dipole in free space.

We need a compromise. If the length is close to 1.0, there is an undesirable instability. It becomes difficult to obtain a good impedance match at both frequencies because the radiation resistances become more unequal. More extreme examples of this conflict follow. At any rate, the outer portions of the antenna are not "disconnected" at FU.

## Some design problems

Other computer studies reveal some fundamental design problems. I assume an antenna of the same length as that of A and B. In **Figures 11** and **12**, I show what happens to the properties of the antenna when the positions of the resonators are changed. **Figure 11** refers to antenna A, which is designed for 18.118 to 24.94 MHz, while **Figure 12** refers to antenna B, which is designed for 14.2 to 28.4 MHz.

Looking at **Figure 11** first, with zero resonator separation (that is, with the resonators at the feed point) the radiation resistances at the two frequencies are very different. At the lower

frequency it is not far from 50 ohms, and a good impedance can be obtained; but at the upper frequency, it is so high that the SWR would be greater than 2. As the resonator separation increases, the resistances become more equal and approach the half-wave dipole value of 73 ohms. There can be a fairly good impedance match to 50-ohm coax at both frequencies—a better one to 75-ohm coax.

For spacings up to 0.4 FU wavelengths, the frequency of the resonators remains essentially constant at about 21 MHz, but the L/C ratio increases. When the separation increases beyond 0.4 wavelengths, the resonator frequency rapidly becomes large, implying an unstable situation. For separations between 0.5 and 0.55, the antenna changes from Type 1 to Type 3. In principle, series L-C resonators can be used, but the L/C ratios are so large as to be impractical. Beyond 0.55 wavelengths, the antenna belongs to Type 4, and it is not possible to produce double resonances with either series or parallel L-C circuits.

The qualitative features of **Figure 12** are identical to **Figure 11**, but they differ greatly quantitatively. In particular, the disparity in the radiation resistances is much greater. As I remarked earlier, the L/C ratio is smaller.

The SWR curves in **Figures 1** and **2** are consistent with **Figures 11** and **12**. The minimum SWRs for the upper frequencies are larger than those for the lower frequencies.

These graphs point to an important conclusion: the designer must make a compromise between a low SWR and stability. If he uses a large separation, he obtains a fairly good impedance match but an unstable situation. If he chooses a low separation, he has a stable design but impedance matching problems.

My experience indicates that the need for this compromise generally applies to antennas with other design parameters. However, with antennas E and F the L and C values for series resonators become practical.

## Part III: conclusions

### One or two-band operation?

It is logical to ask how the performance of a dual-band antenna on each band compares with what it would be if it were tuned up as a single-band antenna. On the assumption that in both cases the reactors are so small geometrically that they make no direct contribution to the radiation, the current distributions are the same. Therefore the patterns and the directivities are the same. The additions of other resistances and reactances causes changes in gain through changes in the efficiencies, the SWRs, and the frequency responses. Furthermore, these changes are interdependent. Replacing induc-

tors with ones of lower Q in most cases is likely to widen the frequency response. My policy is to strive for the highest possible efficiencies and to accept whatever SWRs and frequency responses that come with them. I assume Qs of 200 as consistent with these objectives.

It is possible to evaluate the effects of such changes upon the gains by running my computer program for two-frequency antennas and then rerunning it for each single frequency.

**Table 2** lists the results. Except in the case of F there is a small improvement in the antenna when tuned for a single band. In case F, there is a trivial exception. These changes are inversely proportional to the Qs of the resonators.

It isn't possible to give concise answers with regard to the other properties, partly because there is no unique way of specifying bandwidth or what is a good or bad frequency response. It is relevant, however, to compare the SWR curves with what they would be for half-wave dipoles. Many people define the bandwidth as the difference between the two frequencies for which the SWR equals 2. In regards to the half-wave dipoles mentioned earlier, these were about 0.5, 0.7, and 1.1 MHz for 14, 21, and 28 MHz, respectively. Also E-F, when tuned as a

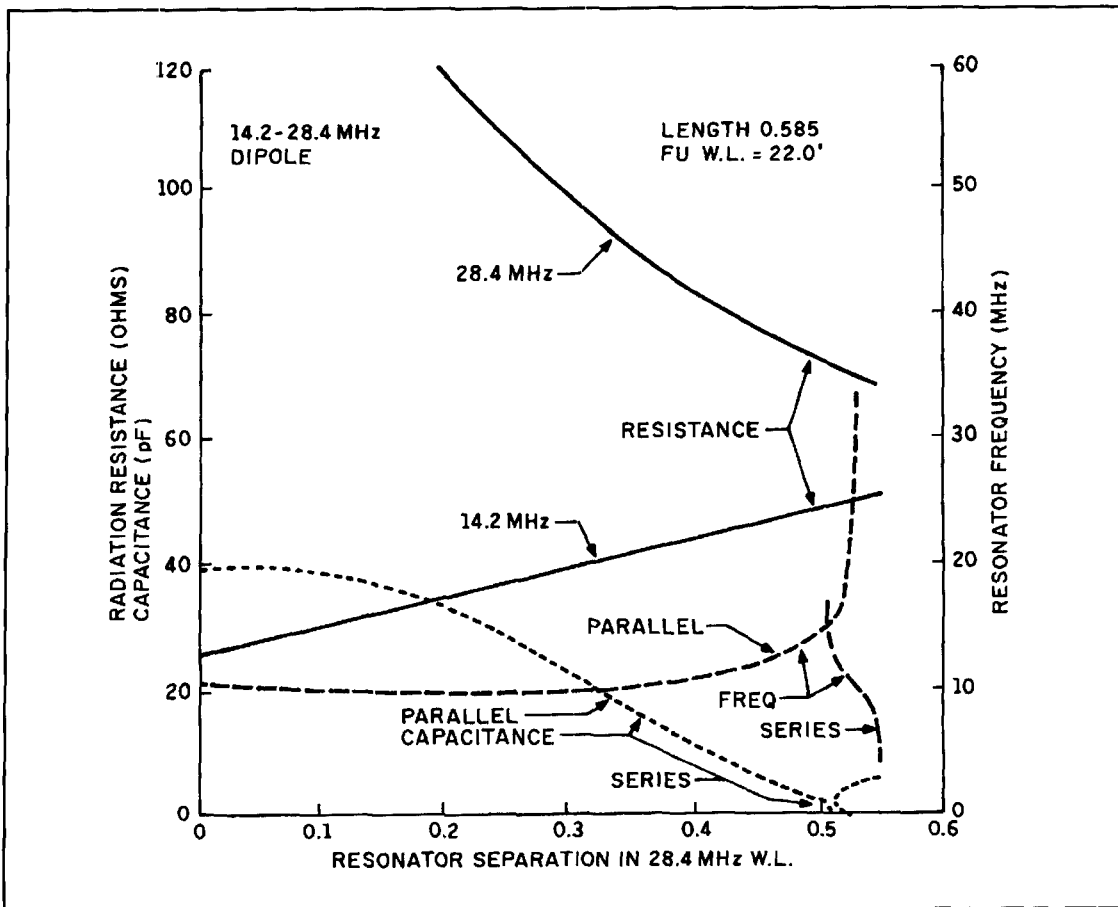
| Antenna | FL       | FU       |
|---------|----------|----------|
| A       | +0.12 dB | +0.17 dB |
| B       | +0.25    | +0.10    |
| C       | +0.02    | +0.22    |
| D       | +0.01    | +0.03    |
| E       | +0.01    | +0.92    |
| F       | +0.21    | -0.06    |

Inductor Q = 200

**Table 2.** Gain in single-band operation.

single-band 28-MHz antenna, had a similar width and minimum SWR.

In **Figure 2** the SWR is higher than 2 at all frequencies in the 28-MHz band, and is barely lower than 2 for only a very small range at 14 MHz. In **Figures 3, 4, 5, and 6** the 14-MHz responses are comparable to those of a half-wave dipole; but those for 28 MHz are generally much poorer—except for **Figure 6**, which is for the Type 3 antenna with the series L-C circuits. Therefore, in general, two-band tuning causes a significant deterioration in the frequency response. **Figure 12** predicts this per-



**Figure 12.** Properties of 14 to 28-MHz antenna B as a function of resonator separation, as calculated by ONETWORES.

formance. From this point of view, it is unfortunate that the amateur community has adopted 50 rather than 75 ohms as its standard for characteristic impedance.

Therefore, two-band tuning generally leads to a deterioration in performance. However, this is usually a small amount—especially when an antenna tuner is used.

## Concluding remarks

In this article I show that there are many antenna designs with resonances at two chosen frequencies—FL and FU. Some are superior at FL, while others are superior at FU. There is a compromise in having a low SWR at both frequencies and having stability; that is, invulnerability to errors, effects of change in location, and effects of rain and ice. It is difficult to get a SWR as low as 1.25 on both bands, however SWRs less than 2 on both are possible. Performance with a SWR of 2 and without the use of an antenna tuner is usually acceptable—especially with short transmission lines. If the user desires optimum performance, he or she should always use an antenna tuner with double-resonant antennas.

The agreement between experiment and ONETWORES has always been qualitatively excellent. The agreement quantitatively has been surprisingly good because of the simplifying assumptions and approximations used in the program. The article describing the program<sup>4</sup> discusses these in detail. Experiment and theory agree very well with regard to reactances, except in the case of antenna F. I am able to determine resistance experimentally only roughly from SWR measurements. With them, the agreement between experiment and theory is fair.

On the basis of my experience with antennas with two resonances, I make the following speculations about those designed for three. I believe that the performance would decline further in gain or bandwidth, or both, by adding a third resonance. It is difficult to believe that very low SWRs can be obtained on all three bands, or if they are, perhaps they are due to the introduction of resistance in low-Q inductors. I believe that the use of an antenna tuner would be even more important.

In principle, I could modify ONETWORES for a third resonance, but I have no plans to do so because of the expected complications. In this article, I show that there are four types of antenna situations, and that there are times when series L-C resonators can or must be used instead of parallel ones. The analogous situation in designs for three resonances appears formidable as there are many more alternatives. As far as I know, no one has explored the pos-

sibility of having one or two of the resonators be of the series L-C type.

## REFERENCES

1. Charles L. Buchanan, W3DZZ, "Duo Band Antenna," *Radio and Television News*, December 1950, page 66.
2. Charles L. Buchanan, W3DZZ, "The Multimatch Antenna System," *QST*, March 1955, page 22.
3. Yardley Beers, W0JF, "Designing Trap Antennas: a New Approach," *Ham Radio*, August 1987, page 60.
4. Yardley Beers, W0JF, "ONETWORES: A C-64 Program for the Analysis of Single and Double-Resonant Dipoles," *Communications Quarterly*, Spring 1993, page 91.
5. Yardley Beers, W0JF, "The 5/4 Wavelength Dipole: A Revival," *Communications Quarterly*, Fall 1990, page 40.
6. John J. Reh, K7GKP, "Simple 5/8 Verticals for 12 and 17 Meters," *QST*, April 1989, page 19 and August 1989, page 41 ("Feedback").
7. Paul D. Carr, N4PC, "Two Bands, No Coil Switching," *QST*, October 1989, page 37, ("Technical Correspondence").
8. L.A. Moxon, G6XN, *HF Antennas for All Locations*, Radio Society of Great Britain, London, 1982, **Figure 4-40**, page 61.

## Addendum: Antenna G, with four-band capability

After the main manuscript of this article entered editorial production, I built a seventh antenna, antenna G, mainly for portable use. I assume that easy access will make small changes possible. Basically, I designed it for double resonance at 14.15 and 21.2 MHz. The total length  $LE = 25.8$  feet is a half wavelength for 18.2 MHz. It is also possible to obtain operation on that band by short-circuiting the parallel L-C resonators with jumpers each having one end soldered to the antenna and the other equipped with a clip. The separation between the resonators  $LL = 16.5$  feet is equal to the length of a half-wavelength dipole for 28.4 MHz. It is possible to obtain operation on that band by disconnecting the resonators and the outer portions. I need not say anything more about the half-wavelength operations.

For double resonance the calculated required reactances are +491 and -450 ohms, which can be supplied by resonators with resonant frequencies  $F_0 = 16.6$  MHz and capacitances  $C = 48.5$  pF. Experimentally,  $F_0 = 17.3$  MHz and  $C = 44.7$ , produced by capacitors with nominal values of 50 pF and 270 pF connected in series. The inductors have 9 turns of plastic no. 18 wire closely wound on 1-inch diameter forms which serve as compression-type insulators.

The SWR = 1.9 at 14.0 MHz, drops to a minimum of 1.25 at 14.2 MHz, and rises to 1.6 at 14.35 MHz. The minimum SWR corresponds to a total resistance of 60 ohms, to be compared to 63 by calculation. The calculated gain is -0.69 dB.

At 21.0, the SWR has a minimum of 1.25 and rises to 1.65 at 21.45 MHz. The resistances are 63 ohms from the minimum SWR and 82 ohms by calculation. The calculated gain is -0.09 dB.

# SIMPLE VERY LOW FREQUENCY (VLF) RECEIVERS

## *Notes on design and construction*

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**T**he very low frequencies (VLF) are located between a few kilohertz up to around 300 kHz, depending upon whose designation system is used. For purposes of this article, VLF represents the 5 to 100 kHz region. The reason for this seemingly arbitrary designation is that many ham band and SWL communications receivers operate down to 100 kHz, and only a few operate below that limit.

There's quite a lot of radio activity in the region below 100 kHz. Perhaps the best known station is WWVB on 60 kHz. This station is operated from Colorado by the National Institutes for Standards and Technology (NIST).<sup>\*</sup> WWVB is a very accurate time and frequency station, and for many purposes is preferred over the high frequency WWV and WWVH transmissions. The United States Navy operates submarine communications stations in the VLF region: NSS on 21.4 kHz from Annapolis, Maryland (400 kW), and NAA on 24 kHz from Cutler, Maine (1,000 kW) are two commonly heard. There are also Omega Navigational System stations in the 10 to 14 kHz range. Principal frequencies are 10.2, 11.05, 11.33 and 13.6 kHz. Other stations, in both the United States and abroad, are found throughout the VLF region.

But DXing in the VLF band isn't all that easy. Besides the fact that propagation doesn't support "skip" the way the 20-meter ham band does, huge noise signals are found in the VLF region. Two sources seem to predominate.

First, 60-Hz power lines are terrible offenders. While it may seem counterintuitive that a 60-Hz signal could be of much concern at, say, 30 kHz, it is nonetheless a fact. High harmonics are present because the alternating current from the power lines isn't pure; consequently, it contains harmonics. Also, the large amount of power carried by normal residential power lines makes even the higher harmonics strong enough to interfere with sensitive receivers.

The second form of interference comes from neighborhood television sets. The horizontal oscillator in a TV receiver operates at 15.734 kHz, and is a pulse. For this reason, harmonics from television sets are found up and down the VLF spectrum. Furthermore, the TV horizontal pulse produces its own "sidebands," so each harmonic actually wipes out a lot of spectrum space on either side of the integer multiple of 15.734 kHz. Listening to VLF allows one to identify the evenings when a popular TV show is on the air. As a result of TV interference, it's common to find VLFers listening during daylight hours and during the period between 2330 and daybreak.

Amateur scientists use VLF receivers in two different types of activity. Some monitor solar activity that affects radio propagation. Sudden Ionospheric Disturbances (SIDs) can be detected by sudden increases in VLF signal levels.<sup>1,2</sup> SID monitoring activity takes place in the 20 to 30 kHz region, although some articles cite activity as high as 60 kHz WWVB.

The other VLF amateur science activity involves looking for naturally created radio signals called "whistlers." These signals are

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<sup>\*</sup>Formerly the National Bureau of Standards (NBS).

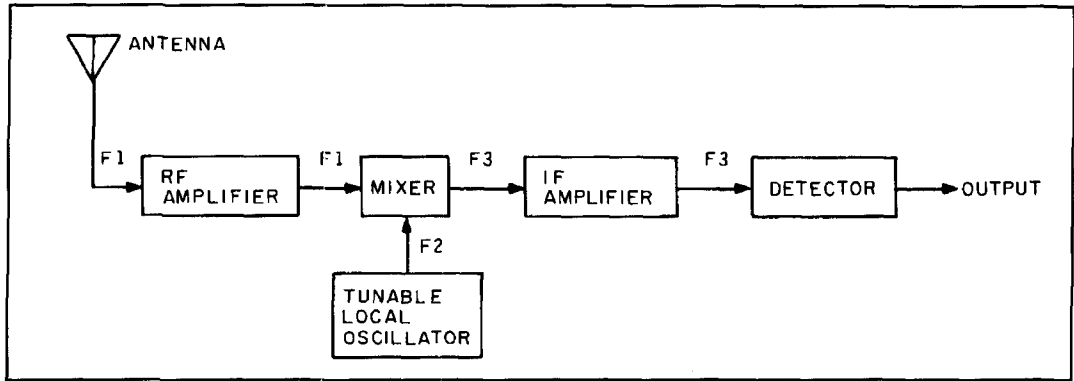


Figure 1. Block diagram of the superheterodyne receiver.

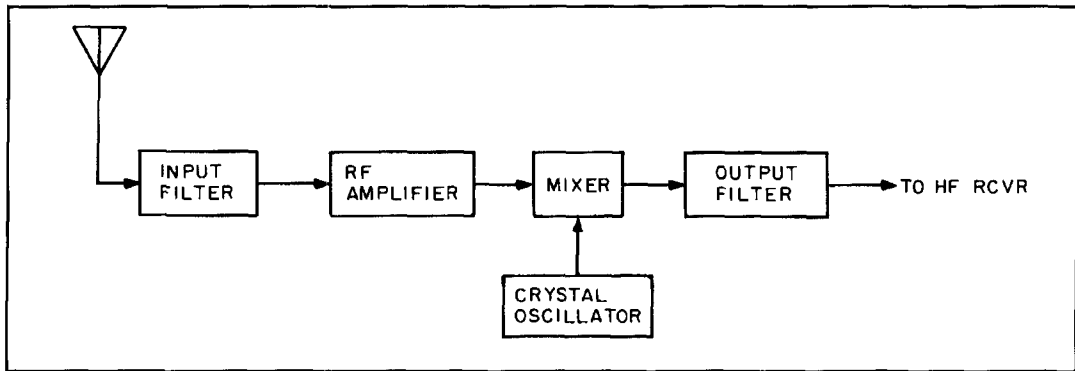


Figure 2. Block diagram of a VLF-to-HF converter.

believed to be created by lightning storms, and are propagated at long distances. They occur in the 1 to 10 kHz region.<sup>3,4</sup> At least one project under NASA sponsorship engaged amateurs to look at whistlers.<sup>5</sup>

### Types of receiver

Virtually all common forms of receiver are used in VLF receiver designs, except possibly

the crystal set. In this article, I'll consider the *superheterodyne*, the *direct conversion*, the *tuned radio frequency*, and the *tuned input gain block* methods. I'll also examine the use of a *converter* to translate the VLF bands to the HF bands, so an ordinary ham band or SWL receiver can be used.

**Superheterodyne receivers.** The "superhet" (Figure 1) is the basic receiver design used in communications and broadcast receivers. It

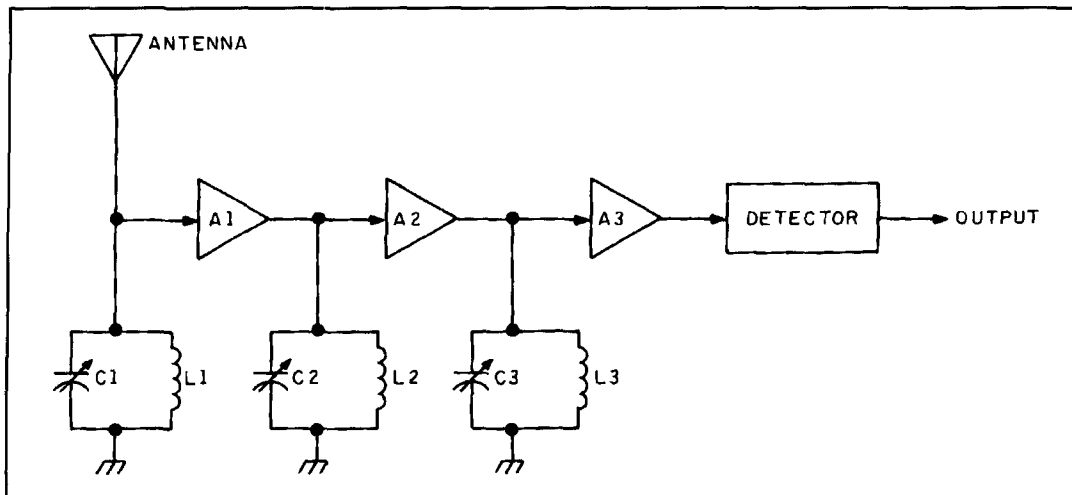


Figure 3. Block diagram of a TRF receiver.

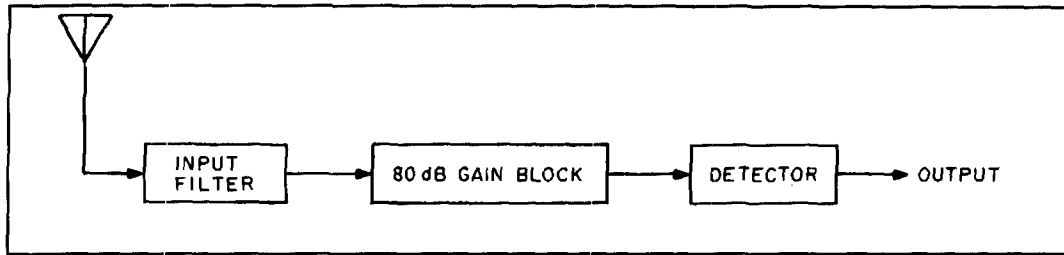


Figure 4. Block diagram of a tuned gain block receiver.

dates from the 1920s, and is the most successful form of receiver design. In the superhet receiver, the incoming RF signal (at frequency  $F_1$ ) is filtered by a tuned RF resonant circuit or a bandpass filter, and then applied to a mixer circuit. In most cases, the RF signal is amplified in an RF amplifier (as shown in **Figure 1**), but that isn't a requirement. The mixer nonlinearly combines  $F_1$  with the signal from a local oscillator (at frequency  $F_2$ ), to produce an output spectrum of  $F_3 = mF_1 \pm nF_2$ . In our simplified case,  $m = n = 1$ , so the output will consist of the two original signals ( $F_1$ ,  $F_2$ ), the sum signal ( $F_1 + F_2$ ) and the difference signal ( $F_1 - F_2$ ). A filter at the output of the mixer selects either sum or difference signal as  $F_3$ ; this is called the intermediate frequency (IF). Most of the receiver's gain and selectivity are provided in the IF amplifier. The output of the IF amplifier is fed to a detector that will demodulate the type of signal being received. A simple envelope detector is used for an AM signal, while a product detector is used for CW and SSB.

Only the difference signal was used for the IF frequency in older radios, but modern receivers use either the sum or the difference. In a VLF receiver, it's possible to use a 10 to 100 kHz RF range, a local oscillator range of 465 to 555 kHz, to produce an IF of 455 kHz (one of the common "traditional" frequencies).

**Converters.** The converter is a subclass of superheterodyne receivers (**Figure 2**) in which the VLF band is frequency translated to the high frequency (HF) bands. The typical converter circuit is rather simple. An input filter (either bandpass or tuned to a specific frequency) feeds an optional RF amplifier, and then a mixer. A fixed-frequency crystal oscillator mixes with the RF signal to produce an output on an IF that's in the ham band, or some other shortwave band. For example, to receive 10 to 100 kHz, the input filter (**Figure 2**) could be a bandpass filter with  $-3$  dB points at 10 and 100 kHz. The local oscillator could be a 3,600-kHz crystal oscillator. The output filter is a 3,610 to 3,710-kHz bandpass filter, the output of which is fed to an 80-meter ham band receiver. It's necessary to reduce the feedthrough of the 3,600-kHz crystal oscillator signal to the

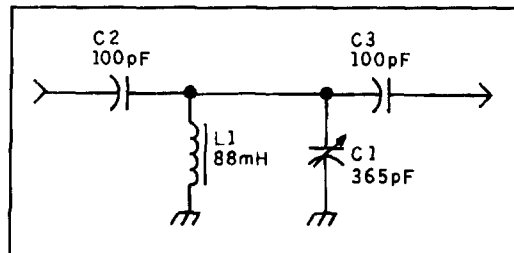


Figure 5. Tuned circuit for the Stokes TRF receiver.

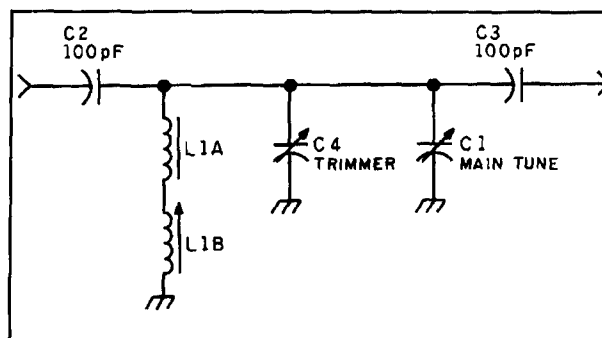


Figure 6. Modified version of *Figure 5* that allows alignment of both L and C.

receiver. A combination of a double-balanced mixer and proper mixer termination will generally do the trick.

**Tuned Radio Frequency (TRF) receivers.** The TRF receiver (**Figure 3**) uses a cascade chain of tuned RF amplifiers (A1, A2, and A3) to amplify the radio signal. The TRF was the first really sensitive design developed in the early 1920s, and was eclipsed by the superhet in popular commercial receivers. However the TRF is still popular in the VLF range, especially among homebrewers. Unfortunately, the TRF receiver can exhibit the unwanted oscillations common in tuned triode devices like NPN bipolar transistors.

Peter Taylor's column in the Spring 1993 *Communications Quarterly* gave details of a 20 to 30 kHz TRF receiver for SID monitoring designed by Art Stokes.<sup>2</sup> A design improvement is presented below.

**Tuned Gain Block Receivers (TGB).** The

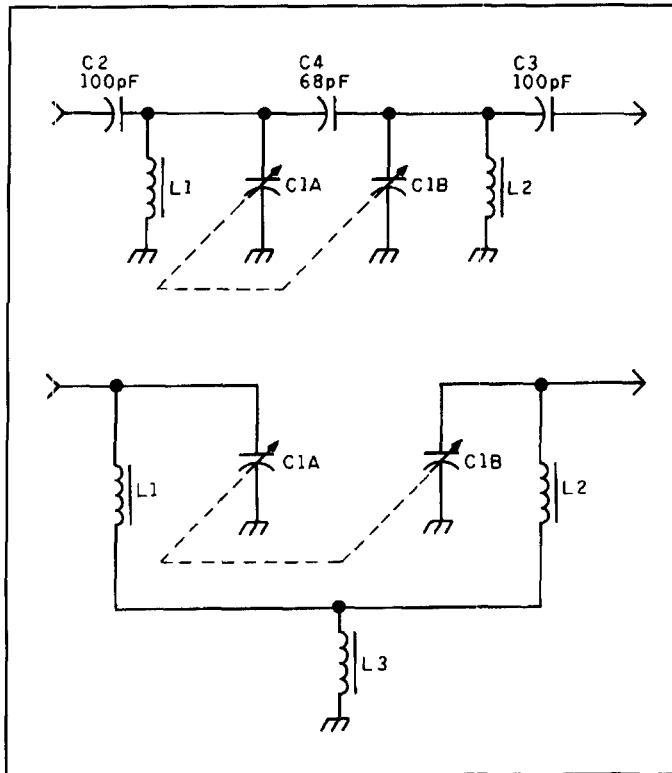


Figure 7. Common reactance dual-tuned circuits: (A) common capacitor, (B) common inductor.

TGB receiver (Figure 4) is basically a variation of the TRF receiver with all the tuning circuits up front, ahead of the gain. This provides two benefits. First, the oscillation problem of conventional TRF receivers is avoided because the gain block is untuned. Second, location of the tuning up front eradicates much of the unwanted noise before it's amplified. This argument was the basis for high-grade receivers of the 1960s such as the Squires-Sanders. Art Stokes'

\*\*See Peter O. Taylor, "The Solar Spectrum," *Communications Quarterly*, Summer 1993, on page 86.

design was based on this concept.<sup>1</sup> I prepared a printed circuit layout for this receiver, and provided it to Peter Taylor and Art Stokes for publication in *Communications Quarterly*.\*

## Tuning circuit problems

The tuning circuits present the principal problem when designing and building VLF receivers. The capacitance and inductance values tend to be rather large. If you wish to use a standard "broadcast variable" capacitor, which is typically 10 to 365 pF in capacitance value, then a 20 to 30 kHz receiver needs an inductor in the 88 mH range. If you actually measure the capacitance needed to resonate a typical 88 mH coil at 20 to 30 kHz, the result can be 160 to 200 pF less than calculated. A smaller variable capacitance is used because the distributed capacitance of large coils, such as 88 mH, is typically quite large.

The Stokes TGB receiver (1991 design) used a tuned circuit like that shown in Figure 5. The circuit originally included a J.W. Miller 6319 inductor, but apparently these are no longer available. The 1993 TRF design used 88 mH "telephone" toroid inductors. The TRF circuit (Figure 5) used the 88-mH inductor paralleled by a 365-pF variable capacitor, and isolated for DC by a pair of 100-pF capacitors (C2 and C3 in Figure 5).

Unfortunately, the tuning range of the simple circuit in Figure 5 isn't easy to adjust; i.e., the receiver cannot be aligned. A variation on the theme, shown in Figure 6, adds a small variable "trimmer" capacitor (C4) shunted across the main tuning capacitor (C1), and a trimmer inductor (L1B) in series with the main fixed inductor (L1A). It would be nice to obtain a single inductor with the tuning range, but they are hard to find these days. As shown, the circuit can be adjusted over about 10 percent of the inductance range. In one version, a 100-mH

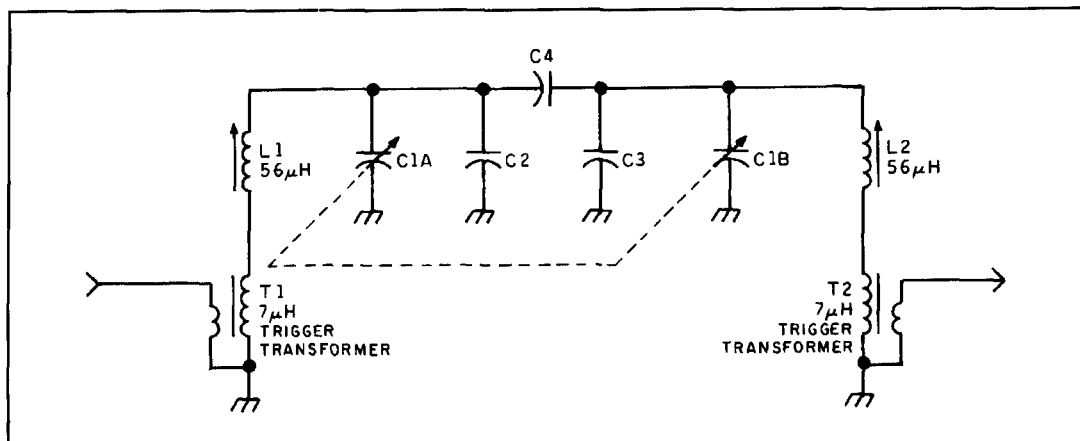


Figure 8. Use of xenon flash tube "trigger transformers" to provide low impedance input and output coupling.

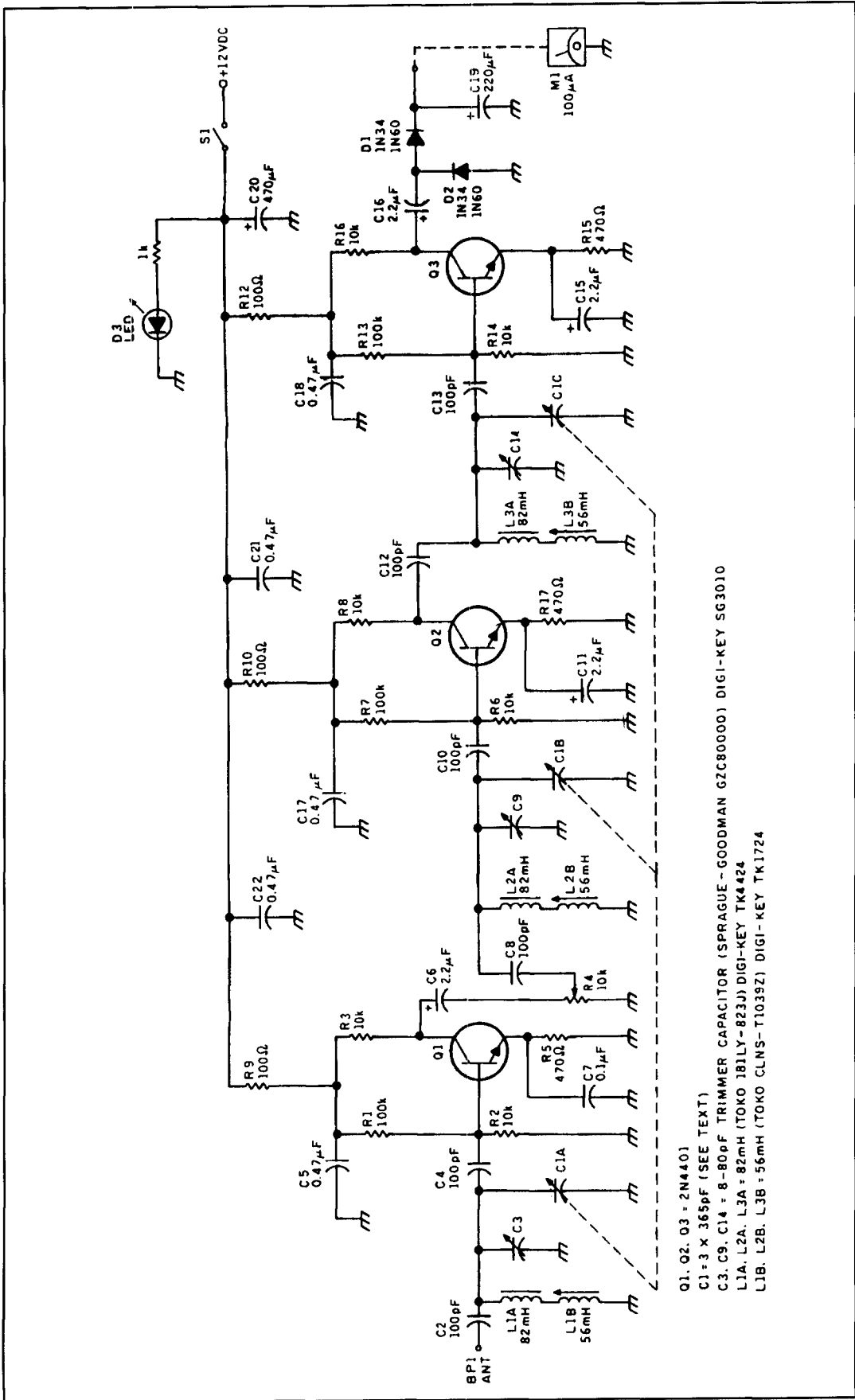


Figure 9. Circuit for a modified Stokes TRF receiver.



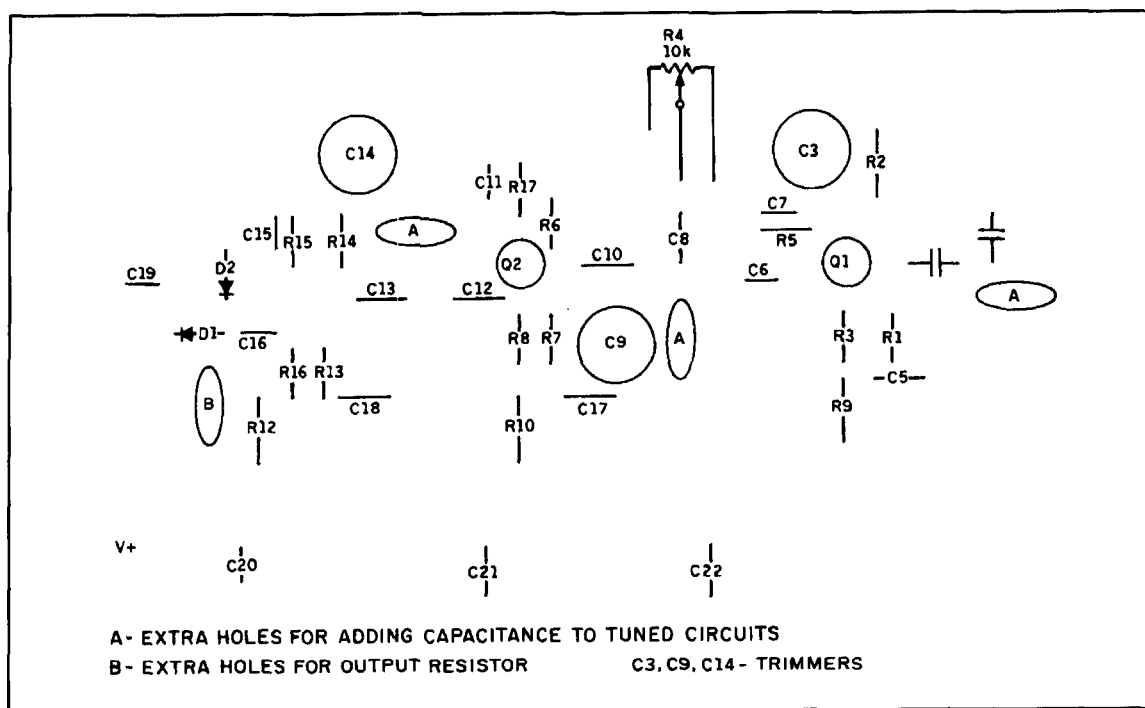
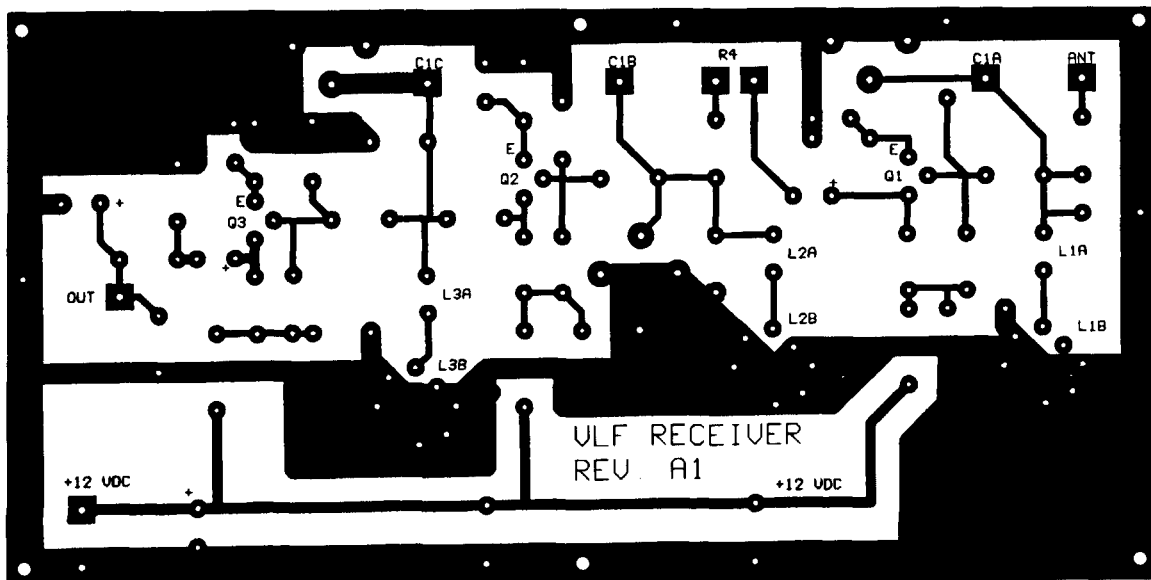


Figure 10. (A) Printed circuit pattern; (B) components layout.

fixed inductor was connected in series with a 56-mH variable inductor.

With the TGB design, all the tuning is done ahead of the gain block. This poses certain problems for the tuning circuit—especially if more than one tuned L-C circuit is desired for selectivity purposes. Figure 7 shows two methods for combining L-C tuned circuits; both of them fall into the “mutual reactance” method, but with different approaches. The version in Figure 7A uses a small capacitance (33 to 120 pF) to couple the two L-C resonant circuits (L1/C1A and L2/C1B). In Figure 7B, a com-

mon inductor (L3) is used for the same purpose. Experiments show that a value of 150 to 700  $\mu$ H is needed for L3. *The ARRL Handbook for Radio Amateurs* (all recent editions) provides details on selecting values for the components in these circuits.

Figure 8 shows a different approach to the design of receiver front-ends. One of the problems in VLF receiver design is providing low impedance link coupling into and out of the L-C tank circuit. Large inductance coils aren't often available with low impedance transformer windings. For example, in the Digi-Key cata-

log, the largest coil with such a winding is a 220- $\mu$ H unit intended for the AM broadcast band. I found a solution in the series inductor method detailed above (**Figure 6**). In this case, however, I connected a 56-mH variable inductor in series with a xenon flash tube trigger transformer. These are T1 and T2 in **Figure 8**. The version selected was intended to fire a 6,000-volt fast rise time pulse into a xenon flash tube, and has a nominal inductance of 6.96 mH  $\pm$  20 percent.\* The measured inductance was 7.1 mH, and the self-resonance frequency was 140 kHz. Without the trimmer capacitors, the tuning range was 30 to 60 kHz when a 2 x 380 pF variable capacitor was used. The addition of a 600-pF trimmer across each section of the main tuning capacitor reduced the tuning range to 20 to 30 kHz.

The trigger transformers are widely available from mail order sources. I ordered several from an English company: Maplin Electronics (P.O. Box 3, Rayleigh, Essex, SS6 8LR, England). They have variable capacitors, coil forms, and a number of other things of interest to amateur radio constructors. United States credit cards accepted include Visa and American Express, and the currency exchange is automatic.

Another alternative, although I've not tested it, is to use pulse transformers. Unfortunately, these transformers typically have limited turns ratios (2:1:1).

## A VLF receiver project

After reading Peter Taylor's column in the Spring 1993 issue of *Communications Quarterly*,<sup>2</sup> I decided to build the modified Art Stokes TRF SID monitoring receiver. It uses three NPN bipolar transistor RF amplifier stages in cascade. The version shown in the article required a different tuning shaft for each tuning capacitor, but I wanted a single shaft tuning system. I also added a small amount of decoupling isolation between each stage.

The circuit for the modified receiver is shown in **Figure 9**. It uses the same basic circuit as the Stokes design, with the modified tuning circuits discussed above. The 82-mH fixed inductors (L1A, L2A and L3A) are the Toko 181LY-823J, available from Digi-Key (P.O. Box 677, Thief River Falls, MN, 56701-0677; 1-800-344-4539) under catalog number TK-4424. The 56-mH variable inductors are Toko CLNS-T1039Z, available under Digi-Key number TK-1724. An additional degree of adjustment is provided by using an 8 to 80-pF trimmer capacitor across each section of the 3 x 365 pF variable main tuning capacitor. These capacitors are Sprague-Goodman GZC8000 units (Digi-Key SG3010).

The output circuit for this receiver reflects the

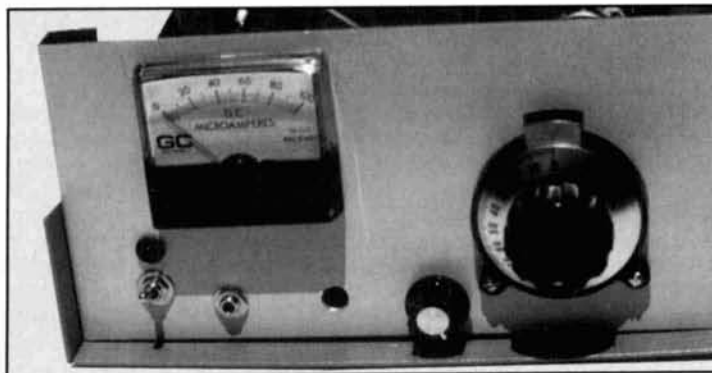


Photo A. Front panel of finished receiver.

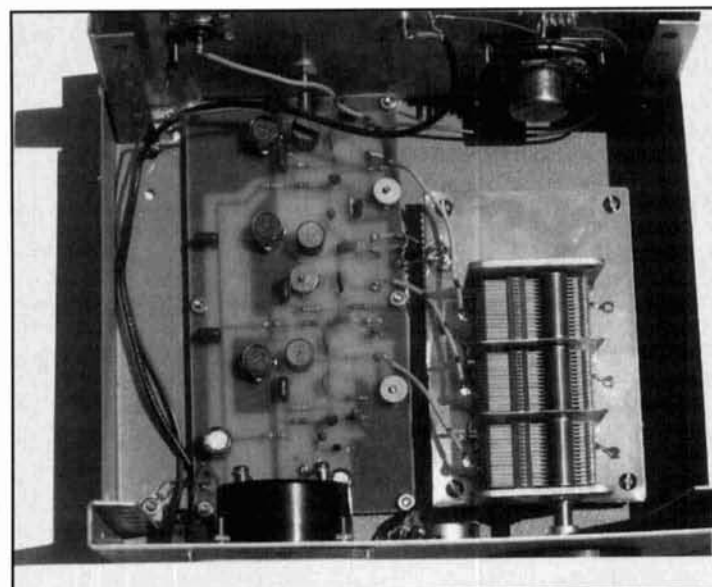


Photo B. Interior view of finished receiver.

fact that it's a SID monitor receiver. The detector is a voltage doubler (D1/D2) made from germanium diodes. The 1N34 diodes were specified originally, but 1N60 also work well. If you can't find these diodes (Radio Shack and Jim-Pak sells them), try using replacements from the "universal" service shop replacement lines like SK, NTE and ECG. The NTE-109 and ECG-109 will work. The output of the detector is heavily integrated by a 470- $\mu$ F electrolytic capacitor. The output as shown is designed to feed a current-input recorder or a microammeter. If a voltage output is desired, connect a resistor (3.3 to 10 k) across capacitor C19.

**Figure 10A** shows a printed circuit board for use with this circuit; **Figure 10B** is the components placement "road map." The board is laid out for the specific components described

\*It escapes me why the manufacturer of a 20 percent tolerance coil lists the inductance to two decimal places.

above, and shown in **Figure 9**. Variations on the theme can be accommodated by using different value inductors from the same Toko series (see Digi-key catalog). The L1 series coils are Toko size 10RB, while the L2 series of coils are size 10PA. Also, if you don't want to use two coils in each tuning circuit, short out the holes for L1 positions and use a coil with the required inductance in the L2 positions.

The final receiver is shown in **Photos A** and **B**. **Photo A** is a front panel view; **Photo B** is an internal view. The tuning capacitor was a three section model purchased from Antique Electronic Supply, Tempe, Arizona. Although I first thought it was a 3 x 365 pF unit, but it measured at 550 pF (which is better for VLF, anyway). A 2-inch vernier dial (Ocean State Electronics, POB 1458, Westerly, RI, 02891; 1-800-866-6626) was used to drive the variable capacitor (note: Ocean State also sells multi-

section variable capacitors). The final receiver tuned from 16.5 to 31 kHz.

Available from the author

The printed circuit board in **Figure 10A** is available from the author. Contact him at P.O. Box 1099, Falls Church, Virginia, 22041 for price and shipping information.

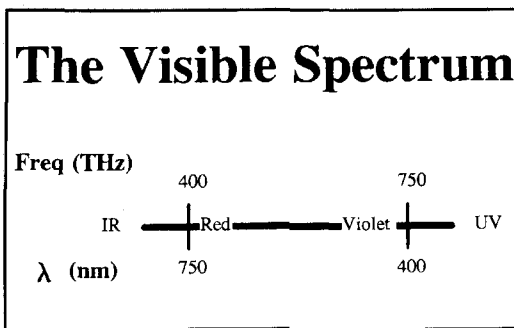
REFERENCES

1. Peter O. Taylor and Arthur Stokes, N8BN, "Recording Solar Flares Indirectly," *Communications Quarterly*, Summer 1991, page 29.
2. Peter Taylor, "The Solar Spectrum: Update on the VLF Receiver," *Communications Quarterly*, Spring 1993, page 51.
3. Michael Mideke, "Listening to Nature's Radio," *Science Probe*, July 1992, page 87.
4. Gary Eggleston, "The Sky Chorus," *Popular Electronics*, July 1993, page 46.
5. Bill Pine, "High School Support for Space Physics Research." Unpublished paper sent to participants in Project INSPIRE.

## Corrections

### The missing figure

In our Winter 1993 issue, we published a letter by Dr. H. Paul Shuch, N6TX, ("Letters," page 106) commenting on "A User's View of Charge Coupled Device Imaging," by Brian Mork, KA9SNF, (Spring 1992). Unfortunately, in addition to misspelling his name (Schuch instead of Shuch), we forgot to include the figure he submitted to accompany his letter. The figure appears here for those of you who are interested. **Ed.**



### A few glitches

A few glitches managed to work their way into Rich Erlichman's article "The Excalibur DAP and the Digital Data System" (Summer 1993, page 43).

On page 45, under the definition of out-of-service signal, N00X0V should read N00BX0V.

In the reference section **Reference 4** (page

48) should read "Switched 56 KB/S Data Service Unit."

And finally, my source for the Editor's note on page 44 was incorrect. AT&T does not call subrate data multiplexing "fractional T1." I apologize for the error. **Ed.**

### Is half a figure better than none?

In the article "Receiver Performance," by Jon Dyer, G4OBU, which ran on page 73 of our Summer 1993 issue, only half of **Figure 3** appeared. Here's the other half of the figure; you'll find the original on page 77 of the article. **Ed.**

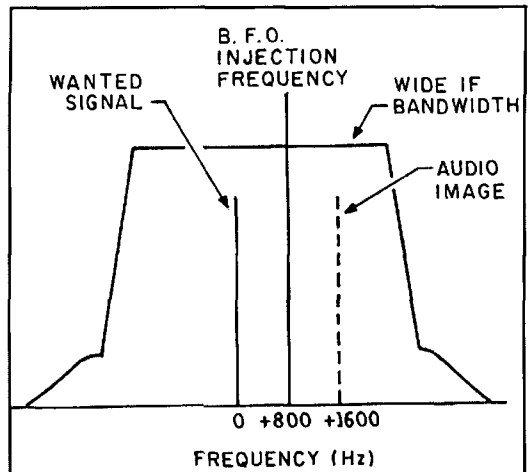


Figure 3

# QUARTERLY DEVICES

## *The NE577 compandor*

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Companing isn't a new idea, but a quick survey of recent journals suggests compandor chips have yet to find wide use in noncellular FM or HF-SSB designs. Despite this, most transceivers in use today use signal compression circuits of various types to improve intelligibility and control gain (ALC, AGC, RF processors, speech clippers, limiters, etc). The compressor portion of the compandor chip, which offers significant advantages over simpler compression circuits, could very well find wider use in this kind of equipment.

Additionally, the dynamic expander portion of the compandor chip might find application in SSB service where speech processing levels of 15–20 dB are common.

The word compandor is an amalgam of the two words "compressor" and "expander." The compression side of the compandor chip squeezes audio signals with large level variations (or wide dynamic range) into signals with proportionally smaller level variations (or narrow dynamic range). Audio compressed in this manner is less subject to noise contamination when transmitted over landline or radio circuits—or when stored on magnetic tape. When the signals are recovered, the expander side of the compandor chip performs the exact opposite function—proportionally expanding signals with small differences in level, so they sound natural once again.

### The NE577

Although compandor chips have been around for a long time, the Signetics NE577 is relatively new and provides some especially attractive features for project designers. First of all, it's a simple chip to use—with more onboard support circuitry than earlier offerings. This translates into designs with low part counts and small pc area. And, unlike serially programmable compandors that require microprocessor input, you

can program the NE577 to your precise specifications with a few resistors and a couple of capacitors.

The NE577 is also attractive to designers because it requires very little power operate, drawing only 1 to 2 mA over its 2 to 7 volt operating range. This feature is especially useful when designing battery-operated portable gear or battery-powered accessories for existing equipment. Specifications and pinout for the NE577 are shown in **Figure 1**.

### Essential homework

If you've never worked with these devices before, it will pay to review some compandor basics before you begin. For openers, I recommend obtaining a copy of Philips Semiconductors application note AN1762. This document provides a practical step-by-step procedure for programming the NE577 to meet your exact application. Calculating the resistor values you'll need for a custom solution is a relatively painless process involving high-school level math. A chart of standard values is also provided for cook-book solutions.

AN1762 also explains how to enable various options on the NE577 and on the somewhat more sophisticated NE578—and it presents a feature-by-feature comparison of all compandors in the Philips Semiconductors line. To get AN1762, request the *RF Communications Data Handbook* from your Philips Semiconductors distributor, or send an SASE to *Communications Quarterly*, P.O. Box 465, Barrington, NH 03825-0465 for a copy of the application note.

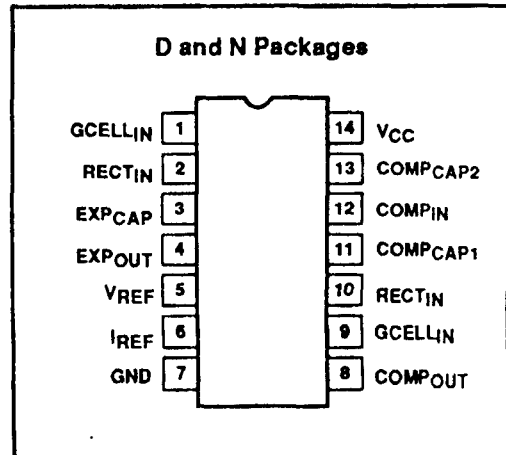
### Programming the NE577

The NE577 is a unity-gain device with a user-programmable output level. When you

## FEATURES

- Operating voltage range: 1.8V to 7V
- Low power consumption (1.4mA @ 3.6V)
- 0dB level programmable (10mV<sub>RMS</sub> to 1.0V<sub>RMS</sub>)
- Over 90dB of dynamic range
- Wide input/output swing capability (rail-to-rail)
- Low external component count
- SA577 meets cellular radio specifications
- ESD hardened

## PIN CONFIGURATION



## ORDERING INFORMATION

| DESCRIPTION        | TEMPERATURE RANGE | ORDER CODE |
|--------------------|-------------------|------------|
| 14-Pin Plastic DIP | 0 to +70°C        | NE577N     |
| 14-Pin Plastic SO  | 0 to +70°C        | NE577D     |
| 14-Pin Plastic DIP | -40 to +85°C      | SA577N     |
| 14-Pin Plastic SO  | -40 to +85°C      | SA577D     |

## ABSOLUTE MAXIMUM RATINGS

| SYMBOL           | PARAMETER                           | RATING      |             | UNITS |
|------------------|-------------------------------------|-------------|-------------|-------|
|                  |                                     | NE577       | SA577       |       |
| V <sub>CC</sub>  | Supply voltage                      | 8           | 8           | V     |
| T <sub>A</sub>   | Operating ambient temperature range | 0 to +70    | -40 to +85  | °C    |
| T <sub>STG</sub> | Storage temperature range           | -65 to +150 | -65 to +150 | °C    |
| θ <sub>JA</sub>  | Thermal impedance                   | DIP         | 90          | °C/W  |
|                  |                                     | SO          | 125         | °C/W  |

Figure 1. Data sheet—Philips Semiconductors NE577 compandor.

design your circuit, you'll essentially tell the chip what output level you want. Once this is done, the NE577 will either amplify or *attenuate* incoming signals to the level you've set. This "start-in-the-middle" approach to setting levels may require some realignment in thinking for those of us who view gain controls as simple voltage dividers. The dividing line between where the chip amplifies and where it attenuates is called its crossover point (see **Figure 2**). Incoming signals with an amplitude above the chip's crossover point will be attenuated.

Incoming signals with an amplitude below the crossover point will be amplified. Because the compandor is a unity-gain device, the crossover point for incoming signals corresponds with the 0-dB point for outgoing signals.

To take advantage of the NE577's full dynamic range, you'll want to program its 0-dB output level somewhere near your average input signal level. If you don't do this, the NE577 will function primarily as an amplifier (or attenuator), and you'll miss out on a portion of its full dynamic capability. In a typical appli-

cation (100 mV RMS = 0 dB), you can anticipate a usable input range of -34 dB to +20 dB. However, this will vary from application to application—depending on available Vcc and the reference current level (I-ref) you program into the device via resistor R2.

The exact 0-dB point for the NE577 compressor function is programmed via resistors R2 and R3 (see **Figures 3 and 4**). You can set this point anywhere from below 10 mV to over 1 volt RMS using the formulas provided in AN1762. Or, if you favor a cookbook approach, you can use typical values shown in **Table 1**. For precise applications, Philips Semiconductors recommends using 1-percent resistor values. However, you may also use two or more standard 5-percent values in series or parallel to make up the desired value. For more casual experimentation or non-critical applications, the nearest standard-value resistor should work satisfactorily.

In addition to setting a 0-dB point, you'll need to set the compressor's attack and recovery time via C8. Attack and recovery times are tied together on the NE577, and can't be set

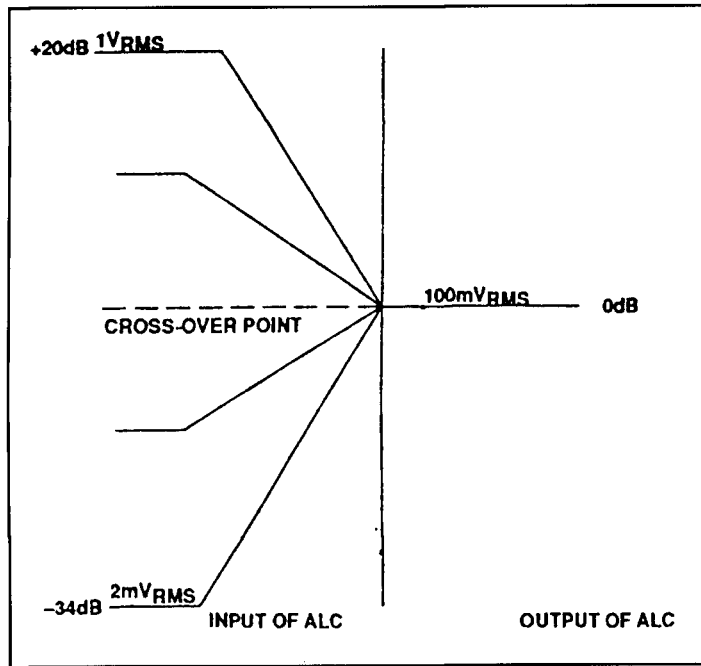


Figure 2. Dynamic range of NE577 with 0 dB set at 100 mV. Signals above crossover point are attenuated. Signals below are amplified.

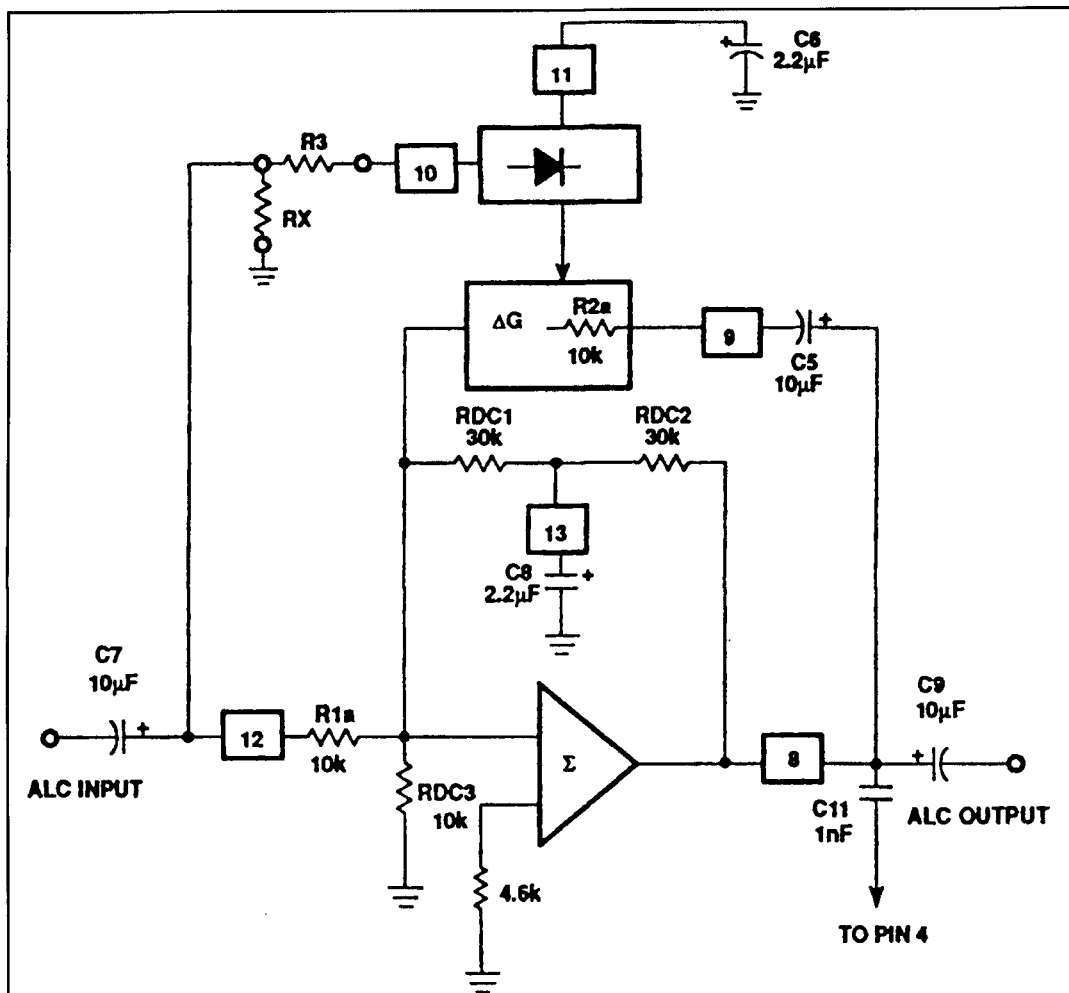


Figure 3. NE577 ALC configuration.

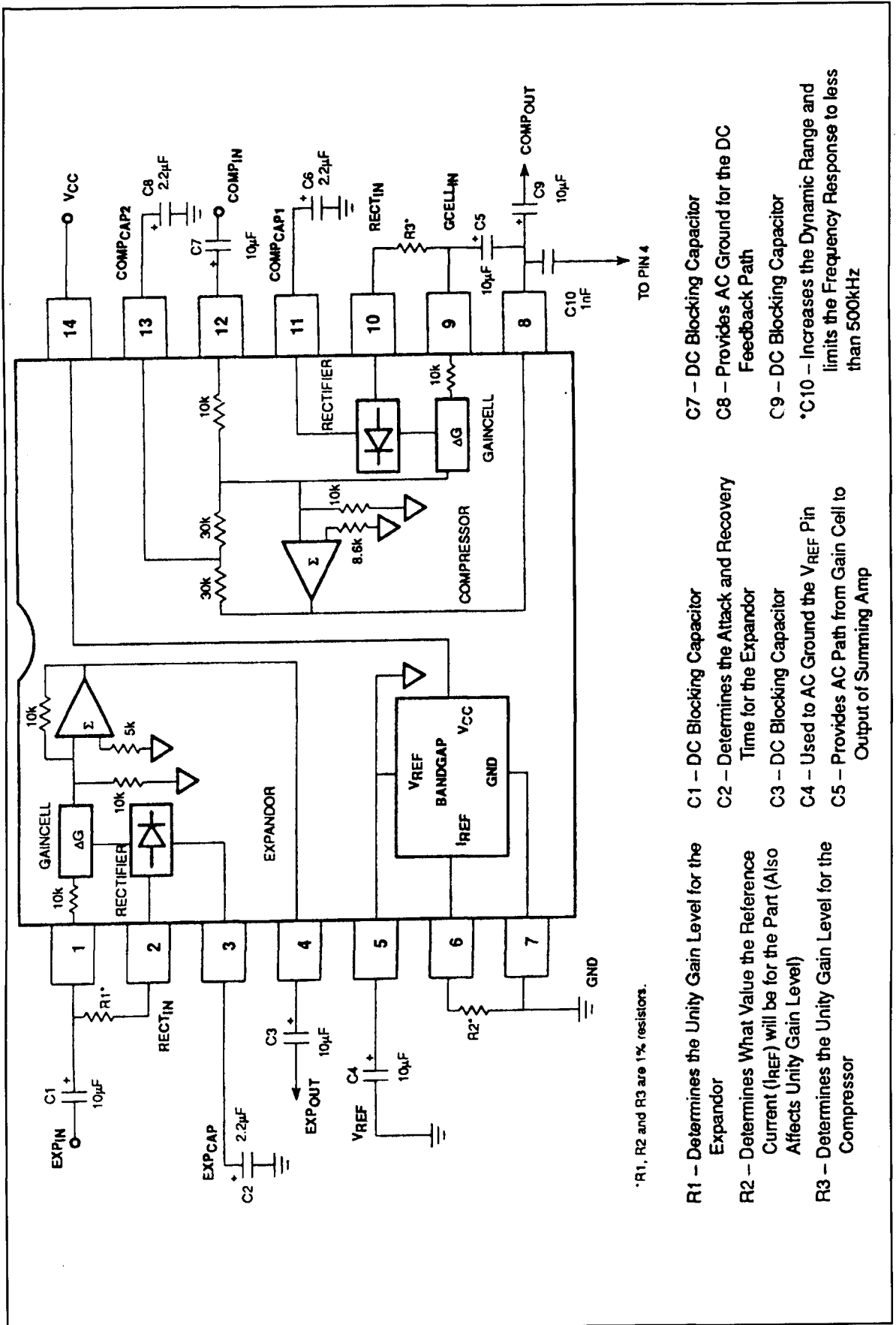


Figure 4. Block diagram and pinout of NE577 compandor.

independently. AN1762 recommends a value of 2.2  $\mu\text{F}$  as a starting point. For a more thorough discussion of compandor attack and recovery times, obtain a copy of application notes AN174 and AN1741

## Using the programmable ALC function

In a simple compressor, any lull in input signal lets the compression amplifier default to maximum gain—often causing an inrush of unwanted amplifier hiss and background noise. However, the NE577 doesn't work this way. For one thing, only about 3/5ths of the device's total dynamic range is achieved through signal amplification—the remaining 2/5ths is achieved through signal attenuation. This means there's less opportunity for the device to contribute its own internally generated noise into the audio system—even at maximum gain.

In addition to this, the amplifier portion of the NE577 is programmable—you can choose (up to the maximum level available) any level of gain you want by installing the appropriate value resistor at  $R_x$ . This, in turn, establishes an ALC threshold for weak signals. When this is done, any signal above the ALC threshold will be boosted to the 0-dB unity gain level in normal fashion. However, any signal falling below the ALC threshold will be amplified by the amount you preset—and no more.

| 0dB Level              | dBv | $R_2$ | $R_1$ & $R_3$ |
|------------------------|-----|-------|---------------|
| 1.0V <sub>RMS</sub>    | 0   | 24.3k | 18.7k         |
| 316.2mV <sub>RMS</sub> | -10 | 100k  | 22.6k         |
| 100mV <sub>RMS</sub>   | -20 | 100k  | 7.15k         |
| 10mV <sub>RMS</sub>    | -40 | 200k  | 1.33k         |

Table 1. Recommended resistor values for different 0 dB levels.

Refer to **Figure 5** for an illustration of how this works. Suppose you install an  $R_x$  value that sets the maximum voltage gain at 10 (20 dB). With this gain limitation in place, a -34 dB background noise will produce -14 dB output. However, with no limitation in place, the same noise would generate a 0-dB output (recall there is approximately 34 dB gain available without  $R_x$  installed). When used properly, gain limiting can significantly reduce unwanted background noise without reducing the compressor's effectiveness at controlling program-level material.

## The expander

The expander side of the NE577 provides a mirror-image response of the compressor circuit—and is equally simple to program. The expander's 0-dB unity gain level is determined

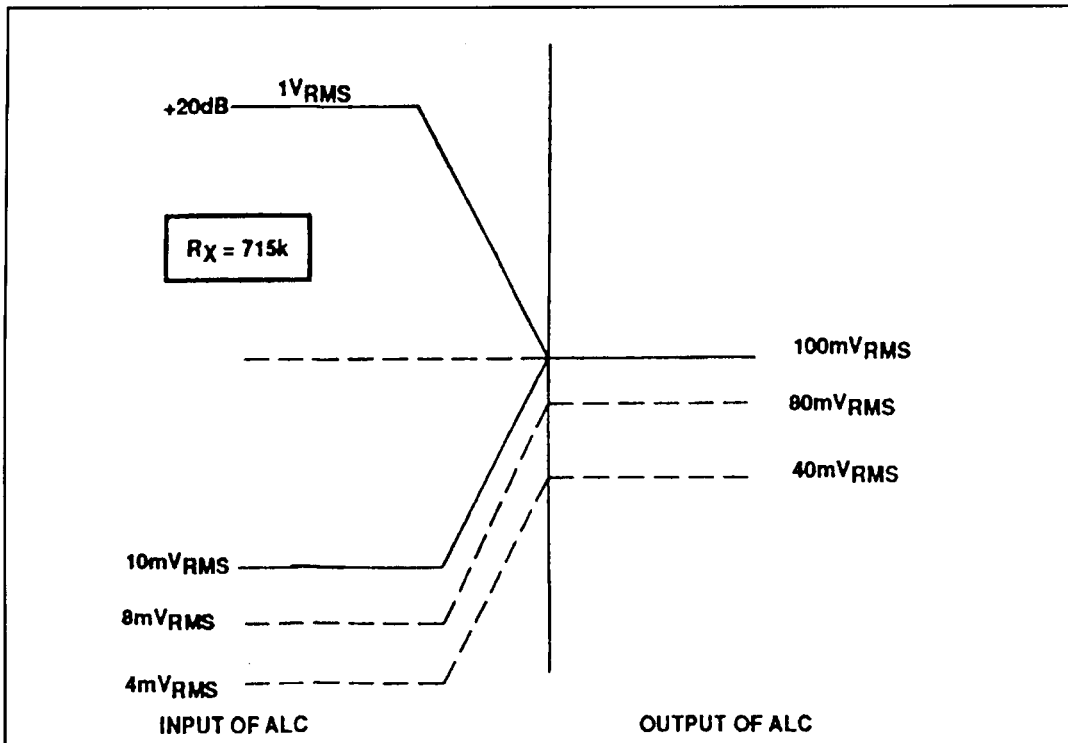


Figure 5. Typical NE577 ALC response with 20-dB gain limitation programmed by addition of  $R_x$ .



by R1. Attack/recovery time is set by C2. When compressed audio is fed into pin 1, it will emerge at pin 4 in proportionally expanded form.

## Applications in radio communication

The NE577 makes an ideal audio-leveler for FM receivers, compensating for differences in recovered audio due to variations in transmitter deviation. As the commercial services begin mandatory conversion to lower deviation levels, scanners and amateur transceivers with expanded-coverage receivers will benefit enormously from the addition of automatic gain tracking. A practical NE577 circuit configured especially for this application appeared in the February 1993 edition of *Electronics Now* on page 41 ("Audio Level Controller" by Steve Szabo). Kits and pc boards for this project are still available from C & S Electronics (see address below).

Other applications for the NE577 compandor might include the following:

- AGC for direct-conversion or simple superhet receivers.

- Wide-range deviation limiter for FM transmitter modulators.
- Expander circuit for restoring dynamic range to heavily processed SSB signals.
- Wide range audio speech processor for SSB transceivers.

## Conclusion

For more information on the NE577—and to obtain a copy of the *RF Communications Handbook*—contact your nearest Philips Semiconductors distributor. You may obtain single quantities of the NE577 for \$3.95 each from C&S Electronics, P.O. Box 2142, Norwalk, CT 06852-2142, phone or fax: (203) 866-3208. Please add \$3.00 with your order to cover shipping and handling. Copies of AN1762 are available from the *Communications Quarterly* editorial office for your SASE.

Finally, if you come up with a unique or practical application for the NE577, we'd like to hear from you. The "Tech Notes" column of *Communications Quarterly* is custom-made for presenting short construction projects and unique circuit applications—and it pays!

## BOOK REVIEW

### *Scanners & Secret Frequencies*

By Henry L. Eisonson

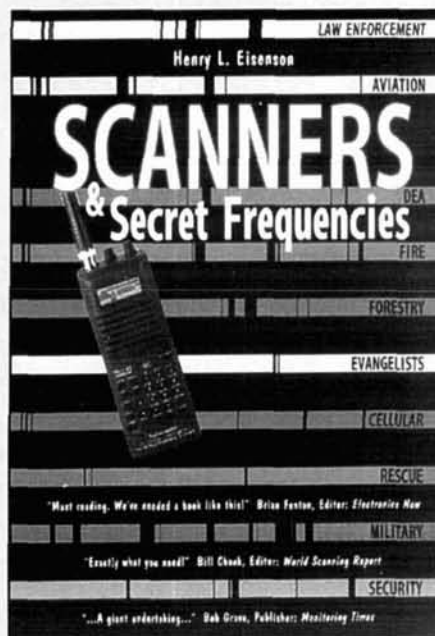
Published by INDEX Publishing Group

*Scanners & Secret Frequencies* is volume three in The Electronic Underground Series. The book covers a variety of topics from an introductory "Radio Principles," to amateur radio, to scanning and advanced scanning in over 300 illustrated pages. Also included is a glossary and appendices which cover the phonetic alphabet and addresses of clubs and organizations in the United States.

Although the book is geared toward scanning and telephones, it does devote a full chapter to amateur radio. Topics discussed in this chapter include allocations, a brief overview of how to become a "ham" and what the hobby is about, amateur radio operators as public service announcers, and monitoring ham radio.

*Scanners & Secret Frequencies*, describes and supports the scanning hobby in a number of interesting chapters. The book is written in an easy to understand and sometimes humorous fashion, and is a good introduction to the world of communications and its branches. It approaches the technical side of scanning and radio by describing radio principles, scanner performance factors, tuning, hardware basics, antennas, modifying scanners, the spectrum, military radio, CB, etc. in a way that is engrossing and informative without compromising the facts.

Considering the amount of information covered, and the technique used to cover the information, *Scanners & Secret Frequencies* is a useful resource for beginners and pros alike.



*Scanners & Secret Frequencies* by Henry L. Eisonson is available in paperback for \$19.95. For more information, contact INDEX Publishing Group, 3368 Governor Drive, Suite. 273F, San Diego, CA 92122 or call 619-281-2957. To place an order call 800-546-6707.

Nancy Barry  
Assistant Editor

# THE SOLAR SPECTRUM

## *The Hayden system for recording ionospheric anomalies and some predictions for sunspot Cycle 22*

For a change of pace we've asked Michael Hayden, AK3F (a regular contributor to our program of recording ionospheric anomalies that result from solar flare activity) to describe the VLF equipment he uses to monitor such effects. The Hayden system is somewhat unusual among our collaborators in that a selective voltmeter (rather than transistorized receiver) is used to record the station's carrier frequency. In keeping with a growing trend among our participants, Michael uses a small computer interfaced to the voltmeter through an inexpensive A to D converter to record the data he collects.

Secondly, since the occurrence of the next solar cycle minimum is of interest to so many of our readers, we've collected the predictions of several experts in this field—both in the United States and abroad—and present them following Michael's description. Our own comments appear at the end of this column.

### Selective voltmeters meet a new 8-bit A to D converter

Frequency selective voltmeters make rugged, commercial grade VLF receivers for the detection and monitoring of flare effects on the earth's atmosphere. Although they are physically bulky, they offer a stable and economical alternative to solid-state VLF receivers such as that described by Arthur Stokes, N8BN, and Peter Taylor in the Summer 1991 issue of *Communications Quarterly*. I have recently interfaced such a voltmeter (**Photo A**) to a very economical 8-bit A to D converter. The synergistic combination of the selective voltmeter and converter makes an effective and versatile computer-controlled monitoring station.



**Photo A.** In the Hayden system, an HP310A selective voltmeter drives an Epson printer through an older model IBM-PC compatible computer and appropriate interfacing. (All photographs appearing in this article are by Michael Hayden.)

If their popularity and availability are any indication, few radio enthusiasts recognize the modest frequency selective voltmeter as a radio receiver. However high-quality units from Hewlett Packard are particularly suited as radio receivers when extreme sensitivity is not required. Models such as the HP302A, HP310A, and HP312A/B are available as factory refurbished units from Tucker Electronics and Computers\* for several hundred dollars. For

those willing to take a chance, the same voltmeters—used and unchecked—are usually plentiful at hamfests and electronics flea markets for under \$50. These can be real bargains. Even the duds are valuable as a source of like-new replacement parts and hardware.

Of course there's more to a station than just the receiver, and monitoring several stations can land you in debtor's prison if each frequency requires its own chart recorder. Consequently, you might want to keep an eye out for other useful hardware as you browse hamfests for clean voltmeters.

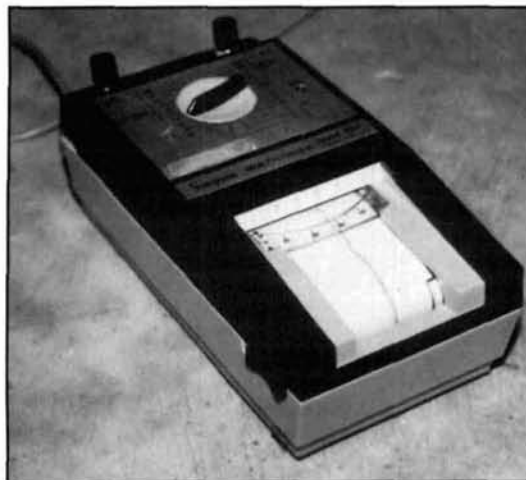
For example at a recent flea market, I found a working Simpson Multicorder 604 (**Photo B**) for just a few dollars. It's an integrated assembly of a multimeter combined with a strip-chart recorder; perfect for the experimenter, or as a standby recording device. The high price demanded by manufacturers for new hardware and equipment is enough to make even the most refined of us resort to digging through piles of surplus junk. Have you priced new Rustrak recorders lately, or tried to have one repaired?

I suspect a show of hands would reveal a number of you have spare PCs or XTs cluttering up your work space. If so, you *do* have another option. A recent issue of the *SID Technical Bulletin*<sup>1</sup> made me aware of an inexpensive eight-channel, 8-bit A to D board that plugs into a minimal IBM-PC compatible computer (**Photos C and D**).

Two different A to D converters are available from Gary Bach, a distributor in Ohio.\*\*

\*Tucker Electronics & Computers, P.O. Box 55419, Dallas, Texas 75355 (1-800-527-4642).

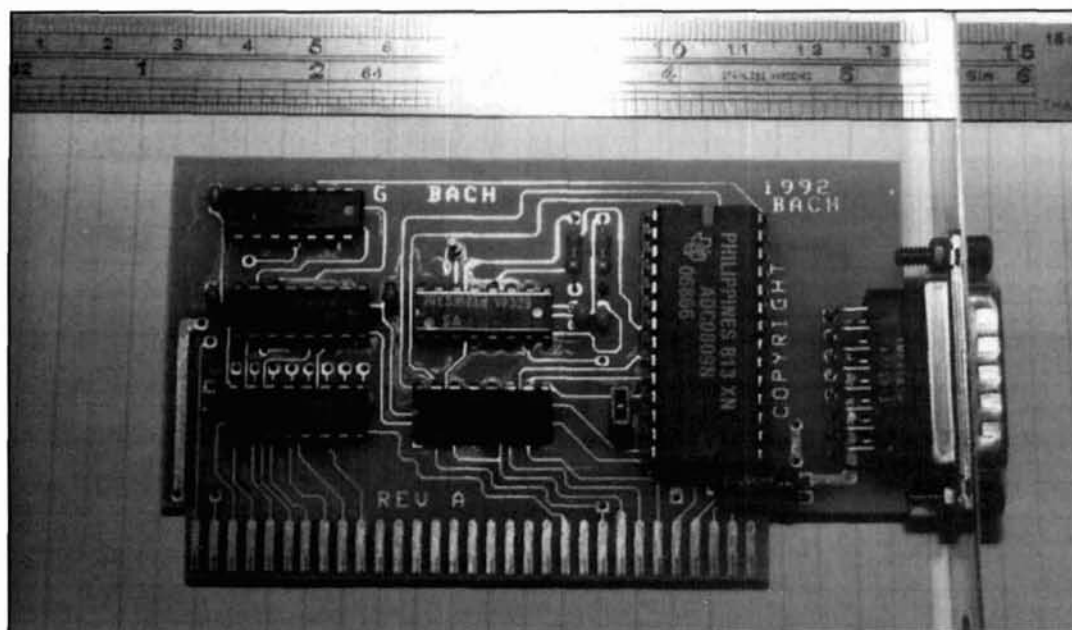
\*\*Gary Bach, P.O. Box 751454, Dayton, Ohio 45475.



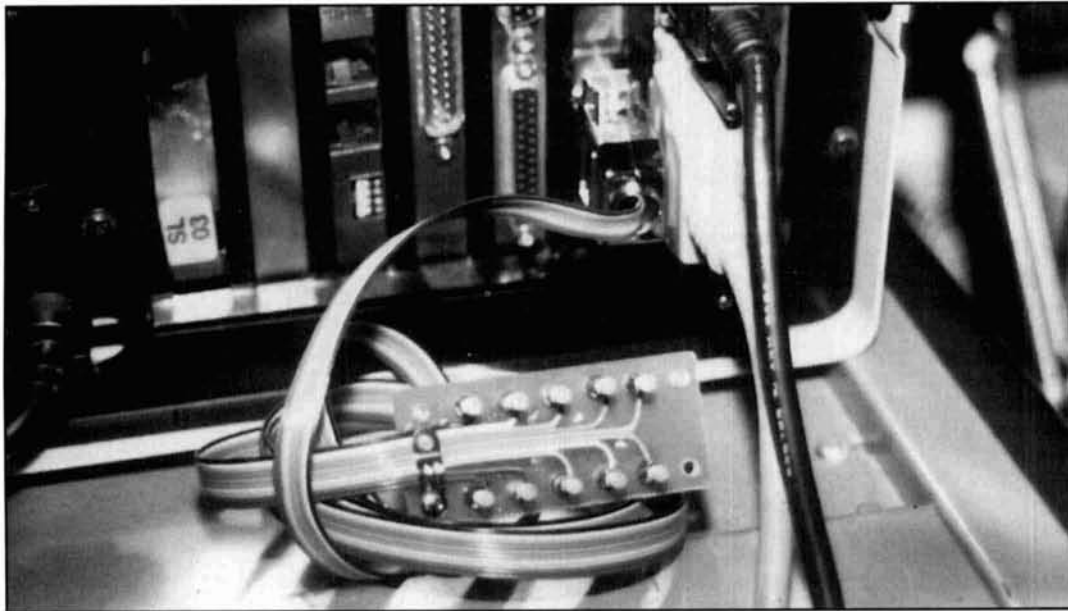
**Photo B.** The Simpson Multicorder consists of voltmeter and small strip-chart recording device. This unit was purchased used and in good working condition for only a few dollars.

The first is an 8-bit external kit (\$30 plus \$2 shipping at the time of my inquiry) that plugs into the PC's printer port. It offers eight channels of input and can digitize up to 200 readings per second. You assemble this kit yourself, and power it with an external 5-volt source.

The second is a higher speed, completely assembled eight-channel internal unit that plugs into any open 8-bit slot in the PC. The sample rate is 3000 to 4000 items per second, and it is powered directly from the PC. It has its own internal 5-volt reference voltage, which can be user-modified as desired to yield better resolution. When I placed my order in early August 1993, the internal card was on sale for just \$50 plus shipping.



**Photo C.** The Bach A to D card, which joins voltmeter and computer through the interface shown in *Figure 1*.



**Photo D.** The back apron of the author's PC. The A to D card is shown installed (second from right). The ribbon connector leads to a barrier strip that is used for inputs.

Software is provided with each unit which is sufficient to allow you to write your own programs to control the card. I combined techniques gleaned from Bach's software with an algorithm written by Arthur Stokes for the Alpha Products FA-154 converter;<sup>2</sup> and programmed a three-channel chart recorder for the Epson LX-810 (and similar Epson-compatible dot-matrix printers).

The software can be readily modified to change the frequency of readings or the monitored A to D channels. The latest version of my program, written in QBASIC, is available on diskette. There's no charge for the program, but interested parties should include a blank diskette and stamped, self-addressed mailer with their request.

Data is read from the card, then coded and preassembled so one pass of the print head prints the last eight readings. As is, it will read channel 0 of the A to D eight times and mirror the data to all three channels of the simulated chart recorder. The program code is sufficiently commented to allow you to add additional control loops to read different data into each recorder channel.

How often a data channel is read—and how often the data are printed—are controlled by timing loops within the program. A line of printed output every four or five minutes will suffice for many applications, if the timing between the eight readings that make up the print-head data is selected appropriately.

When these steps have been completed, all that remains is to interface the selective voltmeter to the A to D board and attach an antenna. The output of the HP310A (and other simi-

lar units) is a negative going signal. Level translation to the 0 to 5 volts DC input requirement of the A to D card is required. The circuit shown in **Figure 1** accomplishes this task.

This interface is a minimal implementation of Steven Hansen's design<sup>3</sup> modified to use a dual BI-FET op amp in an 8-pin mini-DIP package available from Radio Shack (RS 276-1715). Since it offers stability, I used a silvermica type capacitor for the 33-pF unit shown on the diagram, while ceramic-disk styles sufficed for those in the battery circuit. A length of shielded cable connects the meter terminals of the HP to the input of the interface unit.

The output of the latter unit is used as the input signal to the A to D card, or it can be used to drive a conventional chart recorder. Adjust the 100-k input potentiometer (RS 271-284) so a full scale meter deflection on the HP results in approximately 4.5 volts DC as measured on pin 7 of the LF 353. *Do not* allow any input signal to the A to D card to exceed 5 volts.

Attach an antenna of your choice. My favorite by far (**Photo E**) is a small loop antenna made of antenna rotor cable.<sup>4</sup> Mount the antenna with three-axis articulation and orient the loop for maximum signal strength.

SID detection and recording need not be overly expensive. Stations constructed using these guidelines can be both technically challenging and cost effective, and the systems provide an interesting and scientifically productive alternative to our normal activities.

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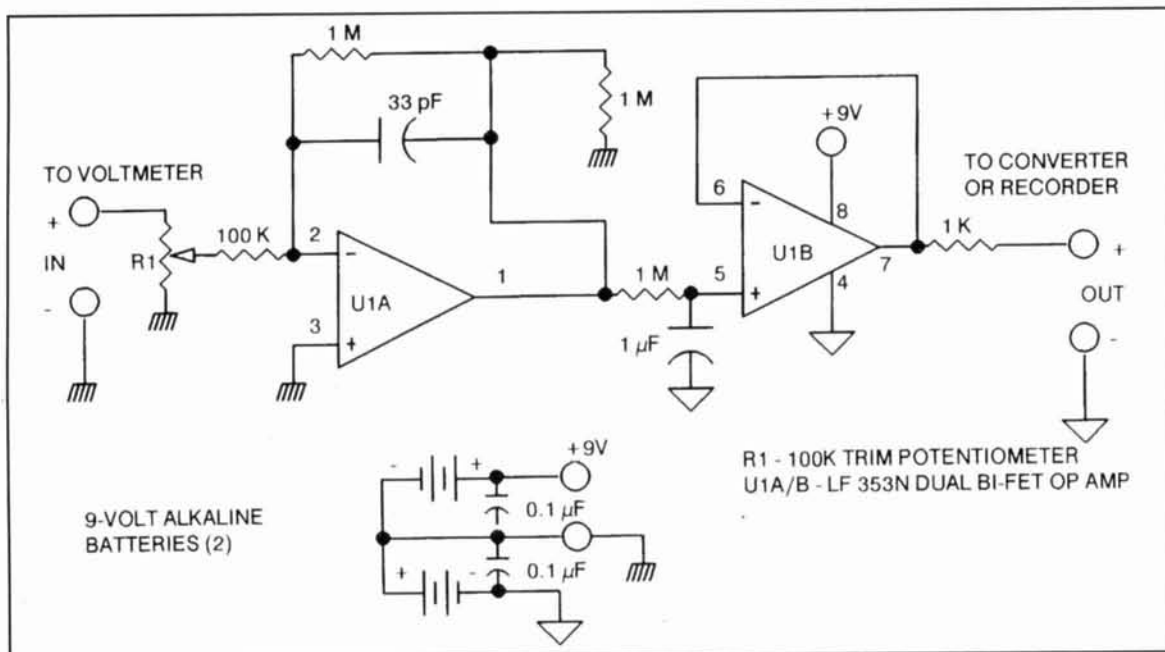


Figure 1. Schematic drawing of the Hayden interface. This circuit connects the selective voltmeter and the A to D converter board. Details are contained in the text.

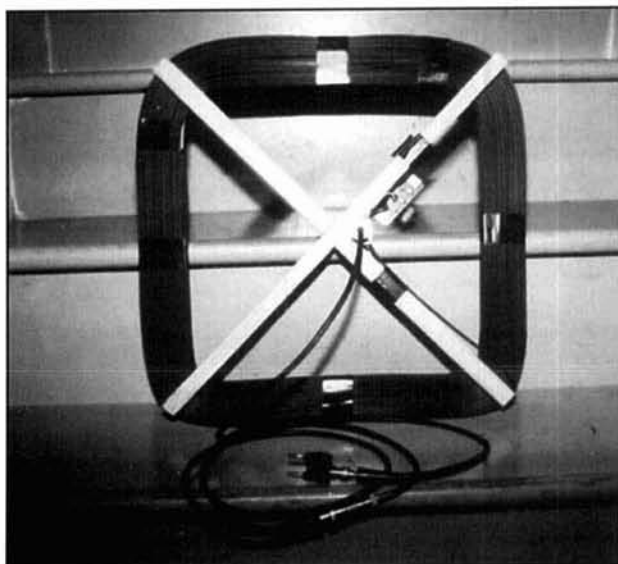


Photo E. One of the small loop antennas used for VLF station monitoring. (Fixed capacitor tuning.)

## Predictions for the minimum of Solar Cycle 22

Dr. Patrick S. McIntosh (NOAA Space Environment Lab—Boulder, Colorado):<sup>5</sup>

Everyone is talking about the extremely low level of sunspot activity in recent weeks. Sunspot minimum should not occur until 1997 if the canonical 11-year cycle is accepted, yet it sure looks like the Sun is heading for the cellar! Extrapolation of the present trend suggests a

minimum sometime in 1995. The previous minimum was September 1986.

The trend in daily values of solar 10.7 centimeter radio flux in September continues a rapid downward trend that has been present since March. This trend, and the values of the flux, resemble the daily 10.7 cm flux values observed in 1984, suggesting that the present cycle is at the same point in the cycle. That was only 9 years ago, reinforcing tentative predictions that the present cycle will end after only 9 years, becoming the shortest cycle in over 200 years! The last cycle recorded at near 9 years in length was Cycle 3 which peaked in 1778!

A tentative prediction of a 9-year cycle was presented to the International Astronomical Union Colloquium #143 in June after updating comparisons among the 5 solar cycles for which there are 10.7 cm flux data. The cycles were plotted one under the other on a single graph, placing the cycles in alignment by use of the times of the abrupt drop in flux that has occurred at the end of the maximum phase of each cycle. This drop was most dramatic in the present cycle, occurring early in 1992.

When the cycles are so aligned, other critical points in the cycles align better than when the cycles are aligned with their times of sunspot minima. These points include the highest peak flux of each cycle and a post-maximum activity peak that occurred in all but Cycle 19. The times of minima at the end of the cycles, except for the anomalous Cycle 20, align more closely than the minima at the beginning of the cycles. This suggests a possibility that there is a constant interval of about 3.5 years between the abrupt drop in flux and the time of sunspot minimum. Using

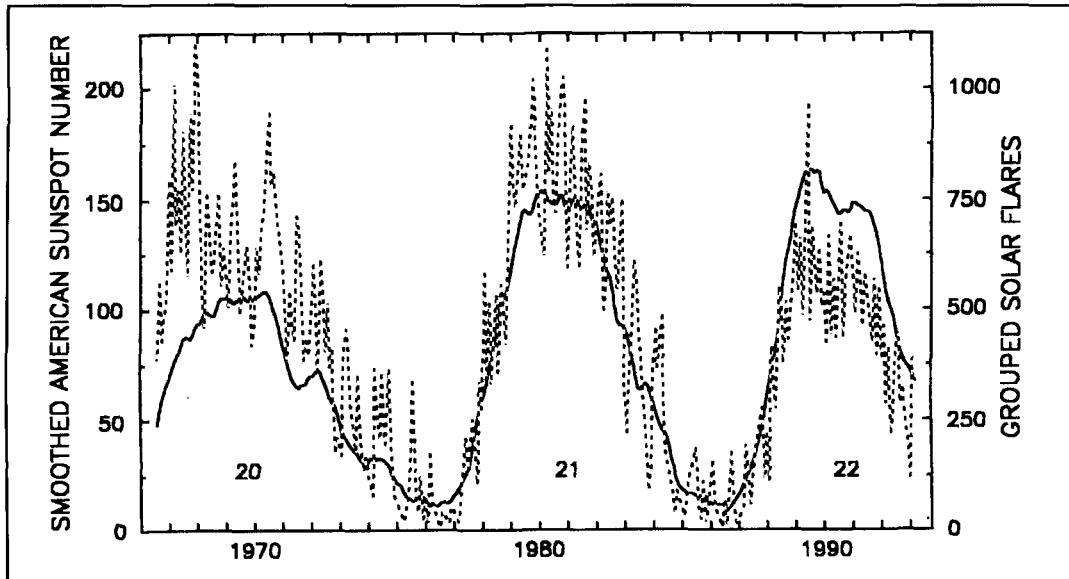


Figure 2. The total monthly numbers of solar flares observed during Cycles 20, 21, and 22 (through March 1993) plotted against the smoothed sunspot number. Note that when measured against sunspot number, the number of flares during Cycle 22 is less than that for recent cycles.

this supposition, the date of the coming sunspot minimum would be in the last quarter of 1995, resulting in a 9-year length to the cycle.

The most anomalous time of starting minimum is that of the present cycle, suggesting that the cycle has a true 'RstartS' 8 to 9 months earlier than the September 1986 sunspot minimum. In a separate comparison between the present cycle and the previous cycle, using smoothed sunspot numbers, the best fit is also achieved with a shift of the 1986 minimum 8 months later than the time of the previous minimum. Hathaway et al. (in an article submitted to the *Astrophysical Journal*, 1993) also concluded that the 'RrealS' start of the cycle was earlier than sunspot minimum would define, using a fresh approach to a statistical treatment of sunspot numbers.

Dr. Richard Thompson (IPS Radio & Space Services—Sidney, Australia):<sup>6</sup>

Some features of Cycle 22 suggest that the cycle is running faster than 10 years. For example, the pulse of geomagnetic disturbances, which were the first sign of Cycle 22, came unexpectedly early in the declining phase of Cycle 21. Cycle 22 then rose very rapidly and reached its maximum in the record short time of 2.8 years. The interval between the maxima of Cycles 21 and 22 was then only 9.6 years. With this length, we can then expect the next solar minimum in April 1996.

The decline of Cycle 22 has been rapid and is between three and eight months ahead of those for Cycles 18, 19, and 21 (unlike these and the current cycle, Cycle 20 was a very low-amplitude cycle and is not considered). This also supports an early solar minimum in the

first half of 1996. Therefore, the evidence seems in favor of a solar minimum in the first half of 1996. However, there is some chance that the minimum could be very early—perhaps late 1995—giving Cycle 22 another distinction as one of the shortest on record.

Dr. Andre Koeckelenbergh (Sunspot Index Data Center—Belgium),<sup>7</sup> Dr. Koeckelenbergh brings a multi-faceted approach to the SIDC predictions of sunspot minimum, explaining:

When one applies (M. Waldmeier's) solar cycle intensity curves to this problem, the result shows that minimum will occur between mid-1995 and mid-1996, most probably during December 1995.

On the other hand, if the mean slope of smoothed sunspot numbers during the 12 months centered on the time that the level  $R_{max}/2$  (i.e., 50 percent of the smoothed monthly Relative Sunspot Number at maximum) is attained during the decreasing phase, minimum should occur very much earlier; sometime between May and November 1994.

Since these two methods generally overstate and understate the predicted time of minimum (respectively), a third forecasting technique can be based on their arithmetic mean. This procedure gives a likely minimum date of April 1995.

Dr. Koeckelenbergh also notes—as do we below—that a prediction may be founded on the observation that minimum for the last several cycles occurs approximately 3 years (32 months  $\pm$  6 months) after the first spotless day of the descending cycle phase. If that actually took place during the fall of 1993 (which is likely) the most probable time for minimum is during the spring of 1996.

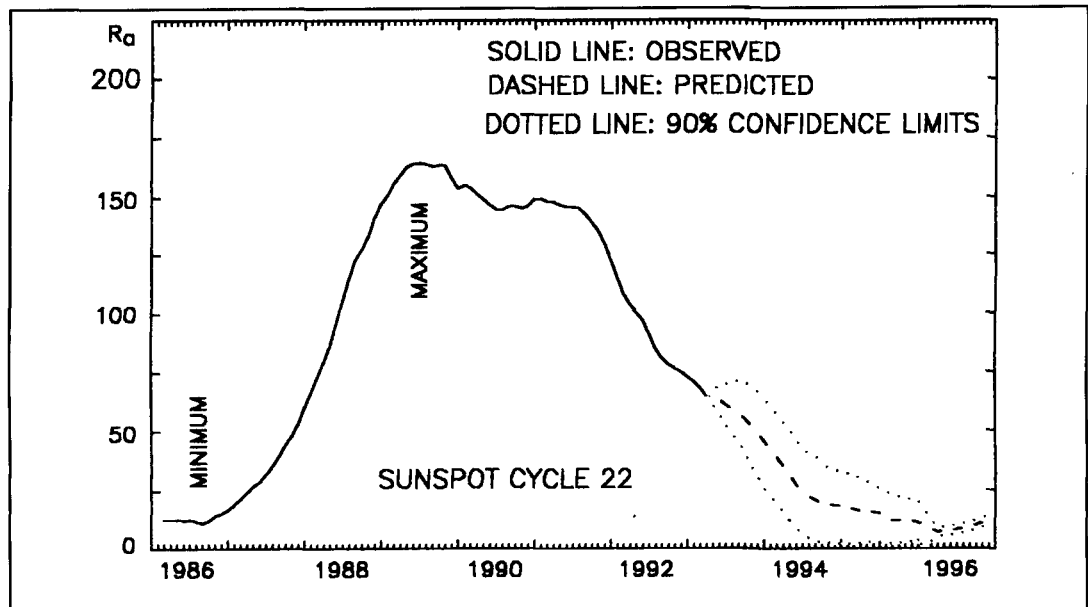


Figure 3. Observed and predicted sunspot activity for Cycle 22. The predicted path results from a statistical analysis of past cycles (dotted lines represent 90 percent confidence limits). Such predictions may regress towards the mean for all cycles after 12 months have elapsed.

It should be understood that each of these forecasts is an educated opinion based upon current and past solar activity. Our own feeling is that in many ways, Cycle 22 has been an extraordinary cycle. As Dr. Thompson points out, its ascending branch is the shortest on record; its maximum amplitude and number of exceptionally intense flares have exceeded many predictions based on previous cycles. On the other hand, when compared with sunspot activity, the number of flares recorded during many months of Cycle 22 is noticeably less than for recent cycles (Figure 2).

In spite of these differences, clues to the occurrence of cycle minimum may still be found in an examination of the historical series of observed spot-cycles . . . provided cycles which resemble the current cycle are selected for comparison. Three such events are similar to the present cycle, at least in maximum amplitude and rate of ascent: Cycle 3 which peaked in 1778, Cycle 18 which reached maximum during 1947, and Cycle 21 which crested late in 1979.

All these cycles attained maxima that exceeded a smoothed monthly-mean sunspot number of 150, and all had ascending branches of less than 3.50 years duration. The descending phase for each cycle is also similar—6.33, 6.92, and 6.75 years, respectively. If we apply this information to the present cycle, it follows that minimum should occur sometime during the latter part of 1995 or early 1996. Again, as others have pointed out, such a scenario means that

Cycle 22 would be one of the shortest on record; a little over 9 years in length.

Further evidence appears in the trend of smoothed sunspot numbers during most of 1992, which indicates that the steep decline we experienced during much of the post-maximum phase of Cycle 22, slowed a bit. During the latter portion of 1992, Cycle 22 pretty well followed a path that describes the average descent for all observed cycles (6.73 years). Moreover, with the exception of Cycle 20, all cycles since 1933 have had fall-rates within the cited ranges.

As Dr. Koeckelenbergh implies, the first consecutive spotless days of both Cycle 18 and 21 occurred about 3 years before minimum. According to Solar Division and Space Environment Services Center observers, the Sun displayed the first post-maximum spotless days of Cycle 22 during September 1993;\* a further indication that the next low in solar cycle activity will occur earlier than for most previous cycles. The observed path of Cycle 22, along with its possible future course as indicated by the McNish-Lincoln statistical analysis during November 1993, is shown in Figure 3.

#### REFERENCES

1. *SID Technical Bulletin*, Volume 4, Number 3 (July 1993). For more information about this quarterly newsletter, contact the author at the address given at the beginning of this column.
2. Arthur J. Stokes, Hudson, Ohio. (personal communication to Hayden).
3. *SID Technical Bulletin*, Volume 3, Number 2 (April 1992).
4. *SID Technical Bulletin*, Volume 3, Number 1 (January 1992). Also see errata in *SID Technical Bulletin*, Volume 3, Number 2 (April 1992).
5. Dr. Patrick S. McIntosh, Boulder, Colorado (personal communication to Taylor).
6. Dr. Richard Thompson, Sidney, Australia (personal communication to Taylor).
7. *Sunspot Bulletin*, 1993, Number 9, Brussels, Belgium.

\*Sunspot Index Data Center observers detected a small amount of sunspot activity at this time.

## Let's talk antennas

*The arrival of this issue of Communications Quarterly signals that winter is nearly over, and that the first robin—the unofficial harbinger of spring—will soon be arriving here in New England. To this end, we've decided to break with tradition in this edition of Tech Notes, by making an early foray into some antenna projects. We hope this will give our readers ample time to plan for those much needed antenna repairs and upgrades, well in advance of the usual Spring offerings made by other magazines.*

*Peter Bertini, K1ZJH  
Senior Technical Editor*

*Here's a great little portable antenna for 20 meters for those who like to ham while they travel.*

## An "Ultralight" Center-fed Vertical Antenna for 20 Meters

*Rick Littlefield, K1BQT*

**Portable antennas always** seem to breed compromise. However the 1/2-wave center-fed vertical presented here may offer a new alternative for itinerant DXers in search of a better sky-hook. This simple no-radial design provides the high radiation efficiency of a dipole, yet delivers a lower take-off angle (TOA) that favors long-range communication. Best of all, it's easy to transport and sets up in five minutes or less.

### Size

My objective was to build a portable vertical with the highest efficiency possible. However, a full-sized radiator would require a 34-foot element plus 8 feet of insulated mast on this band; more antenna than I care to wrestle with. So, my first task was to find ways to shorten the vertical element without destroying its efficiency. I considered the following two steps:

1. Reduce element length with high-Q loading coils. Recent data presented by Charles Michaels, W7XC, suggested that by installing loading coils with Q exceeding 300, I could reduce element length by as much as 33 percent with an incurred loss of 1 dB or less.<sup>1</sup>

2. Rotate the lower loading coil and element tip into the horizontal plane. This would further reduce height and, as a secondary benefit, pro-

vide a more favorable exit point for my feedline (see Decoupling below).

Together, these steps would shorten the vertical radiator by nearly 14 feet with only minimal loss in performance. Final height would be a more manageable 28 feet—including an 8-foot insulating base mast.

## Element Design

In addition to reducing height, I decided to alter the symmetry of the dipole to redistribute weight and provide a more favorable impedance match. To accomplish this, I decided on the following steps:

1. Make the upper leg physically longer and electrically shorter than the bottom leg. This would place a small loading coil at the top (where the weight is critical) and the larger coil at the base (where weight is less important).

2. Electrically position the lower loading coil near the end of its element. End-loading at 0.75 to 0.80 of leg length would limit my horizontal element tip to around 3 feet, which would hopefully minimize unwanted ground coupling and pattern distortion.

3. Adjust the ratio of top and bottom loading-coil inductance to force the feedpoint off center. Off-center feed could be used to elevate the predicted feedpoint resistance from 30 ohms to the more useful value of 50 ohms.

Lacking the mathematical tools to factor this many variables into one calculated solution, I decided to use the technique of affective approximation to determine the ratio and values for my inductors. (In other words, I decided to take an educated guess.) This approach would—worst case—provide a viable starting point for making empirical adjustments with the aid of network analyzer.

## Decoupling the Feedline

It's no secret that end-fed 1/2-wave antennas can be tricky to decouple from their feedlines. This is because the coax must exit the element at a voltage node where impedance is very high. Generally, antenna manufacturers use a combination of decoupling radials, ferrite sleeves or cores, and other exotic tricks to choke off RF energy from the outer surface of the feedline as it departs the antenna element. Since the reactance of any decoupling network will be finite, some loss of antenna Q and efficiency will inevitably result.

To avoid this problem, I planned to route my



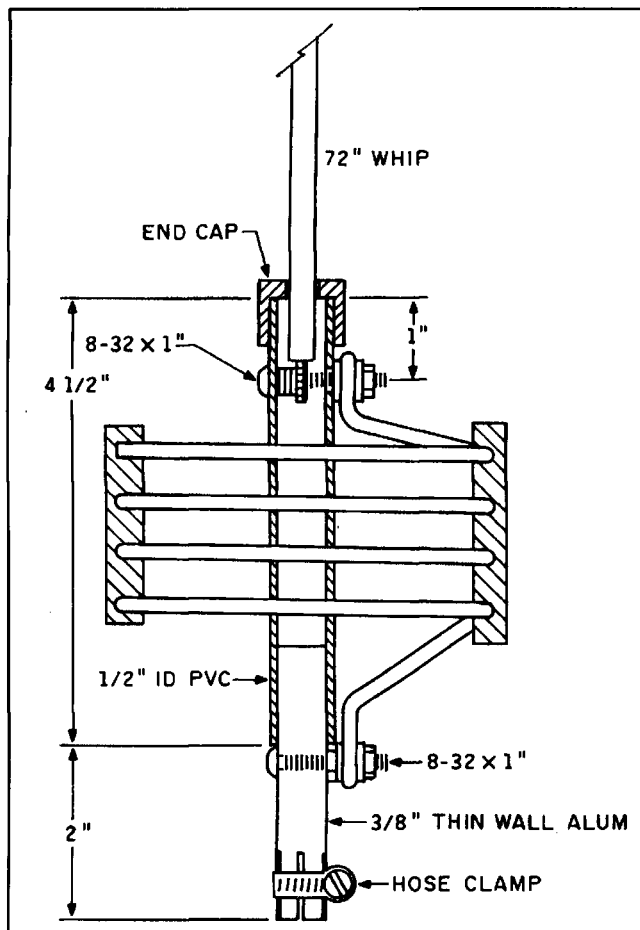


Figure 1. The antenna tip is a Radio Shack 6-foot collapsible whip, limiting the weight and mass of the top section.

feedline through the element wall at the base of the vertical element. Electrically, this point is at the low-Z end of the horizontal loading coil, about  $1/8$ -electrical wavelength removed from the voltage node at the element's tip. Because of this, my decoupling network would have little impact on antenna Q or efficiency. Rather than using ferrite materials to decouple my line, I decided to use a high-Q solenoid-type series choke made from RG-316/U mini-coax. Unlike the more common RG-176, RG316/U features silver-plated conductors and a Teflon™ outer jacket. These qualities are important for achieving high Q and maximum power-handling in the inductor. While this decoupling method is a bit unique, it's not original; a similar approach was used successfully by MFJ Enterprises in the design of their multiband  $1/2$ -wave vertical antenna.

### Construction

With the possible exception of the RG-316/U, I used no special materials to construct this antenna; only common hardware, a few

plumbing supplies, scraps of aluminum tubing, and parts from Radio Shack. The base section is a 1-inch diameter fiberglass flagpole purchased from a local hardware store. Drawings in Figures 1, 2, and 3 illustrate how I assembled the antenna. I claim no special expertise when it comes to mechanical design and encourage others to make any improvements that make sense.

I was especially careful to limit the weight and mass of the top section. As shown in Figure 1, the antenna tip is a Radio Shack 6-foot collapsible whip, no. 270-1408 (for specific whip mounting instructions, see details below). I made all antenna insulators from short lengths of  $1/2$ -inch ID PVC water pipe. The 4-turn loading coil is lightweight aluminum, and the lower segment of the leg is a 6-foot length of  $3/8$ -inch thin-wall. Together, these parts make up a 12.5-foot antenna leg that's extremely light and flexible.

As Figure 2 illustrates, the center insulator is friction-fitted over the top of the base section. A slotted stub is then installed to support the upper leg. (In both cases, I used a rubber mallet to drive the  $1/2$ -inch ID PVC and the  $1/2$ -inch OD tubing together.) An angled hole, drilled at the insulator's center, passes the RG-58 feedline for connection to the top and bottom leg.

The 8-foot bottom leg is made from telescoped  $1/2$ ,  $5/8$ , and  $3/4$ -inch thick-wall tubing salvaged from an old TA-33Jr beam. RG-58 is threaded down the interior of the mast to an angled hole drilled 7 inches above the butt (note: feedline could run along exterior surface of the element with no loss in performance). I installed a Molex connector on my coax for connection to the feedline choke. I drilled additional holes slightly below the feedline exit for cross-arm mounting and for the lower element terminal. I left the bottom 6 inches of the element unobstructed—this segment slips into the  $3/4$ -inch fiber glass base for support.

Figure 3 and Photo A show the  $1/2$ -inch ID PVC cross-arm assembly. This supports the decoupling-choke form, loading coil, and horizontal element tip (Radio Shack no. 270-1403). I cut a vertical slot into one side of the cross arm to lock it perpendicular to the element. It's locked into place by a  $1/4$ -inch nylon screw and wing nut.

### Feedline Choke

The choke form is a 5-inch scrap of  $1-1/2$  inch ID PVC thin-wall drain pipe with two  $5/8$  inch holes drilled at the top to slip onto the cross arm (glue it in place with Genova PVC cement). I close wound 33 turns of mini-coax onto the form (about 16 feet) and secured the ends with no. 6 nylon screws tapped into the

form. This winding provided approximately 22  $\mu\text{H}$  of inductance. I installed a Molex connector at the top end of the choke winding for connection to the antenna, and spliced an electrical 1/4 wave of RG-58 to the bottom to serve as feed-line. A short scrap of 1/2-inch ID PVC is used as a waterproof housing for this splice and secured to the coil form with tie wraps to provide stress relief for the RG-316/U.

## Whip Mounting

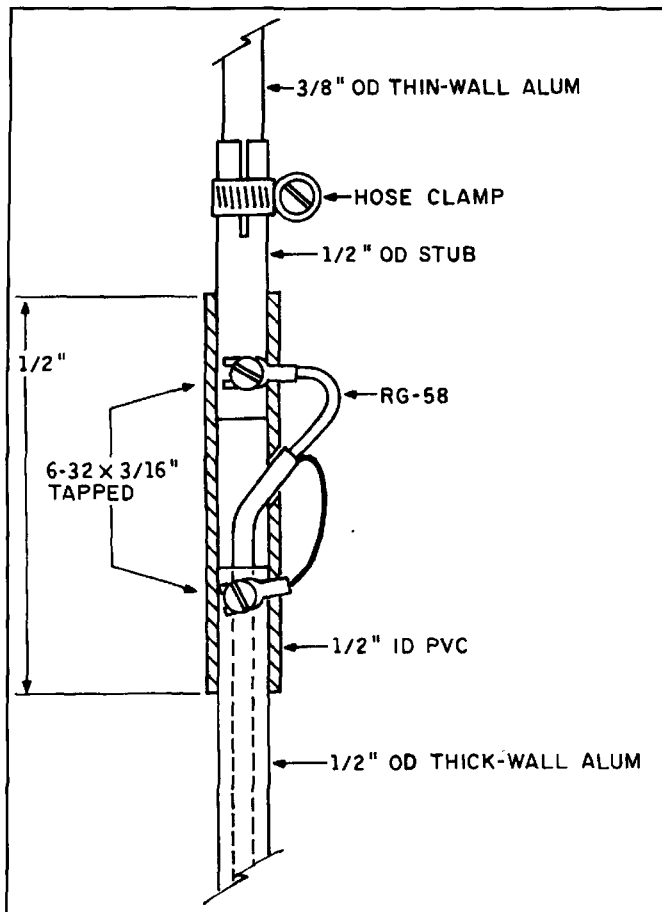
Each collapsible whip protrudes from the center of its PVC pipe mount (see **Figure 1**). The outboard coil-mount stud supports the end tab of the whip, and a PVC end cap provides a second point of support. This particular mounting procedure can be a bit fussy to perform, but it's the best looking and sturdiest method I've found. First, redrill and tap the whip's mounting tab for no. 8 hardware. Then immobilize the cross arm—or loading coil insulator—in a vice. Partially insert a 1 inch by no. 8 mounting screw up into the insulator hole and, using tweezers or hemostats, install 4 split lockwashers through the opening in the end of the pipe. Now, carefully insert the antenna mounting tab into the pipe and tighten it down. The whip should be securely fastened in the center of the pipe when the screw is tight and the washers are collapsed. To finish the operation, drill a 1/4-inch hole in the top of a 1/2-inch PVC end cap—then slip it over the whip and onto the pipe. (Do not glue this cap in place or whip replacement will be extremely difficult!)

## Loading Coils

The antenna's two air-wound loading coils are made from Radio Shack no. 8 solid ground wire no. 15-035. Each coil is 4-1/2 inches in diameter with 10 mm turns spacing (approximately 3 TPI). The upper coil, wound from a 5 foot 3 inch length of wire, has 4 turns, and provides a measured inductance of 2.7  $\mu\text{H}$ . The bottom coil, wound from a 12 foot 4 inch length, has ten turns and an inductance of 9.3  $\mu\text{H}$ .

To wind the coils, I used a 3-inch ID PVC drain-pipe coupling with a 1/8 inch hole drilled at one end (this has an OD of about 4 inches). I uncoiled and straightened a length of aluminum wire, cut it to length, and inserted one end about 3 inches into the 1/8 inch hole. I then close-wound the coil by slowly rolling the form across a carpeted floor, exerting heavy pressure to force the wire to wind tight and straight onto the form. The completed coil expanded by about 1/2 inch as soon as I released pressure, allowing easy removal from the form.

To maintain turn spacing for each coil, I used keepers made from strips of 1/4-inch poly-



**Figure 2.** The center insulator was friction-fitted over the top of the base section.

styrene stock (**Figure 3**). I grooved the poly stock with a table saw at 10 mm intervals and cut it into several 1/4-inch strips. I then cut these to length and heat-pressed the aluminum coil turns in place with a 60-watt soldering iron. Alternatively, you could drill holes in strips of stock and thread them onto the coil. Next, I shaped the coil leads, which are held in place by compressing between no. 10 washers on the mounting studs.

## Final Assembly and Mounting

The antenna is made to go together quickly from subassemblies (see **Figure 4**). To start, slide the top whip and loading coil assembly onto the 6 foot x 3/8 inch thin-wall section of tubing and secure with a small hose clamp. Next, slide the base end of the 3/8-inch tubing into the centerblock and secure. Now slip the entire element into the fiber glass base section and install the cross-arm jumper. Finally, fully extend the 72-inch whip at the top. To raise, gently walk the antenna up from its center insulator toward the base. With practice, assembly takes about 2 minutes.

In soft ground, mount the fiber glass mast by

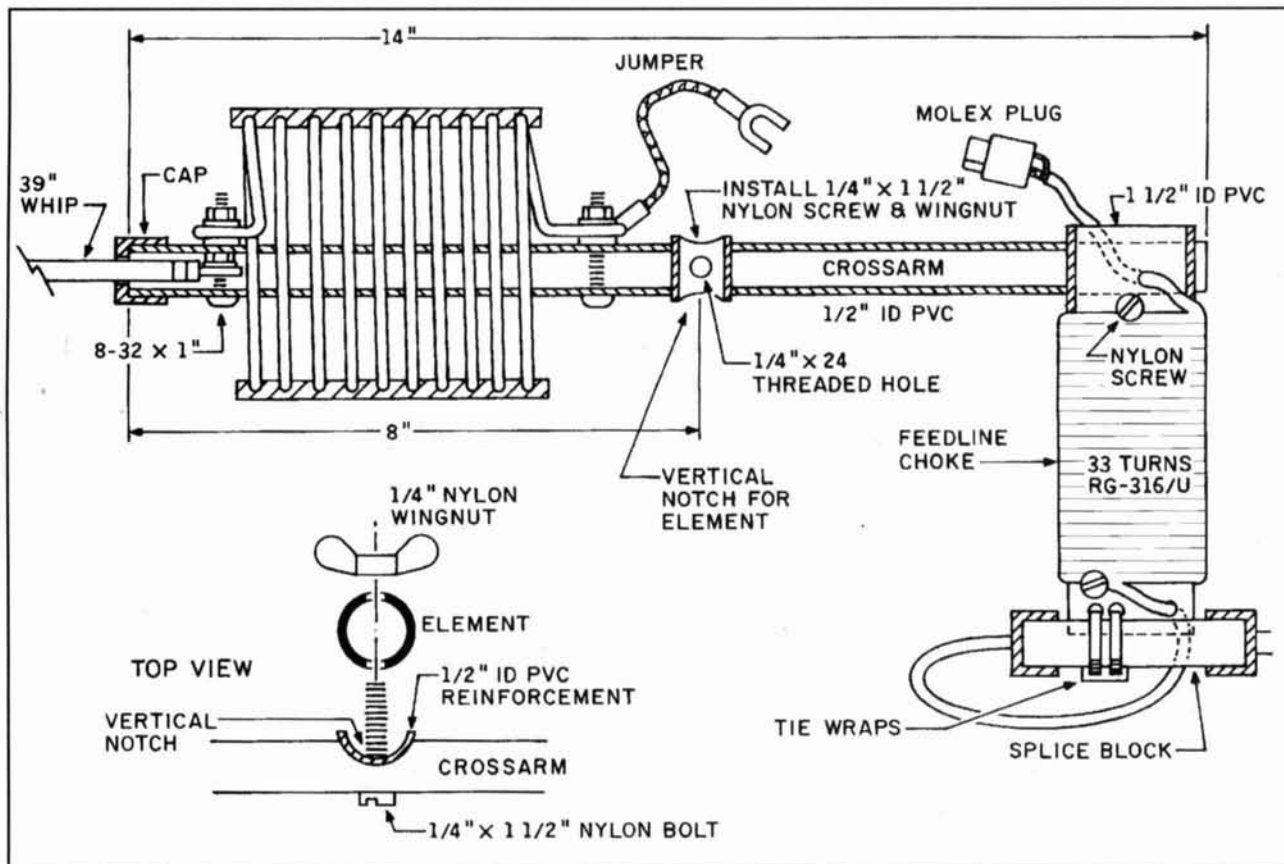


Figure 3. The 1/2-inch ID PVC cross-arm assembly supports the decoupling-choke form, loading coil, and the horizontal element tip.



Photo A. Close-up of the 1/2-inch ID PVC cross-arm assembly.

firmly pushing it about a foot into the soil. On hard ground, drive a pointed 3 foot by 1 inch angle-iron stake part way into the soil and lock the mast into the channel with two hose clamps. Alternatively, lash the mast to an existing support like a wooden fence post (avoid tall metal posts). For roof mounting, use conventional TV antenna hardware. Always keep the feedline

choke and radiating structures well clear of nearby objects.

### Safety Concerns

With any ground-mounted vertical antenna, safety is always a primary consideration. *Never install where children, animals, or distracted adults could contact the radiating portion.* Also, never attempt to tune the bottom element with RF applied; the element tip is a voltage node and even QRP power levels can inflict serious burns here. Finally, don't assemble or raise the antenna near a powerline; hams really *do* get killed this way!

### Initial Testing and Tuneup Procedure

When my antenna was fully assembled, I set it up in a side yard—taking care to avoid proximity to nearby trees and feedlines. For initial tuneup, I connected an MFJ-247 VSWR analyzer to the antenna via an electrical 1/2-wave length of RG-58 and set the analyzer output frequency at 14.200 MHz. Next, I adjusted the horizontal element tip for minimum VSWR. I achieved resonance with the lower element extended to approximately 32 inches. I

obtained a VSWR of 1:1 on the first tuning trial, so no subsequent adjustment to the loading coils or element legs was required to implement a 50-ohm match.

## Selecting a Mounting Site

Virtually any resonant antenna with reasonably high Q will be detuned by proximity to conductive objects. For example, I observed that moving this antenna to within 20 feet of a dipole feedline raised minimum VSWR from 1:1 to 1.2:1. Obstructions that alter VSWR will have some impact upon radiation pattern and efficiency (most often, a negative one). Therefore, it's best to avoid setting up next to thick foliage, buildings, wires, RVs, or anything large and metallic that could distort the pattern or soak up RF.

## Bandwidth

Because the radiating element is shortened by 33 percent, the antenna has a relatively narrow bandwidth (see **Figure 5**). The 1.5:1 VSWR bandwidth measured 225 kHz (1.6 percent) and the 2:1 bandwidth was 400 kHz (2.8 percent). However I haven't found this to be a problem. When ground mounted, I adjust the horizontal element for minimum VSWR in the band segment I'm using; much like I would adjust a tuner. When roof mounted, I adjust it for minimum VSWR at midband.

## Feedline Considerations

During tests, VSWR measurements were unaffected by feedline handling and the outer surface of the cable appeared "cold" along its length. This indicates that feedline decoupling is effective. When setting up, I simply allow the feedline to drop to the ground directly beneath the antenna, then I run it along the ground's surface to my operating position. Avoid draping the feedline through the air in the antenna's near-field pattern, as this may elevate VSWR.

For convenience, I permanently installed an electrical half wave of feedline at the antenna's input (about 21-1/2 feet of RG-58/U). I did this primarily to ensure the accuracy of VSWR readings during tests. In many cases 21-1/2 feet is sufficient to reach my operating location; however, I also carry an additional 50 feet of RG-58 and a barrel connector in case I need to position the antenna away from buildings, wires, or other obstructions.

## On-air Performance

Without benefit of an antenna range, it's dif-

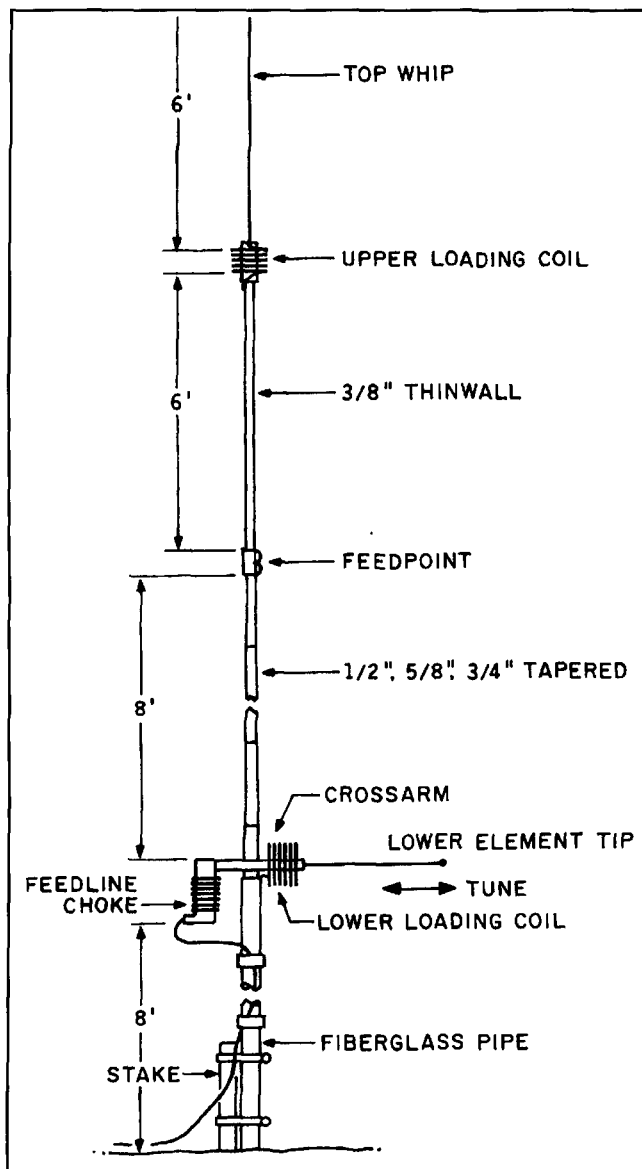


Figure 4. Subassemblies let you put the antenna together quickly.

ficult to quantify antenna performance in any meaningful way. To gauge how well the antenna works, I connected it to my home station for the classic "A/B dipole comparison" that homebrew builders often use. I mounted the portable antenna in the ground in a side yard near a grove of trees (a typical "quick-and-dirty" installation). My dipole is permanently mounted in the clear at 60 feet and oriented broadside to Europe.

On the whole, signals averaged around 1 S-unit better with the dipole. There were plenty of exceptions both ways; sometimes the vertical did better, and sometimes the dipole provided a clear 2 S-unit advantage. In two hours of testing, I only encountered one situation where my 10-watt "test" SSB signal was readable on the dipole and unreadable on the vertical.

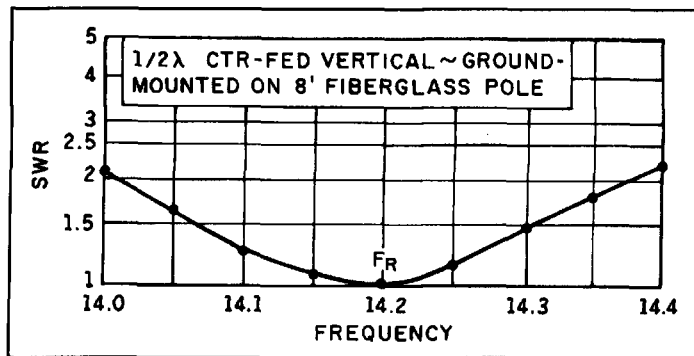


Figure 5. The antenna has a relatively narrow bandwidth suggesting high Q and good efficiency.

Considering the obvious height and orientation advantage enjoyed by the dipole, I was pleased with this performance.

### Other Bands

Although specifically designed for 20-meter operation, I've used the antenna on 15 and 17 meters with minor alterations. To change bands, disconnect the cross-arm jumper wire from the element (the lower loading coil and element tip are not used). Make sure the feedline balun remains connected. On 17 meters, attaching a 17-inch length of rigid aluminum wire at the lower element lug produced resonance at 18.100 MHz with a flat 1:1 VSWR. On 15-meters, the antenna resonated at 21.2 MHz with the top whip shortened to 39-1/2 inches and nothing connected to the bottom element lug. VSWR at resonance was 1.2:1—not perfect, but quite acceptable. On both bands, the feedline remained unreactive to movement and touch.

### Conclusion

From a technical standpoint, the VSWR characteristics, bandwidth (Q), and comparative on-air performance all suggest an antenna that radiates efficiently on 20 meters. It's well matched to 50-ohm line and handles 100 watts CW without difficulty. The design appears easy to replicate. I've built two thus far with identical operating characteristics. I don't know to what extent the element's induced asymmetry and 90-degree element bend impact upon the antenna's radiation pattern.

From a more subjective standpoint, the antenna does what I intended it to do. It's highly portable and weighs only a few pounds. The disassembled sections fit easily into a subcompact car and go together in a matter of minutes on virtually any site. This enables me to operate successfully from any location I choose.

#### REFERENCES

1. Charles J. Michaels, W7XC. "How Short Can You Make a Loaded Antenna." *Communications Quarterly*, Summer 1992, pages 73-80.

Dave Barton, AF6S, questions manufacturer's gain figures for a series of amateur Yagis.

## Yagi Gain versus Boom Length

David M. Barton, AF6S

The published gain figures for a new series of amateur Yagis grabbed my attention; they were six dB higher than I thought possible. A note at the bottom of the data sheet said the gains were calculated using Brian Beezley's YO or MN programs, for antennas 70 feet above average

| Antenna<br>Filename | F<br>MHz | Gain<br>dBd | f/b<br>dB | #EI | Boom<br>λ |
|---------------------|----------|-------------|-----------|-----|-----------|
| 20-3CD              | 14       | 6.0         | 23        | 3   | 0.28      |
| K6NA 340            | 7        | 6.0         | 26        | 3   | 0.30      |
| 12-4 CD             | 25       | 6.3         | 25        | 4   | 0.44      |
| 10-4 CD             | 28       | 6.6         | 23        | 4   | 0.45      |
| HG205CA             | 14       | 6.5         | 29        | 5   | 0.49      |
| HG155BA             | 21       | 7.3         | 21        | 5   | 0.54      |
| Amazing             | 14       | 7.0         | 43        | 4   | 0.55      |
| HG204BA             | 14       | 6.0         | 23        | 4   | 0.55      |
| Short 5             | 14       | 7.6         | 24        | 5   | 0.57      |
| W2PV 4              | 14       | 7.8         | 22        | 4   | 0.57      |
| KLM 510             | 28       | 7.2         | 18        | 5   | 0.58      |
| A50-5S              | 50       | 7.7         | 19        | 5   | 0.60      |
| KLM 520             | 14       | 7.4         | 19        | 5   | 0.60      |
| HG175CA             | 18       | 7.5         | 24        | 5   | 0.62      |
| HG105BA             | 28       | 7.7         | 19        | 5   | 0.65      |
| KLM 615             | 21       | 8.4         | 24        | 6   | 0.77      |
| W2PV 620            | 14       | 8.7         | 22        | 6   | 0.77      |
| KLM 610             | 28       | 8.0         | 20        | 6   | 0.79      |
| Nice 5              | 14       | 8.7         | 25        | 5   | 0.80      |
| Nice 6              | 14       | 8.7         | 27        | 6   | 0.80      |
| K8CC                | 28       | 8.5         | 25        | 5   | 0.82      |
| Packet              | 144      | 9.2         | 9         | 4   | 0.84      |
| Wideband            | 28       | 9.4         | 24        | 6   | 0.96      |
| A50-6S              | 50       | 8.9         | 31        | 6   | 1.00      |
| GreatFB             | 21       | 9.5         | 33        | 6   | 1.03      |
| Nice 7              | 28       | 9.9         | 26        | 7   | 1.15      |
| Six 5               | 50       | 10.2        | 20        | 5   | 1.17      |
| NBS 56              | 50       | 10.3        | 15        | 6   | 1.20      |
| KLM 620             | 14       | 8.4         | 23        | 6   | 1.21      |
| DXped               | 50       | 11.4        | 14        | 6   | 1.65      |
| Chen                | 144      | 10.5        | 5         | 6   | 1.69      |
| 617-6B              | 50       | 10.0        | 21        | 6   | 1.70      |
| A147-11             | 144      | 10.9        | 16        | 11  | 1.76      |
| Six 7               | 50       | 12.2        | 20        | 7   | 2.02      |
| NBS 122             | 144      | 12.0        | 17        | 12  | 2.20      |
| Max 10              | 144      | 14.0        | 14        | 10  | 3.50      |
| KLM 16LBX           | 144      | 14.1        | 22        | 16  | 4.10      |
| 17B2                | 144      | 14.5        | 25        | 17  | 4.50      |
| W6TSW 20            | 14       | 13.7        | 17        | 13  | 4.60      |
| K1FO 2270           | 432      | 15.7        | 22        | 17  | 6.11      |
| HG215DX             | 144      | 14.1        | 21        | 15  | 8.40      |
| Long 50             | 432      | 20.1        | 24        | 17  | 17.80     |

Table 1. Key figures for every design on YO.

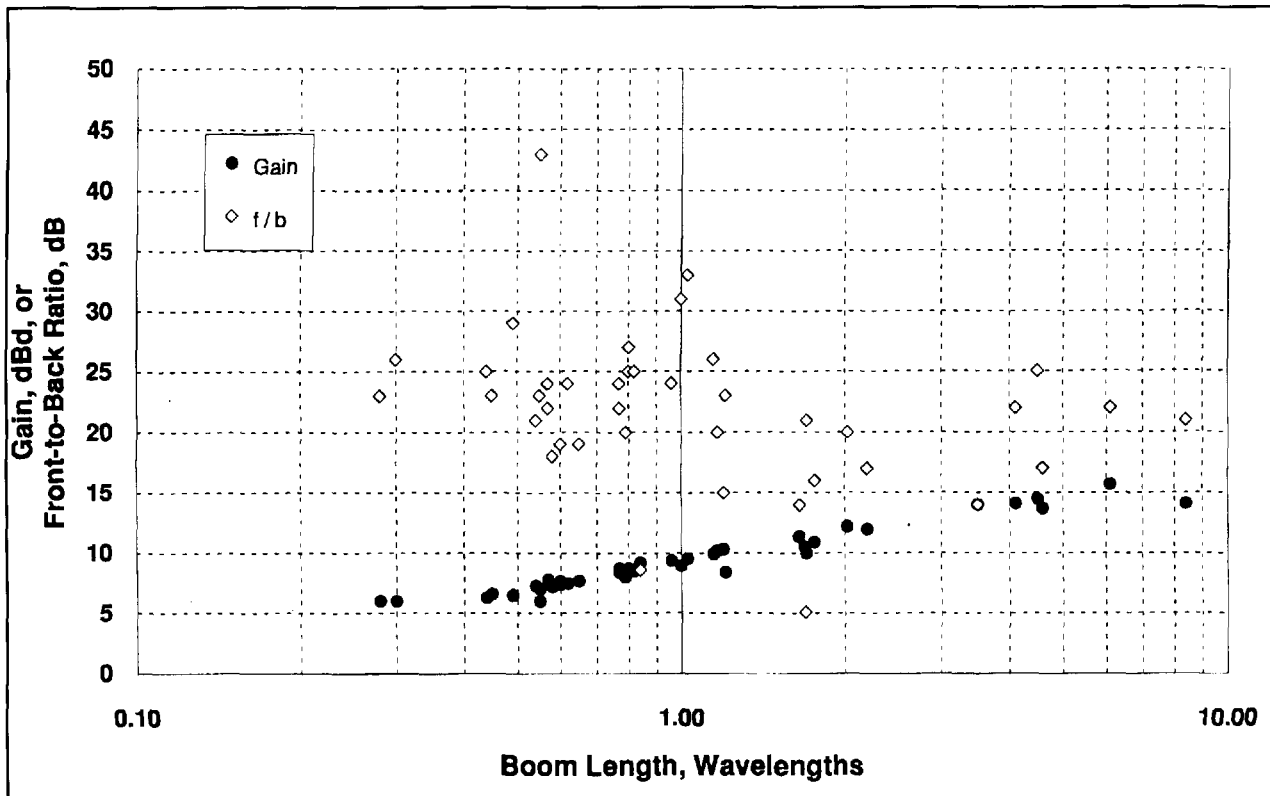


Figure 1. Gain and front-to-back ratio versus boom length.

ground, and that the figures were “computed in dBd (as compared to a dipole).”

There’s the rub! Gain in dBd means gain relative to a dipole in free space. But comparing a dipole in free space to another antenna over ground gives one antenna the advantage of a ground reflection.

What’s the bottom line? Over average ground, you get “ground gain” of about 5.5 dB for *any* horizontally polarized antenna. For a fair comparison, *both* antennas should be in free space or *both* should have the ground reflection.

To correct for claims of manufacturers who include ground gain in their figures, just subtract 5.5 dB. Doing so brings the 12.4 dBd gain of the four-element 20-meter Yagi (on the data sheet mentioned) down to 6.9 dBd. As we shall see, that’s “right” for a Yagi with a half-wavelength boom.

When comparing figures, it’s worth knowing how much gain an antenna of a particular size could have. Yagi gain increases with boom length. The number of elements, their placement, and tuning affect gain too, but for any boom length, all other variables can be optimized. One way to learn how much gain is possible, consistent with constraints (reasonable front-to-back ratio, bandwidth, etc.), is to look at computer-modeled figures for existing designs.

Brian Beezley’s YO (Yagi Optimizer) comes with antenna files on a great variety of Yagis—commercial designs, submitted designs, and famous published designs—such as those by W2PV and NBS (now NIST). It’s a good bet these designs have about as much gain as their boom lengths allow.

I ran YO and recorded the key figures for every design on the disk. **Table 1** lists the results in order by ascending boom length. **Figure 1** graphs the data, showing gain sweeping upward with increasing boom length. A boom 0.3 wavelength long gives about 6 dBd. To achieve 10 dBd, you need a 1-wavelength boom. More than 15 dBd is possible with a boom 5 wavelengths long.

The front-to-back ratios plotted in **Figure 1** don’t seem to correlate with boom length. Facing a tradeoff between gain and front-to-back, designers tend to limit front-to-back to no more than the application requires.

What does it all mean? Along with wooden nickels, be suspicious of quoted gains that greatly exceed those plotted in **Figure 1!**

*Now that we’ve looked at Yagi gain figures, let’s continue with some information building wire Yagis.*

## Design and Construction of Wire Yagi Antennas

Floyd A. Koontz, WA2WVL

**Wire Yagis** can be designed for high gain at radio amateur frequencies as low as 1.8 MHz. The mechanical construction I will describe was used to build a Yagi with a boom length of 350 feet and just two supports. The length could be increased beyond 1000 feet with additional supports. This antenna gives fixed area coverage in one direction (or two with reversible designs).

It's possible to stack two or more wire Yagis horizontally to increase gain and allow beam steering to obtain additional azimuth coverage. High gain necessarily results in narrow beamwidth, hence the need for steering.

### Construction

There are various construction methods for wire Yagis, but it's essential to have a practical way to raise and lower long booms before undertaking a computer design of the "ultimate" DX antenna. My European Yagi is supported between two 100-foot, Rohn 25 towers using 2100-pound Phillystran nonmetallic guy wire for the boom. I hung a 2.5-inch pulley at

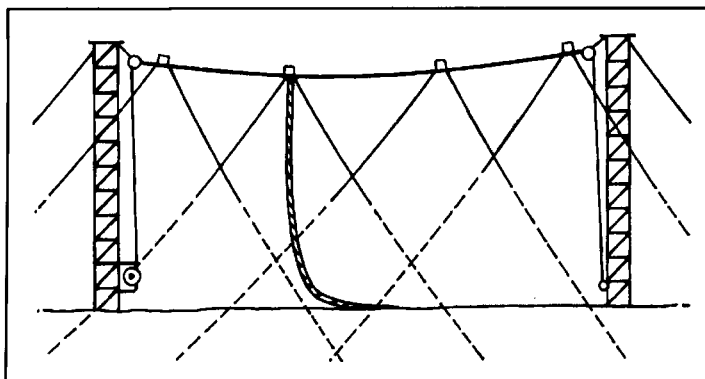


Figure 1. The author's European Yagi.

the top of each tower using a short length of heavy chain; a Quickline secures the chain and pulley to a tower leg. A beacon plate on the top of the tower prevents sidepull from damaging the tower (see **Figure 1**). The Phillystran is long enough to allow the boom to be lowered to the ground, so no additional tower climbing is required after the pulleys are mounted. A rope attached at each end of the Phillystran lets me raise the boom to 90 percent of its final height. The rope is then tied off, a wire rope is attached, and a boat winch is used to tension the boom. Using the catenary design information in *The ARRL Antenna Book*, and estimating the weight of the boom and wire elements, an 8-element Yagi for 75 meters requires a pull of 200 pounds to limit the sag in the middle of the span to 10 feet. This sag has a negligible effect on the electrical performance of the antenna, but you must consider the sidepull in guying the tower. As you can see in **Figure 1**, I used inverted-Vee elements and only two towers (or other supports) were needed.

The first Yagi I erected used 1/4-inch plastic ropes to pull out the ends of the wires. This worked, but I don't recommend it. On my next antenna, I used 130 pound test Dacron trolling line for this purpose. The Dacron is more suitable due to its low weight, low wind resistance, and near invisibility to neighbors. In my location (New York state), the Dacron has been outside for more than three years with no apparent damage from ultra-violet rays or bad weather. The Dacron lines must be anchored to ground supports above head level to prevent accidents. I made element clamps of 1 x 2 x 0.25-inch pieces of polyethylene sheeting. I then mounted a wire rope clamp, for 1/4-inch cable, to the 1 x 2 block with the nuts on the bottom. Small holes at each of the block let me secure the no. 12 hard-drawn copper wire used for the element.

### Computer Modeling

After you choose your boom length, you need to design the Yagi. How many elements

| No. of Elements | Spacing | Total Boom Length | Maximum Gain | 10° Gain  | Takeoff Angle |
|-----------------|---------|-------------------|--------------|-----------|---------------|
| 3               | .25λ    | 131 feet          | 12.79 dBi    | 6.45 dBi  | 32°           |
| 4               | .31λ    | 241 feet          | 14.07 dBi    | 8.55 dBi  | 30°           |
| 5               | .34λ    | 353 feet          | 15.02 dBi    | 10.19 dBi | 26°           |
| 6               | .36λ    | 472 feet          | 15.74 dBi    | 11.49 dBi | 23°           |
| 7               | .37λ    | 576 feet          | 16.29 dBi    | 12.55 dBi | 21°           |
| 8               | .39λ    | 705 feet          | 16.80 dBi    | 13.40 dBi | 20°           |
| 9               | .39λ    | 813 feet          | 17.23 dBi    | 14.14 dBi | 19°           |
| 10              | .41λ    | 961 feet          | 17.60 dBi    | 14.65 dBi | 19°           |

**Computed using K6STI's YAGI Optimizer Program (YO).**

Table 1. Boom length for maximum gain. 3.8-MHz horizontal wire beam at 85 feet (no. 12 copper conductors with losses).

| Average Height | Boom Length<br>at 3.8 MHz | No. of Elements   |
|----------------|---------------------------|-------------------|
| 135 feet       | 200 feet                  | 4                 |
| 120 feet       | 300 feet                  | 5                 |
| 100 feet       | 400 feet                  | 6                 |
|                |                           | (15.10 dBi @ 23°) |
| 87 feet        | 465 feet                  | 7                 |
| 73 feet        | 530 feet                  | 8                 |
| 63 feet        | 600 feet                  | 9                 |
| 56 feet        | 700 feet                  | 10                |
|                |                           | (15.46 dBi @ 23°) |
| 50 feet        | 800 feet                  | 11                |

**Computed using K6STI's YAGI Optimizer Program (YO).**

Table 2. Boom length versus average height for 6-dB gain over W1CF 4-square antenna at 10 degrees (11 dBi). (No. 12 copper conductors with losses.)

with what spacing should you use?

I gained a great deal of insight from Jim Lawson's, W2PV, book, *Yagi Antenna Design*, which is available from the ARRL. Jim did extensive computer modeling of Yagis up to 6 elements using NEC (Numerical Electromagnetic Code). His book is certainly required reading for anyone designing Yagis, and most of his conclusions have been verified by using Brian Beezley's software programs YO and MN.

When it comes to designing Yagis, there's no single best design. A tradeoff is always required between gain, front/back, broadband operation, feedpoint resistance, and so on. As W2PV and others have pointed out, the gain is proportional to boom length. The number of elements and their spacing has a minor effect on gain (assuming the minimum number of elements are used).

One of the first things I did was to compute the boom length providing maximum gain when the number of elements are fixed. The results are quite different when the element losses are included, and tend to result in wider spacing than is commonly used in aluminum-constructed Yagis.

Table 1 shows the optimum boom length for maximum gain with 3 to 10 elements at 3.8 MHz with an average height of 85 feet. What is meant by average height? The YO software is limited to analyzing horizontal Yagis, so most of the designs I'll describe are optimized on YO then converted to inverted-Vee designs and recomputed using MN. The elements generally must be lengthened 12 to 30 inches (3.8-MHz design) to get back to the design frequency. For the estimated vee angle expected (120 degrees), a Vee-Yagi hung from 100 feet provided about the same gain as a horizontal Yagi at 85 feet.

You can draw two conclusions can be drawn from the data in Table 1.

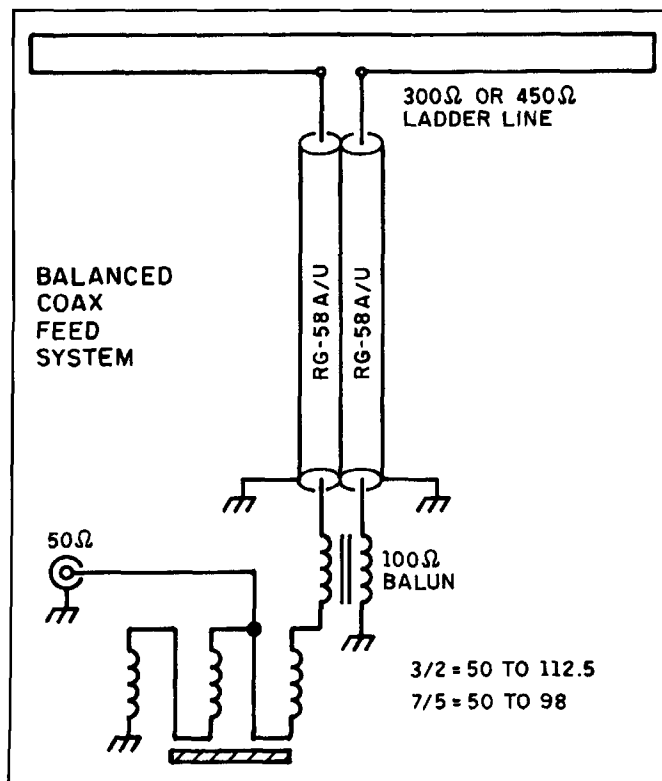


Figure 2. Balanced coax feed system used on Yagi 3.

a) Takeoff angles from the antenna can be lowered significantly by lengthening the boom at the same average height above ground.

b) As the boom is lengthened, gain at angles lower than the main lobe increases faster than at the main lobe. The gain at 10 degrees is shown versus the boom length.

The gains and boom lengths shown in Table 1 would change somewhat at other average heights, but the trends are expected to be the same. On the longer booms, one or two addi-



tional directors should be used because the pattern will improve with little decrease in gain. The wide spacing that provides maximum gain also allows a slight adjustment of the driven element position to obtain a 50-ohm feed impedance. All of the wire Yagis I've built to date have been fed directly with RG-58a/u, without a balun, to minimize the weight that must be lifted on the boom. RG-58 is adequate for maximum legal power in intermittent modes like CW and SSB. The coax drops straight down from the boom and should be anchored at both ends with stress relief on the cable jacket to prevent the wind from pulling the cable from the connectors.

## Yagi Designs

Before discussing specific Yagi designs, it's helpful to have a reference antenna to compare against. On 75 meters, the W1CF, "4-square array" is becoming the DXers' antenna of choice, so I used it as the reference for most of the antennas discussed below. The 4-square array has about 6.5 dBi of gain with a takeoff angle of 21 degrees over average soil. **Table 2** gives boom length versus average height for 6 dB gain over the W1CF 4 square at 10 degrees.

I designed several Yagis using the YO/MN technique and over plotted with the 4-square patterns. A summary of my results follows.

**Yagi 1.** Four horizontal elements on a 180-foot boom, optimized for front-to-back. This antenna has a gain of 11.7 dBi, an F/B greater than 30 dB, and a feed resistance of 20.5 ohms. Yagi 1 exceeds the gain of a 4 square above 10 degrees.

**Yagi 2.** Four inverted Vee elements on a 180-foot boom, 90-degree vee angle. This antenna has a 10.8 dBi of gain, an F/B greater than 27 dB, a resistance of 19.7 ohms, and exceeds the gain of a 4 square above 11 degrees.

**Yagi 3.** Five active horizontal elements, reversible with two relays on the boom. Effective boom length is 188 feet. Total span is 304 feet.

This antenna will impress your friends with its great front-to-back. It has a gain of 11.8 dBi and an F/B of more than 35 dB. It was necessary to use a balanced feed system, so I adjusted the feed resistance to approximately 25 ohms. A piece of transmitting "ladder line" would be used as a folded dipole, transforming the feed resistance to 100 ohms. A pair of RG-58 coax cables would bring the feed to the ground where a ferrite transformer would step down the impedance to 50 ohms (see **Figure 2**). Gain exceeds a 4 square above 9 degrees.

**Yagi 4.** Eight horizontal elements on a 350-foot boom, reversible with relays on the boom. Element lengths and spacings are symmetrical

about the center of the boom, so the pattern can be reversed by relays. The end elements are reflector length with center capacitors for director tuning. The second and seventh elements are the correct length to be fed as a driven element or tuned as a director with a series capacitor. With a uniform spacing of 50 feet between all elements, gain is 14.3 dBi, F/B is 26.2 dB and the feed resistance is 34.1 ohms. By moving the driven element (both ends) to 65 feet from the reflector, the feed resistance rises to 48.9 ohms, while gain is 14.27 dBi and F/B is 33.49 dB. Gain exceeds a 4 square above 4 degrees. Average antenna was 85 feet.

**Yagi 5.** Eight-element Vee-Yagi on a 350-foot boom, reversible with relays on the boom. This antenna is the inverted-Vee version of Yagi 4. Support height is 100 feet and the vee angle between the wires is 120 degrees. Gain is 14.0 dBi, F/B is 23.5 dB, and feed resistance is 46.3 ohms. Gain exceeds a 4 square above 4 degrees.

**Yagi 6.** Eight-element vertical Yagi on 350-foot boom. The antenna is a vertical version of Yagi 4. Although the main lobe is at 12 degrees, gain is poor and barely exceeds a 4 square at low angles. The sidelobes are also very poor.

**Yagi 7.** Dual eight-element horizontal Yagis, spaced 325 feet apart. This antenna is a pair of Yagi 4s. When fed in-phase, gain is 17.4 dBi, F/B is 31.4 dB, and feed resistance of each Yagi is 47.4 ohms. Take-off angle is 25 degrees, with a horizontal beamwidth of 23 degrees. Gain exceeds a 4 square above 2.5 degrees, and by more than 10 dB at higher angles. Feeding one Yagi at -90 degrees moves the main beam by 10 degrees. Feeding 180 degrees out-of-phase produces two lobes about 20 degrees off-axis. Gain is reduced to 15.1 dBi.

**Yagi 8.** Four horizontal elements on 160 meters at 80 feet. This antenna uses 4 elements, uniformly spaced on a 300-foot boom. With an average height above ground of only 80 feet, gain is 11.0 dBi with an F/B of 19.3 dB. A 1/4-wavelength vertical is used for plot comparison.

**Yagi 9.** Four inverted-Vee elements on 160 meters hung from 100 foot supports. This antenna is the inverted-Vee version of Yagi 8, with the ends near the ground. Computed gain is 8.7 dBi, with an F/B of 31.9 dB. Feed resistance is 23.3 ohms, but is probably in error due to ground proximity.

**Yagi 10.** Four elements on 160/8 elements on 75 interlaced. This antenna consists of Yagi 4 and Yagi 8 interlaced on the same boom. At 1840 kHz, gain is 11.1 dBi and F/B is 17.4 dB. At 3800 kHz, gain is 13.8 dBi, while F/B is 22.4 dB. By moving the 75-meter driven elements back to 50 feet from the reflector, the feed resistance was restored to 48.0 ohms with essentially no change in performance on either band.

**Yagi 11.** Three-element, short-boom, 75-meter reversible Yagi at 80 feet. This small three-element Yagi has 10.3 dBi of gain with an F/B of 17.3 dB. Gain exceeds a 4-square above 14 degrees.

### Editor's Note

Mr. Koontz first presented his paper on Yagi design and construction at the 1993 Dayton Hamvention™ Antenna Forum. For plots and pattern information for all antennas discussed here send an 8 x 10 SASE with \$1 postage to *Communications Quarterly*, P.O. Box 465, Barrington, New Hampshire 03825-0465. For a single plot, send a business envelope with \$.29 postage. Be sure to indicate which plot you wish to receive.

*For this issue's final Tech Note, we present an antenna coupler from down under—a Z-Match that uses a single coil.*

## A Single Coil Z-Match Antenna Coupler

*T.J. Seed, ZL3QQ*

*Reprinted with permission from Break-In, March 1992.*

The genesis of impedance matching circuits is in the "L-section" network of which there are four arrangements. One of these uses a series capacitor and a shunt inductance. Such a circuit (**Figure 1A**) will match a high resistance  $R_{hi}$  on the load (inductance) side to a low resistance  $R_{lo}$  on the generator (capacitor) side with  $Q$  given by:

$$Q = \sqrt{\frac{R_{hi}}{R_{lo}} - 1}$$

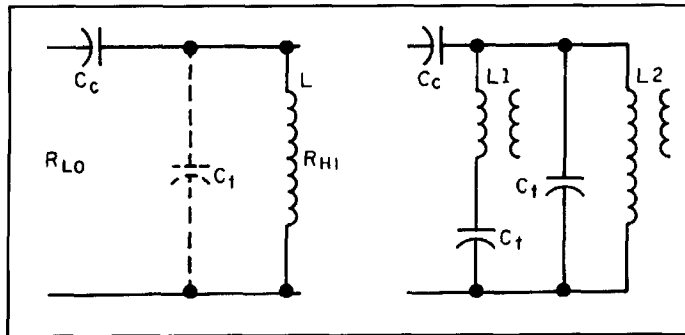
and component values:

$$X_L = R_{lo} \times Q$$

$$X_C = R_{hi} \div Q$$

If  $Q^2 \leq$  either (1) the source and load may be interchanged, or (2) a step-down secondary winding may be placed on  $L$ .

To cover a range of operating frequencies, both the capacitor and inductance must be variable. Variable capacitors are commonly available, while an inductance can be made "variable" by placing a capacitor  $C_T$  across it and tuning this parallel combination to the low side of the operating frequency. This, and the "secondary winding" technique is what is used in the Z-Match—and also in the Gamma match on beam antennas.



**Figure 1.** (A) Single coil Z-Match. (B) Conventional Z-Match.

The conventional Z-Match shown in **Figure 1B** uses two coils  $L_1$  and  $L_2$  and two capacitors  $C_T$ ,  $C_T$ , which here are taken to be ganged, variable, and of equal capacity, to form what may be thought of as the "variable" inductance of an "L-section" network.

This combination exhibits parallel resonance at two different frequencies  $F_{lo}$  and  $f_{hi}$  with a series resonance  $f_{series}$  between them for any particular setting of the twin capacitor  $C_T$ .

This circuit is known to have been described as early as March 23, 1918 in Circular C74 of the Bureau of Standards, which includes reference to the use of the series resonance condition to suppress unwanted harmonics!

There are seven other possible configurations of two coils and two capacitors that can produce the same characteristics.

The choice of  $L_1$ ,  $L_2$ , and  $C_T$  determines the frequency coverage of the relevant sectors  $f_{lo}$ ,  $f_{series}$ , and  $f_{hi}$ . It is generally preferred that no mutual inductance coupling exists between  $L_1$  and  $L_2$ , if only to avoid the algebraic complication it introduces into the network's solution.

The frequency coverage of this multi-resonant circuit versus the rotation of the ganged condenser tuning shaft is of the general form shown in **Figure 2**. The lines subscripted "hi" and "lo" and "series" represent the loci of the two parallel and the series resonances, while the bars below the frequency abscissa show the frequency ranges of the low and high frequency parallel resonances obtained simultaneously as the capacitor is tuned through its minimum to maximum range. Though shown here as straight, such lines will be curves that are functions of the tuning law of the particular capacitors used. The parallel resonant frequencies are found from the relations:

$$f_{hi} = H \times f_d, f_{lo} = J \times f_d$$

where  $f_d$  is a design frequency that, with the multiplying factors  $H$  and  $J$  for the case of the single coil Z-Match, will be derived below and in the Appendix.

Given the principle outlined above, Z-Match

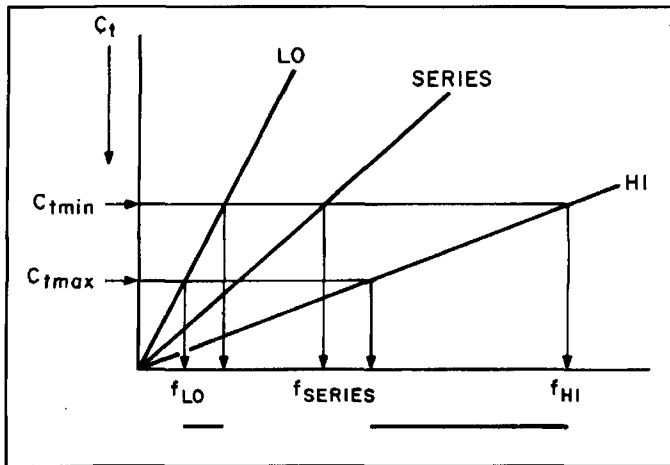


Figure 2. The frequency coverage of the multi-resonant circuit versus the rotation of the ganged condenser tuning shaft.

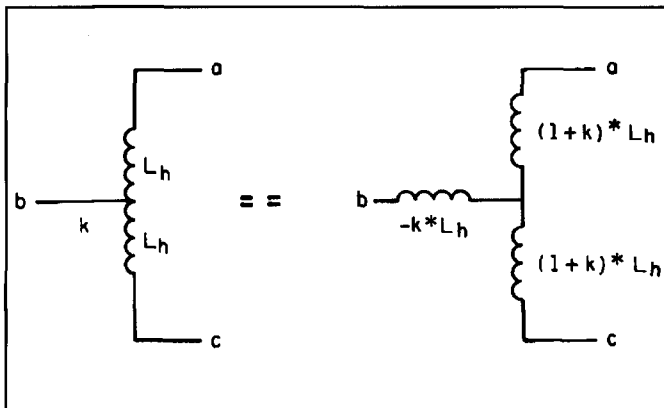


Figure 3. When a coil is tapped as shown in (A), the equivalent circuit of (B) is formed.

construction can be simplified to a single coil configuration by forming the series element  $L_1 C_1$  of **Figure 1B** by connecting one of the  $C_T$  to a tap on the coil.

When a coil is tapped as shown in **Figure 3A** (and here only a tap at the center of the coil is considered), the equivalent circuit of **Figure 3B** is formed. In the figure,  $L_h$  is the self-inductance of one-half of the coil and  $k$  is the coefficient of coupling between halves. Limiting the approximations to those applicable to calculations for the self-inductance of coils whose length is greater than about  $0.8 \times$  diameter, numerical values may be calculated from:

$$L_h = \frac{d \times N_h^2}{40 \times S + 18} \text{ and } k = \frac{9}{20 \times S + 9}$$

where:

- $L_h$  = inductance of half coil in microhenries
- $S$  = shape factor of coil =  $l \div d$
- $l$  = length,  $d$  = diameter of coil in inches, and

$N_h$  = half the total number of turns on the coil.

The Z-Match coupler using the center-tapped coil is shown in **Figure 4**. The design equations in terms of the coupling-coefficient  $k$  and a design frequency given by:

$$f_d = \frac{1}{2\pi \sqrt{L_h \times C_T}}$$

are the same as those above for two coil, two capacitor design, but the multiplying factors  $H$  and  $J$  have a different basis. Since the frequency tuning ratio of a capacitor is inversely proportional to the square root of its capacity ratio, and since  $f_d$  varies with the value of  $C_T$ , the frequency range covered is given by:

$$\frac{f_{d\ hi}}{f_{d\ lo}} = \sqrt{\frac{C_{T\ max}}{C_{T\ min}}} = \frac{H}{J}$$

Consequently, whether the low and high frequency ranges (shown as bars along the abscissa in **Figure 2**) will be separated, or just touch to give continuous coverage, or overlap with reduced coverage, will depend on the ratio  $H/J$ , which it is convenient to denote by  $M$ .

The values of  $H$  and  $J$ , which are functions of  $k$  only, vary slowly with  $k$  as may be seen in **Figure 5A**; their numerical values are listed in the Appendix. The square of their ratio,  $M^2$ , as a function of  $k$  is more relevant to this discussion since this has been shown to be equal to the ratio of the maximum to minimum value of, or section of, the capacitor to be used. However, within the approximation, the value of  $k$  is dependent only on the shape factor  $S = l \div d$ ; the relation between  $S$  and  $k$  is shown in **Figure 5B**.

By entering a known value of capacity in **Figure 5C** and dropping a line vertically from the intercept with the curve, the required value of  $k$  may be found, and continuing the line up to **Figure 5B** the intercept with that curve yields the shape factor  $S = l \div d$ . Continuing on up, the values of the multipliers  $H$  and  $J$  may be read from **Figure 5A**, whence  $H$  lies between about 1.6 and 2.0, and  $J$  between 0.6 and 0.5.

Alternatively, if one has a coil available, calculate the coupling coefficient  $k$  from the shape factor  $S$ , and a vertical line at this value through the curves will yield the capacitor ratio, and  $H$  and  $J$ .

To see how this works in practice, suppose one wishes to use a capacitor with maximum and minimum values of 350 pF and 39 pF, then  $M^2 = 9$ . From **Figure 5C**,  $k$  is found to be 0.14. The value of  $k = 0.14$  in the top graph given  $H$  and  $J$  roughly, but substituting in the equations or from **Table 1** in the Appendix yields, to two decimals,  $H = 1.43$ ,  $J = 0.58$ .

Since the measurement of  $C_{Tmax}$  is more reliable than that of  $C_{Tmin}$ , it is better to start calculating from the low frequency end.

Suppose this to be 3.4 MHz:

$$\text{then } 3.4 = J \times (f_d)_{min} = 0.58 \times (f_d)_{min}$$

$$\text{whence } (f_d)_{min} = 5.9 \text{ MHz}$$

and therefore using  $C_{Tmax} = 350 \text{ pF}$  in the expression for  $f_d$ , the half coil inductance  $L_h$  is found to be  $2.1 \text{ } \mu\text{H}$ .

The frequency tuning ratio of the capacitor being 3:1, the upper value:

$$(f_d)_{max} = 17.5 \text{ MHz}$$

$$\text{and } (f_{io})_{max} = 10.2 \text{ MHz.}$$

$$\text{Similarly, } (f_{hi})_{min} = H \times (f_d)_{min}$$

$$= 1.73 \times 5.9$$

$$= 10.2 \text{ MHz}$$

$$\text{and } (f_{hi})_{max} = H \times (f_d)_{max}$$

$$= 1.73 \times 17.7$$

$$= 30.6 \text{ MHz}$$

Thus this capacitor will enable continuous coverage, in the sense that there will always be a parallel resonance between 3.4 and 30 MHz.

From the earlier relation for  $(f_d)_{min}$ , the half-coil inductance  $L_h$  was found to be  $2.1 \text{ } \mu\text{H}$ . The middle graph tells us that for  $k = 0.14$  the desired length to diameter ratio is 2.76.

Reworking the equation for inductance in terms of length, diameter, and turns:

$$N_{Total} = 2 \times \sqrt{\frac{(18 + 40 \times S) \times L_h}{d}}$$

If a coil diameter of 2 inches is used, then 23 turns over a length of 5.5 inches, center-tapped, should do the job.

Design of the secondary winding will not be dealt with here as the number of turns and its coupling coefficient will depend upon the impedance of the antenna to which it is connected—very likely a wildly varying frequency dependent quantity peculiar to each station's installation. However, this part of the application should present little difficulty. If the load impedance is low and/or unbalanced, the secondary winding is best wound over the earthy end of the coil. If it is high (on the order of hundreds of ohms) and balanced, then winding over the center of the coil preserves a better potential distribution when the coupling capacitor is connected to the center of the coil.

The author uses a 300-pF coupling capacitor to the top of a coil of 14 turns spaced over 3 inches on a 2.25-inch former, and a twin tuning capacitor of 240/28 pF. The secondary winding is nine turns inter-wound with the primary tapped at two and five turns. This allows two, three, four, five, seven, or nine turns to be connected to the load.

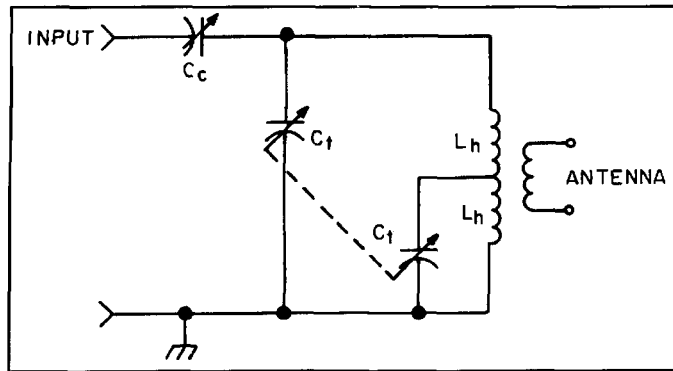


Figure 4. Z-Match coupler using the center-tapped coil.

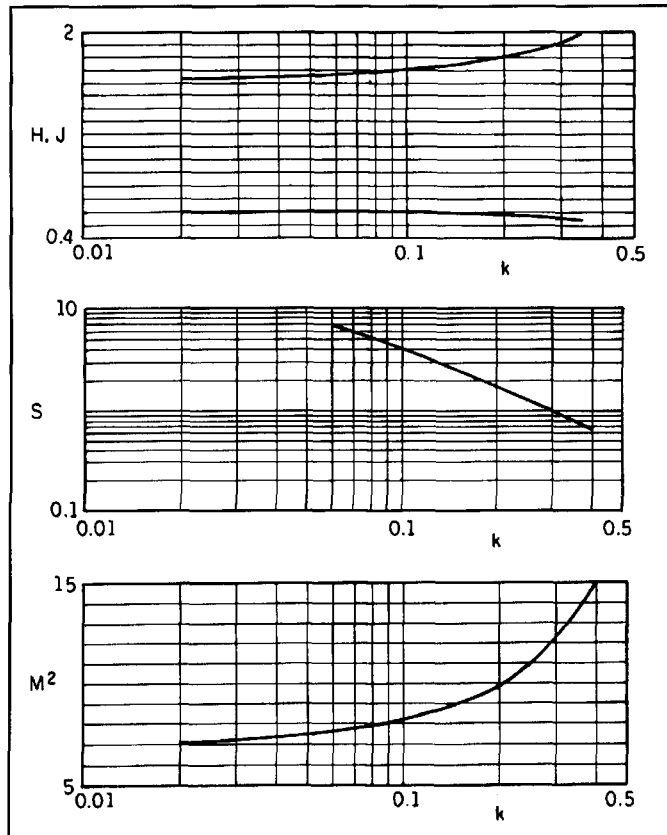


Figure 5. (A) The values of H and J, vary slowly with k. (B) The relation between S and k. (C) Finding the required value of k.

## Appendix

It is required to obtain resonance conditions that exist in the circuit when the quantities from **Figure 3B** pertain. The impedance expression results in a fourth-order equation, the solutions to which are conveniently expressed for sum and difference conditions as follows:

$$\left[ \frac{f}{f_d} \right]^2 = H^2 \text{ and } \left[ \frac{f}{f_d} \right]^2 = J^2$$

where:

| k    | S     | H     | I     | J     | M <sup>2</sup> |
|------|-------|-------|-------|-------|----------------|
| 0.02 | 22.05 | 1.633 | 1.414 | 0.613 | 7.105          |
| 0.04 | 10.8  | 1.648 | 1.415 | 0.607 | 7.366          |
| 0.06 | 7.05  | 1.664 | 1.417 | 0.602 | 7.639          |
| 0.08 | 5.175 | 1.68  | 1.419 | 0.597 | 7.924          |
| 0.10 | 4.05  | 1.698 | 1.421 | 0.592 | 8.222          |
| 0.12 | 3.3   | 1.715 | 1.425 | 0.587 | 8.534          |
| 0.14 | 2.764 | 1.734 | 1.428 | 0.582 | 8.861          |
| 0.16 | 2.363 | 1.753 | 1.433 | 0.578 | 9.203          |
| 0.18 | 2.05  | 1.773 | 1.438 | 0.573 | 9.563          |
| 0.20 | 1.8   | 1.794 | 1.443 | 0.569 | 9.941          |
| 0.22 | 1.595 | 1.816 | 1.45  | 0.565 | 10.339         |
| 0.24 | 1.425 | 1.838 | 1.457 | 0.56  | 10.758         |
| 0.26 | 1.281 | 1.862 | 1.465 | 0.556 | 11.199         |
| 0.28 | 1.157 | 1.886 | 1.473 | 0.552 | 11.666         |
| 0.30 | 1.05  | 1.912 | 1.482 | 0.548 | 12.16          |
| 0.32 | 0.956 | 1.939 | 1.493 | 0.544 | 12.682         |
| 0.34 | 0.874 | 1.967 | 1.504 | 0.541 | 13.237         |
| 0.36 | 0.8   | 1.996 | 1.516 | 0.537 | 13.827         |
| 0.38 | 0.734 | 2.027 | 1.529 | 0.533 | 14.454         |
| 0.40 | 0.675 | 2.06  | 1.543 | 0.53  | 15.124         |

Table 1. Data required for HF band use.

$$H^2 = \frac{(3 + 2 \times k) + \sqrt{8 \times k^2 + 12 \times k + 5}}{2 \times (1 - k^2)}$$

and:

$$J^2 = \frac{(3 + 2 \times k) + \sqrt{8 \times k^2 + 12 \times k + 5}}{2 \times (1 - k^2)}$$

These relations were shown in the text as:

$$f_{hi} = h \times f_d, \text{ H constant, } >1,$$

$$f_{lo} = j \times f_d, \text{ J constant, } <1$$

The series resonance, which as noted earlier may be used for harmonic suppression, may be found from:

$$f_{series} = I \times f_d, \text{ where } I = \sqrt{\frac{2}{1 - k^2}}$$

As may be seen from **Figure 5**, the parameters H and J vary slowly with k, but their ratio less so. The coupling coefficient k varies only slowly over wide variations in shape factor S, so that design is very tolerant.

The data required for HF amateur band use is presented in **Table 1**.

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One of the chip's features is field recordability which accommodates local accents and

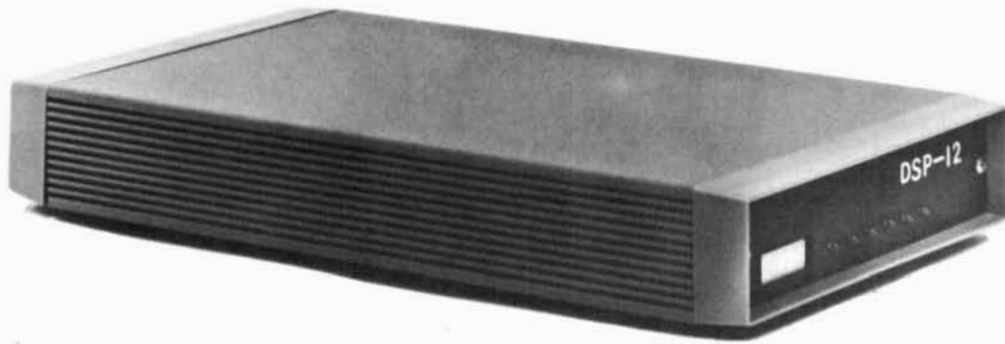
dialects in different languages.

The chip technology includes non-volatile power which saves messages during power outages; high voltage for writing to non-volatile memory cells; digital chip management functions; and, CMOS low power operation. This combination makes possible self-contained recording functions like pre- and post-amplification, filtering, analog signal processing, digital control and power management circuits.

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# LETTERS

## **Polarity dots helpful**

Jerry Sevick gave a number of reasons why he does not use polarity dots in the schematics of his baluns. The schematics are valid for him and others of his stature, but for those of us (including myself) who wondered why he didn't, they were necessary for us to follow his explanations on how the baluns work and how to wind them, in our efforts at understanding and learning what he is presenting.

Winding directions and sequence of connections (which end is which) are important, and although he and others in the know do not need instruction on how to wind and connect the coils, we do!

Since polarity dots normally signify transformers and this is not the concept he wants to instill, another way to help us in our learning how the baluns operate and how to wind them can be to use S and F, for Start and Finish, assuming all the coils are wound in the same direction.

When I tried to follow his schematics against his explanations, I found it extremely difficult and sometimes impossible to correlate the two in many situations, and it appeared as if I would have to reverse the connections to some of the coils in the schematics to make things work according to his explanation. I was unsure that I had understood correctly, at sea on the subject.

When two or more coils are wound together there are flux linkages between them, whether they operate as a coiled transmission line or otherwise, and then direction of current flow (polarity, if you will) does become important, more so when three or more windings are interconnected in a complicated (to us) hook up.

I eventually had to give up, and the articles were of no help, for lack of some kind of identification of the start and finish ends and the winding direction. The fact that transformer and polarity concepts were not involved, transmission line concepts instead, made it more difficult for us in the learning situation, and the lack of any identification whatsoever made it worse.

The reason many of us "wondered" why he didn't use polarity marks is that we were in trouble understanding. It wasn't idle curiosity. As it stands now, the articles were almost a total loss as far as I am concerned, and I

wouldn't be at all surprised if this was true of many others, especially those who wanted polarity marks. I wonder if you can prevail upon him to publish the same schematics with at least S and F on the windings, to shed more light on the subject. I spent much fruitless time trying to correlate explanation with schematic with photographs (very difficult to make out), eventually for naught. Even his use of not strictly apropos polarity dots to help us learn is far better than those horrible water analogies that are used to "explain" to learners how electrical circuits work!

**Ted Chernin, KH6GI**  
**Honolulu, Hawaii**

## **A disappointed reader**

I received my first issue of *Communications Quarterly*, Spring 1993, and started reading at the beginning with Dick Weber's article on wind loading. I was disappointed. I don't have a Yagi or a tower, but I am in the process of figuring out what I need in that department, so wind loading is an important consideration for me.

I found the article hard to read. Subscripts were not printed as subscripts.  $Vc^2$  looks to me a lot like  $mc^2$  as in Einstein's very famous formula  $E=mc^2$ . In the article, the square applies to V, not the c, but one could not tell it from the way it was printed.

The use of "ang" for an angle was also disappointing. If one wants to avoid the use of Greek letters, such as theta (this dumb computer does not seem to have a theta), one could have used "B" instead. I find "ang" less than satisfactory.

I also find it peculiar that there were two figures, 6A and 6B, that appear to give identical results, or maybe I just gave up at that point.

My point is that the article was trying to present something of potential interest, but the editor did not bother to edit it so it turned out worse than it should have.

**C. Darden**  
**Lexington, South Carolina**

## **A complete address and correct call sign**

Thank you for your very kind letter of February 26, 1993, and for publishing my letter in your Spring 1993 issue.

*(Continued on page 106)*

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| RS-7A  | •      | •     | 5                      | 7           | 3 $\frac{3}{4}$ x 6 $\frac{1}{2}$ x 9               | 9                   |
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| RS-12A | •      | •     | 9                      | 12          | 4 $\frac{1}{2}$ x 8 x 9                             | 13                  |
| RS-12B | •      | •     | 9                      | 12          | 4 x 7 $\frac{1}{2}$ x 10 $\frac{3}{4}$              | 13                  |
| RS-20A | •      | •     | 16                     | 20          | 5 x 9 x 10 $\frac{1}{2}$                            | 18                  |
| RS-35A | •      | •     | 25                     | 35          | 5 x 11 x 11                                         | 27                  |
| RS-50A | •      | •     | 37                     | 50          | 6 x 13 $\frac{3}{4}$ x 11                           | 46                  |
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| RS-35M                          | 25                     | 35          | 5 x 11 x 11                             | 27                  |
| RS-50M                          | 37                     | 50          | 6 x 13 $\frac{3}{4}$ x 11               | 46                  |
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| VS-20M                               | 16                     | 9      | 4     | 20          | 5 x 9 x 10 $\frac{1}{2}$                | 20                  |
| VS-35M                               | 25                     | 15     | 7     | 35          | 5 x 11 x 11                             | 29                  |
| VS-50M                               | 37                     | 22     | 10    | 50          | 6 x 13 $\frac{3}{4}$ x 11               | 46                  |
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| RS-10S | •      | •     | 7.5                    | 10        | 4 x 7 $\frac{1}{2}$ x 10 $\frac{3}{4}$              | 12                  |
| RS-12S | •      | •     | 9                      | 12        | 4 $\frac{1}{2}$ x 8 x 9                             | 13                  |
| RS-20S | •      | •     | 16                     | 20        | 5 x 9 x 10 $\frac{1}{2}$                            | 18                  |
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So far I have gotten one reply to the published letter, from H.H. Marsh, W6TFQ. He suggested four possible sources. If push comes to shove, I will write to those four.

Meanwhile, and quite by chance, I have picked up a box of 50 coil forms of the smallest size. These were made by Cambion. They will meet my needs for some time. I will keep looking for the larger sizes of coil forms, which are more widely useful. The small ones came from Alltronics in San Jose.

Thank you again for your help.

**Jim Lomasney, WA6NIL**  
2501 Waverly Street  
Palo Alto, California 94301

P.S. I see that you incorrectly gave my call as WAINIL with an incomplete address when you published my letter. Perhaps this is partly why I got only one response. Thanks again

# PRODUCT INFORMATION

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Communications Specialists, Inc. announces their new 25th Anniversary Catalog. The catalog is free and contains listings and descriptions of CTCSS and Digital CTCSS encoders and decoders, repeater products, paging encoders and decoders, and other miscellaneous tone devices.

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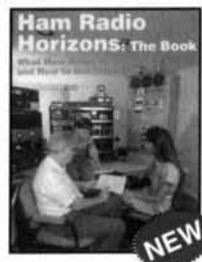
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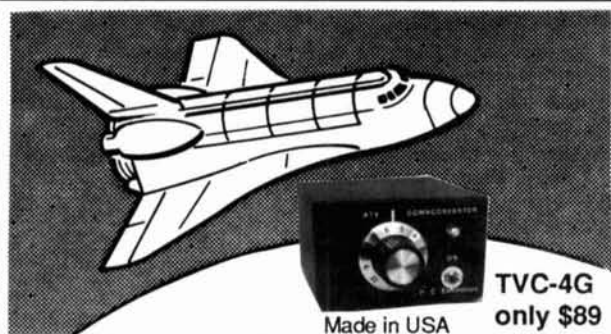
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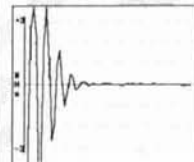
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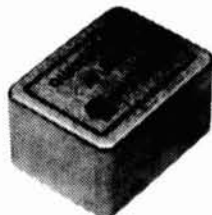
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