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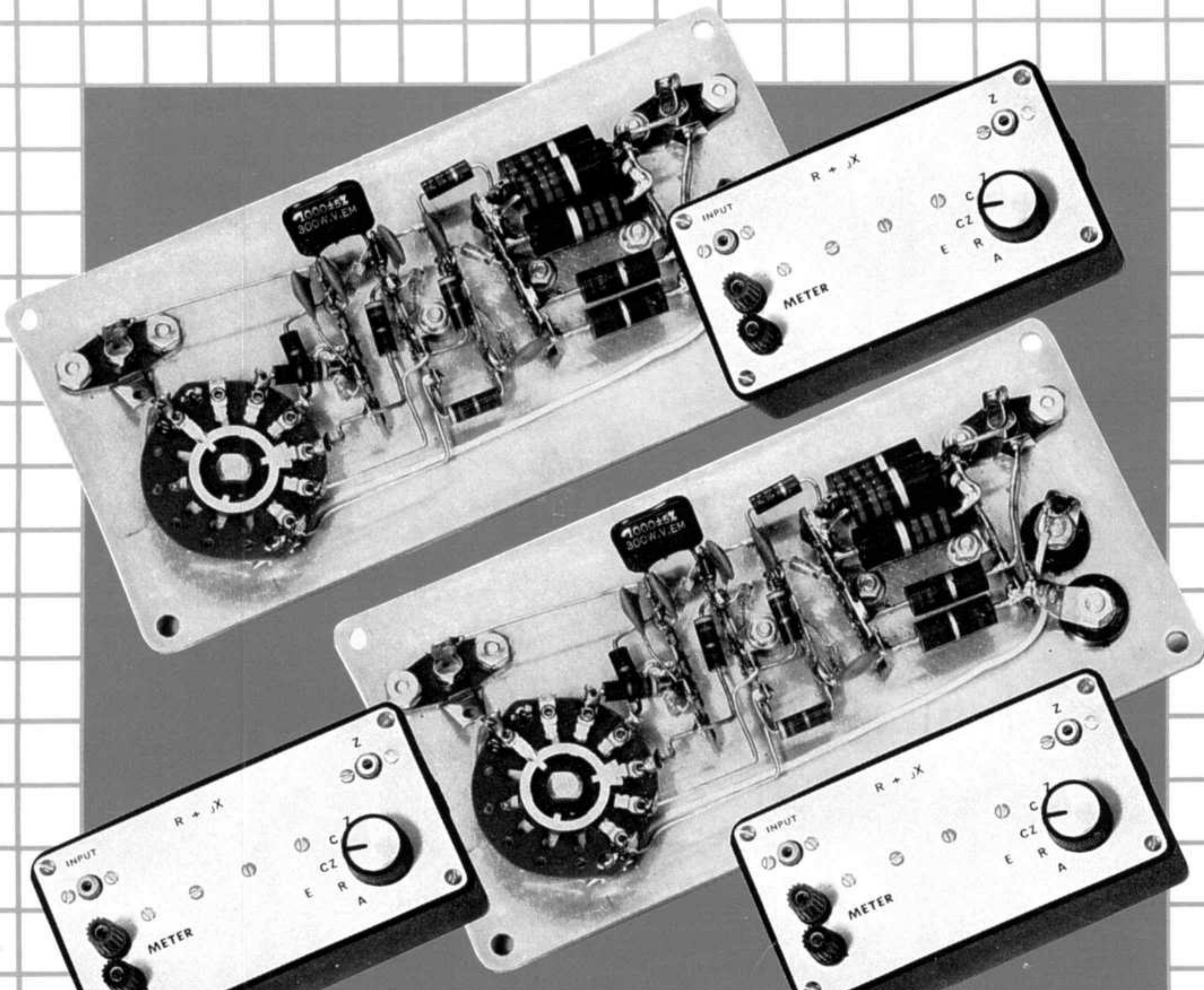

Amateur Measurement of R + jX

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By Barry McLarnon, VE3JF

The ripple counter found in previous encoder circuit designs has been replaced with a synchronous binary counter to enhance operation of the circuit. At the flip of a switch, you can select either the Manchester encoded output needed to drive an FM transmitter for a JAS-1/OSCAR 12 uplink, or binary PSK which is compatible with the JAS-1 PSK demodulator.

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By Bill Olson, W3HQT

RF relays come in many varieties to handle different power levels and frequencies. Good isolation, coil voltage, switching time characteristics, and its impedance rating are only some of the considered specifications. Find out how to choose the right relay for your station.

13 Centimeters — **15**

By Bill Olson, W3HQT

Interested in getting on the 13-cm band? Here's a description of available commercial equipment, and where to find it.

ABOUT THE COVER

Strandlund's impedance measuring unit. The front aluminum panel measures 3 × 5 inches, and the circuit is housed in a plastic enclosure. Input and output jacks are mounted in the upper corners. The VTVM terminals reside at the left of the unit, and the voltmeter switch is shown to the right. The internal view shows resistors and capacitors supported on tie-point strips.

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Purposes of *QEX*:

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2) document advanced technical work in the Amateur Radio Field
3) support efforts to advance the state of the Amateur Radio art.

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Both theoretical and practical technical articles are welcomed. Manuscripts should be typed and double spaced. Please use the standard ARRL abbreviations found in the 1985 and 1986 ARRL Handbooks and in the January 1984 issue of *QST*. Photos should be glossy, black-and-white positive prints of good definition and contrast, and should be the same size or larger than the size that is to appear in *QEX*.

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Empirically Speaking. . .

Getting a Handle on Sporadic E

Michael Owen's article, "Midlatitude E_s at 220.1 MHz," in the October 1987 issue of *QEX* should get a few juices flowing. How often, and when, is sporadic-E propagation present on 220 MHz? What about even higher frequencies? Does the fact that we haven't seen it before indicate that it wasn't there before, or just that we weren't there to observe it? There was a time that sporadic E wasn't seen very often on 2 meters—now it's a fairly common occurrence. It can't be entirely equipment and reduced noise figure, as 2-meter E_s signals can be fairly strong. Some detective work is clearly called for.

Amateurs have great advantages over other radio services for observation of propagational phenomena: quantity of stations, geographical dispersion, and operating hours (without the payroll meter running). Obviously, one way to tackle the problem is to stir up the troops and get them on 220 MHz weak-signal frequencies en masse. They can't all be just monitoring; someone has to transmit occasionally. No one transmitting is worse than the classic question of is there any sound when there is no one in the forest to hear the tree fall. It's like having someone to hear a tree fall, but the trees aren't cooperating.

The competitive spirit is alive in many VHF weak-signal operators. Weekend contests help to provide some good sport, increase operating activity, and help to uncover various propagational modes. How would you like your grid, Sir? Rare, of course. Gridpeditions tend to be a good drawing card for concentrated VHF activity.

But there is a limit to human dedication and endurance. Some of the life-support necessities (electricity and beer) can be piped to the shack, but most hams find it desirable to leave the cocoon occasionally to gather coins of the realm. So, how do we launch a round-the-clock effort to stalk the elusive E_s with the operators not transmitting enough and sometimes wandering off to work? Beacons solve the half of the puzzle having to do with transmitting so someone can listen. Automatic listening of some sort could take care of the other problem.

Packet radio seems to be an ideal solution. The terminal node controller (TNC) can be commanded to transmit a beacon periodically. Receiving stations can be set up to receive and store *all* beacon transmissions heard. If transmitting stations use a simple computer program to send the date and time in each packet transmission, receiving stations can store the data for later analysis. A simple way of making a histogram-type graph on a printer is to have times starting with the same hour or minute (depending on how often beacon transmissions are sent) print out on the same line. It would also be useful to coordinate a packet beacon network so not everyone transmits at once, else collisions and lost soundings. Even the Aloha channel-access scheme will work, but time slotting (such as used by NCDXF 14.1-MHz beacons) is very attractive to avoid collisions entirely.

With packet propagational sounding, the operator availability problem is solved. The data recording and analysis can be handled by computer, and reception reports can even be sent to a central collection point via amateur packet radio.

Of course, E_s is not the only propagational mechanism that such a packet sounding network could unveil. Often when hams have moved up in frequency and stepped up their observances, something new has been discovered. Computers make it possible to correlate soundings with other natural observances.

Does this whet your appetite? Who out there can champion such a packet sounding network? Who can write some software with all the right bells and whistles? Who knows the station-engineering considerations?—W4RI

Surviving in the Intermod Jungle

By Mark Bacon, KZ9J
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I live on top of a gentle rise, a good location for transmitting and receiving signals. I also live in the shadows of two broadcast towers: an AM antenna 300 yards west of my back yard, and a commercial FM/amateur site less than a mile to the east. My station is subject to intermodulation interference (*intermod* or *IM*), and I can quickly tell from my operating position whether a receiver has a strong front end and good spurious rejection. If the receiver is deficient in these areas, a menagerie of squawks, blurps, and groans greet my ears!

Radio frequency interference (RFI) generally falls into two categories: (1) Interference to home entertainment equipment from amateur transmitters, and interference to receivers from commercial and household items such as medical equipment and microwave ovens.[1] (2) Interference to well-designed receivers from one or more transmitters. Some radio equipment that works correctly and complies with FCC regulations can generate or respond to interference! This RFI often takes the form of IM.[2]

What the Receiver Hears

Interference present on the same frequency as another signal causes receiver *degradation*. When strong off-channel interference decreases RF (and possibly IF) gain, the effect is desensitization or *desense*. The receiver suddenly, but only temporarily, loses its oomph! In severe cases, the receiver may experience both degradation and desense.

To explain how desense works, think of a receiver with a minimum discernible signal (MDS) of −135 dBm, and an overload immunity specification (also known as blocking dynamic range) of −100 dB at the interfering frequency.[3] The level of interference that causes receiver desense is greater than −135 dBm − (−100 dB) = −35 dBm or 3.98 mV across 50 ohms—a rather potent signal! By contrast, any on-frequency interference with a level greater than −135 dBm has the potential to cause degradation. In other words, on- or near-frequency interference may be apparent at a level up to 100 dB lower than off-frequency interference. Small wonder most interference is of the on-frequency variety.

Another important receiver specification is the intermodulation distortion (IMD) dynamic range. This is the receiver's ability to avoid generating IM in its front end when subjected to two or more strong, off-frequency signals.[4] For a given IMD dynamic range, the greater the sensitivity, the greater the receiver's susceptibility to IMD.

Let's consider two receivers—each has −85 dB IMD dynamic range. Receiver A has an MDS of −140 dBm while receiver B is 13 dB less sensitive at −127 dBm. Receiver A detects IM when both mixing signals are at a level of −140 dBm − (−85 dB) = −55 dBm. On the other hand, the threshold mixing signal level in receiver B is −127 dBm − (−85 dB) = −42 dBm. Although receiver B is 13 dB less sensitive than receiver A, it has a 13 dB better immunity to IM. This illustrates a point often overlooked—receivers with identical IMD dynamic range do not generally have the same *susceptibility* to IMD! Adding a preamplifier to improve the sensitivity of a receiver also increases its IMD susceptibility—usually by *more* than the gain of the preamplifier!

Sources of IM

Most IM is generated either in the RF amplifier and mixer of the receiver, or in the final amplifier of a nearby transmitter. IM, however, can also be produced in the environment—diode or nonlinear action in rusty tower joints, weathered feed-line connections, corroded dissimilar metal junctions, and saturated ferrite cores, for instance.

The most common IM is of the third-order, 2A-B variety. Here, the second harmonic of transmitter A mixes with the fundamental of transmitter B to generate a product near the fundamental frequencies of both transmitters, assuming both fundamentals are within about 5% of each other. For example, transmitters A on 444.525 MHz and B on 444.550 MHz can mix to radiate IM products on 444.500 MHz (2A-B) and 444.575 MHz (2B-A). IM of the 2A+B type can also occur, but is generally less important than 2A-B.

This phenomenon can be demonstrated convincingly with two hand-held transceivers operating on the same band and by use of a spectrum analyzer. Set the two transceivers on unused adjacent or alternate-channel simplex frequencies. Tune the spectrum analyzer to a frequency midway between the two transmitters. Set the sweep width to 0.1 MHz per division. Place the transceivers back-to-back (for tight antenna coupling) and key both units. Note the strong third-order IM products on either side of the two fundamentals. (You'll probably see a "picket fence" of odd-order products through at least the ninth order!) Now, while keeping both radios keyed, move them away from each other. Watch the higher-order IM products drop out and the intensity of the 2A-B products decrease as the antenna coupling decreases.

Another frequently encountered form of intermodulation is second-order, $A \pm B$ IM. Signals from a cable channel AA (on 301.25 MHz) can mix with a 154.310-MHz commercial high-band signal to produce interference on 146.94 MHz (A-B), and on 464.560 MHz (A + B) in the UHF commercial segment. (By the same token, emissions on 301.25 MHz and 146.94 MHz can mix to produce interference on 154.310 MHz and 448.190 MHz!)

In dense RF areas, third-order IM of the A + B-C variety, involving three transmitters, is possible. Fifth-order IM, 3A-2B where frequencies A and B are fairly close, is known to cause trouble as well.

Pinpointing the Problem

Is the IM being generated in the receiver or external to it? Insert a 6-dB attenuator pad in the antenna line to the receiver (Fig 1). If the IM strength decreases by 6 dB with the pad switched in, the IM is being generated *outside* the

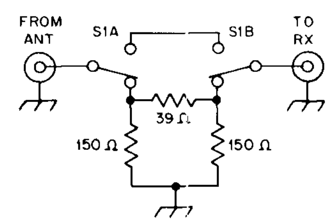

Fig 1—A 6-dB switchable attenuator suitable for receiver IM tests. The attenuator can be housed in a small, die-cast box. Resistors are ¼-W, 5% metal-film or carbon composition. Keep component leads as short as possible. S1 is a miniature double pole, double throw switch.

[1]Notes appear on page 14.

receiver. If the IM is reduced more than 6 dB, the mixing occurs in the receiver's front end. Second order, receiver-generated IM drops 6 × 2 = 12 dB with a 6-dB pad. Third order or 2A-B IM decreases 18 dB, and so forth.

IM that is produced outside the receiver and conducted down the feed line is more difficult to track. Before the National Guard is called out, some evidence gathering is in order. Is the interference more audible at your location than at those of neighboring hams? If so, chances are you're dealing with external rectification on or near your premises. Detective work with a portable receiver helps. When you get close to the source, replace the whip antenna with a "sniffer" loop or RF current probe.[5] Look for culprits like rusty chain link fences, loose or corroded tower bolts, and antennas overdue for maintenance. Environmental IM is sometimes traced to another receiver in the shack that generates the IM in its front end and radiates it.

If you and other amateurs within a several mile radius are experiencing the intermodulation at about the same signal strength, the IM is likely to be 2A-B IM. This form of IM is generated in the final stage of a local transmitter. A 100-W transmitter can easily radiate 10 mW of IM by signal mixing with a nearby transmitter of similar power. (If 10 mW sounds insignificant, I've used that power level several times over a distance of 2 miles to check into a 2-m net at nearly full quieting!)

Intermodulation usually has a characteristic signature that distinguishes it from other signals. A signal that comes and goes erratically, with a conversation, is most likely IM. If two voices are heard simultaneously at normal levels, you're probably hearing second-order IM. If at least one voice sounds loud and distorted, the IM is likely to be 2A-B third order (or possibly even fifth order). In 2A-B IM, the deviation of A is doubled along with the carrier frequency, whereas the deviation of B stays the same. Sometimes signaling tones or data are heard from a paging or mobile telephone service.

Commercial services, like most amateur repeaters, have automatic CW identifiers. Diligent monitoring may reward the listener with a call sign, the key to identification. Several years ago, a mysterious, but persistent IM at my QTH finally yielded the call of a land mobile service. A check of a computer listing of regional commercial services gave me positive identification and the service frequency.

If you can get one call sign of a commercial service, call the shop manager of a large, local land-mobile service facility. Most service shops are interested in community relations, especially if one of their own services might be involved.

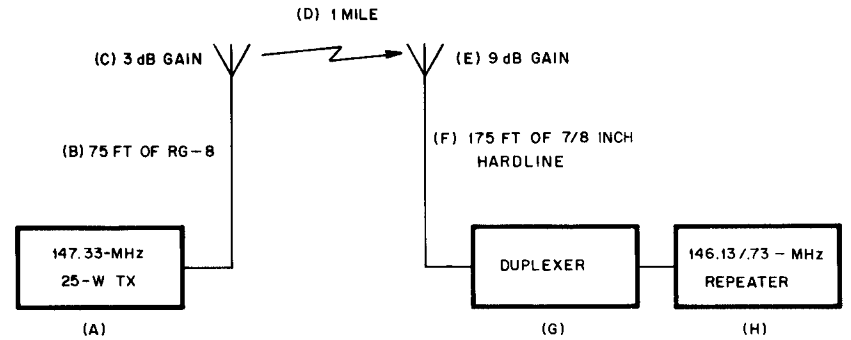

Fig 2—Estimating the IM level in the transmitter of a repeater (see text).

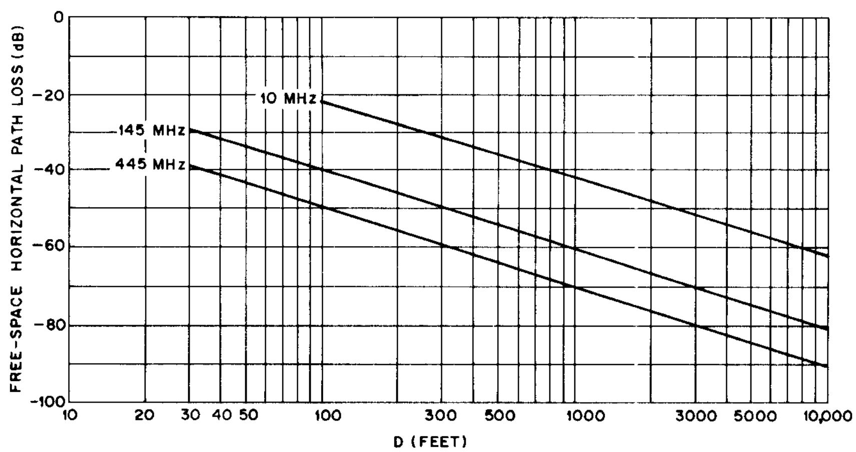

Fig 3—Free-space horizontal path loss, L, between two antennas separated by distance, d.

Two Case Histories

A 2-m hand-held transceiver that I converted from the commercial high-band service frequently picked up paging messages and QSOs over the local repeater. The interference was heard on all channels, and had the character of A-B IM. Some detective work revealed the mixing signals were on 158.43 MHz (a local, industrial paging service) and 146.73 MHz (the output of our club repeater). The difference frequency is 158.43 − 146.73 = 11.7 MHz, exactly the first IF frequency of my hand held! The hand-held had a "soft" front end and poor shielding. A combline band-pass filter centered on 147 MHz would have helped filter out the 158.43-MHz component, but at the expense of portability. (Popular in the 1950s and '60s, a combline filter is a multiple section VHF/UHF band-pass filter. The resonators are basically parallel-tuned strips of copper supported at one end. They resemble the teeth of a comb, hence the name combline.)

My second example involves a repeater with its input on 146.13 MHz and an output on 146.73 MHz. At times, the repeater would transmit continuously after the input dropped, emitting an unpleasant mixture of bleeps and chirps. Some work with a spectrum analyzer showed that the repeater, once keyed, was "staying up" whenever a strong carrier, the output of another repeater, was present on 147.33 MHz. (The carrier of the second repeater didn't key the first, however.) A 2A-B IM analysis revealed 146.73 × 2 − 147.33 = 146.13 MHz—exactly the repeater's input frequency.[6] Another (less likely) mixing possibility is 2 × 146.43 − 146.73 = 146.13 MHz, where the extraneous signal's fundamental frequency is 146.43 MHz. The chirping heard when scanning across an open 2-m band sounds like feeding time in an aviary, suggesting this sort of IM is fairly common.

A partial cure for the repeater involved retuning the transmitter and receiver circuits in accordance with the repeater's maintenance manual. The problem occurred on rare occasions thereafter, although the duration and severity were

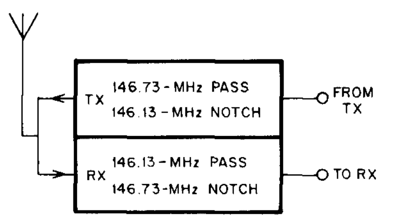

Fig 4—The path the 146.13-MHz IM takes through a duplexer to arrive at the 146.13-MHz repeater input.

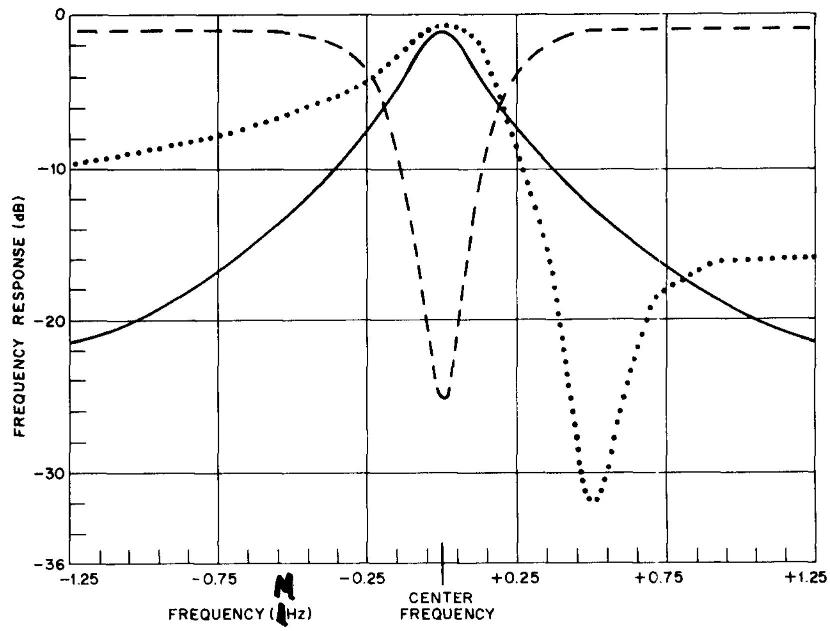

Fig 5—Typical frequency response curves for bandpass (——), band-reject (— — —), and pass-reject or notch (. . . .) cavities.

greatly reduced. Elimination of the problem required installation of a device designed to combat repeater inteference (see below).

Basically, *any* two neighboring repeaters on the same band with the same input/output split pose the possibility of mutual interference via A-B+C third-order IM. For example, the 146.13/146.73-MHz repeater can suffer IM from a nearby 146.34/146.94-MHz repeater through the following frequency relationship: 146.73 - 146.94 + 146.34 = 146.13 MHz. The symptom is the same as discussed. If the .73 machine comes up when the .94 machine is also in use, the .73 repeater hangs up until it times out or the .94 repeater drops. The .94 repeater is subject to similar interference from the .73 machine.

A similar form of IM is possible on other repeater subbands where standard input-output splits are used. For example, a repeater with its input on 449.150 MHz and an output 5 MHz lower can be interfered with by a 447.475/442.475-MHz repeater as follows: 444.150 - 442.475 + 447.475 = 449.150 MHz. If repeater operators used minimum power, this problem would all but disappear.

Estimating IM Levels

We can gain a perspective on IM magnitudes by tallying signal gains and losses over an RF path *en route* to becoming an IM. The .73 machine and the 147.33-MHz interference illustrates the bookkeeping. Fig 2 traces a typical route for the RF. Summing the gains and losses (letters in parentheses refer to Fig 2) yields:

(A) 25-W 147.33-MHz transmitter	+44.0 dBm
(B) loss in 75 ft of RG-8 coaxial cable	- 1.7 dB
(C) 3-dB gain antenna	+ 3.0 dB
(D) 1 mi of horizontal separation (see Fig 3)	-74.0 dB
(E) 9-dB gain repeater antenna	+ 9.0 dB
(F) loss in 175 ft of 7/8-in hardline	- 2.1 dB
(G) 147.33 MHz loss through duplexer	-15.0 dB
(H) mixing loss in repeater transmitter	-10.0 dB
total	-46.8 dBm

The -47 dBm is a reasonable, but rough, approximation of the generated IM level. For a given RF route, uncertainties, particularly in (D) and (H), may cause a variation of 15 dB either way. The horizontal path loss (D), determined from Fig 3, is subject to variables such as the nature of the terrain between the two antennas.

In a well-shielded repeater, the duplexer (next section) may make or break this IM as a source of trouble. To enter the repeater input, the IM must find a path through the cavities of both the transmitter and the receiver (Fig 4). The attenuation of this route is about 78 dB, the 146.13-MHz notch of the transmitter section. An additional 5 dB of loss occurs because of radiation from the repeater and loss through the receiver cavities. The total IM loss through the duplexer is -78 dB + (-5 dB) = -83 dB. It reduces the IM level entering the receiver to -47 dBm - 83 dB = -130 dBm, near the minimum detectable signal of the receiver. If the duplexer is untuned, the notch may have a depth of only -45 dB, yielding a total IM loss of -50 dB through the duplexer. The IM power appearing at the receiver is now -47 dBm - 50 dB = -97 dBm. This IM level fully quiets the receiver.

Our exercise illustrates the vulnerability of even a well-filtered repeater to transmitter-generated IM. Many repeaters using separate transmitting and receiving antennas have little or no outboard filtering. These machines are fair game for intermodulation.

Anti-IM Devices

If a stubborn case of IM doesn't yield to conservative treatment, a number of specialized devices are available, especially for the VHF/UHF bands. Pretuned filters can be inserted in the transmission lines of either receivers or transmitters. These filters are usually either cavity resonators or helical resonators, and they are supplied with three basic responses: bandpass, band-reject, and pass-reject (also called notch). The helical configuration offers compactness at the modest expense of efficiency (slightly lower loaded Q). Typical response curves are sketched in Fig 5.

A duplexer is a combination of resonators in the input to a repeater receiver and in the output of the transmitter, interconnected with critical lengths of coaxial cable to maintain proper impedance relationships. Duplexing the input and output of a repeater allows use of the same antenna for transmitting and receiving—a convenient and practical arrangement, and one which offers protection against off-frequency signals.

(continued on page 14)

Measurement of Antenna Impedance

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One way to find out what is happening in a transmission-line system is to measure the antenna impedance. The impedance bridge uses a simple resistor-capacitor bridge to accomplish this task; a digital or electronic high-impedance voltmeter, a transmitter, and a pocket calculator, or home computer completes the test station.

Measuring Complex Impedance

One method used to measure complex impedance was described by Doyle Strandlund, W8CGD.[1] The system he describes is simple and the results are accurate. To recap the original article, two fixed components only are used in a bridge circuit. Calibration is unnecessary. Figs 1 and 2 show Strandlund's methods of measurements. In Fig 1, a signal at the frequency of measurement applies power to Z through R and C. The voltages across these two components are measured together with the input voltage E_a, the voltage across Z, and the voltage across Z plus C. The input signal is adjusted until E_r is 5 V, then all the other voltages are measured. The results are used to produce a vector diagram as shown in Fig 2.

[1]D. Strandlund, "Amateur Measurement of R + *jX*," *QST*, Jun 1965, p 24.

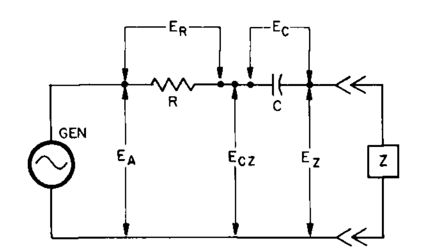

Fig 1—Block diagram of impedance-measuring system, showing the various voltages of interest.

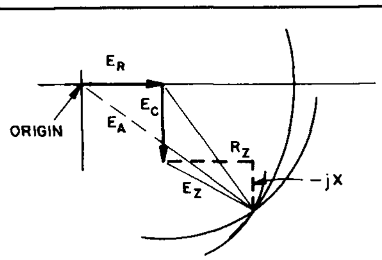

Fig 2—Vector diagram illustrating the method of determining the resistive and reactive components of a complex load from the voltage readings of Fig 1.

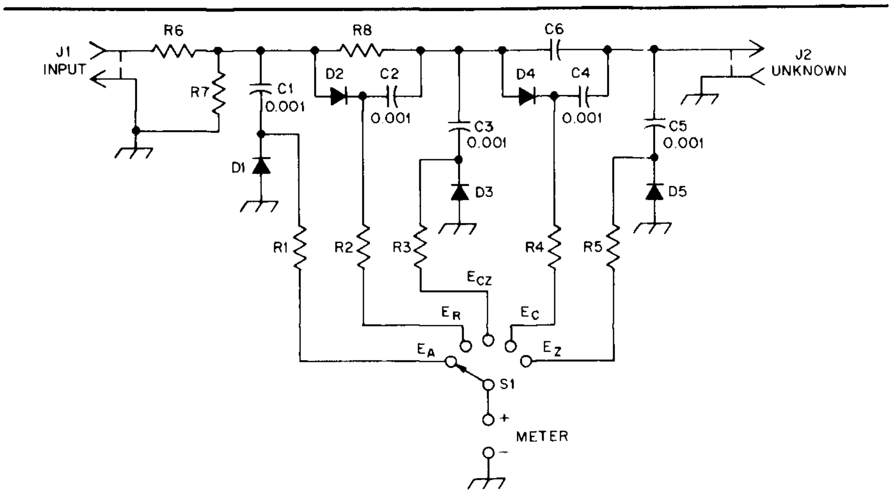

Fig 3—Circuit of the impedance-measuring network.

C1-C5—0.001 µF disk ceramic, 20%, 500 V.
C6—Silver mica capacitor. Suitable values are 0.002 µF for 1.9 MHz, 0.001 µF for 3.9 MHz, 500 pF for 7 MHz, 300 pF for 14 MHz, 200 pF for 21 MHz, 100 pF for 28-50 MHz. See text.
D1-D5—Germanium diode, 1N191 or equiv.
J1, J2—Phono jack.
R1-R5—Resistances should be as nearly equal as possible. Common values may be anything from 1-5 MΩ.
R6—Five 220-Ω, 2-W carbon resistors in parallel.
R7—10 Ω, 2 W, carbon.
R8—51 Ω, ½ or 1 W, carbon, 5% or better.
S1—Single section, single-pole, 5-position rotary switch, phenolic or ceramic.

Voltages are measured with diode probes and are selected by means of a switch. The probes measure peak volts and require the use of a high-impedance voltmeter. The complete circuit is shown in Fig 3.

A voltage divider used at the circuit's input allows a transmitter to be used as a signal source. The divider also isolates the transmitter from impedance variations as the transmitter frequency changes during a series of readings. R6 and R7 must be capable of dissipating the transmitter power without overheating; otherwise, the voltage readings will drift during measurement. The ratio of these two resistors can be changed if a QRP transmitter is used as a signal source. The value of C is not critical; the original article suggests using a reactance value of between 25 and 50 ohms, although values of up to 100 ohms gives good results. The capacitor value, therefore, has to be changed for different bands. The capacitor is soldered in place to minimize the effects of stray capacitance.

The Impedance Programs

In Strandlund's article, voltage readings were plotted as vectors using a compass, and the complex impedance was identified as the point where the arcs intersected. Since 1965, the calculator and home computer have become a fact of life. The rest of this article shows how impedance computation is done using a BASIC program. For this program to work correctly, the BASIC keywords must include Arc Cosine (ACOS or ACS).

```
10 CLS
20 Y=0
30 B=50
40 INPUT "A",A
50 INPUT "C",C
60 INPUT "D",D
70 INPUT "E",E
80 F=(B*B+C*C-A*A)/(2*B*C)
90 PRINT "F",F
100 G=ACS F
110 PRINT "G",G
120 H=(C*C+D*D-E*E)/(2*C*D)
130 PRINT "H",H
140 J=ACS H
150 PRINT "J",J
160 K=(A*A+B*B-C*C)/(2*A*B)
170 PRINT "K",K
180 L=ACS K
190 PRINT "L",L
200 M=(D*D+E*E-C*C)/(2*D*E)
210 PRINT "M",M
220 N=ACS M
230 PRINT "N",N
240 Q=ATN (B/D)
250 PRINT "Q",Q
260 T=B/SIN Q
270 PRINT "T",T
280 ZZ=(T*T+E*E-A*A)/(2*T*E)
290 P=ACS ZZ
300 PRINT "P",P
310 S=P-Q
315 PRINT "S",S
320 IF H>0 THEN X1=D-A*SIN L
    ELSE X1=D+A*SIN L
330 X2=E*M
340 X3=E*COS S
350 R1=A*K-B
360 R2=E*SIN N
370 R3=E*SIN S
380 X=(X1+X2+X3)/3
390 R=(R1+R2+R3)/3
400 V1=ABS(X1-X)
410 V2=ABS(X2-X)
416 PRINT "X",X
420 V3=ABS(X3-X)
430 W1=ABS(R1-R)
440 W2=ABS(R2-R)
450 W3=ABS(R3-R)
460 IF V1>=V2 THEN GOTO 480
470 IF V2>=V3 THEN EX=V2:GOTO 500
480 IF V1>=V3 THEN EX=V1:GOTO 500
490 EX=V3
500 IF W1>=W2 THEN GOTO 530
510 IF W2>=W3 THEN ER=W2:GOTO 550
520 ER=S3
530 IF W1>=W3 THEN ER=W1:GOTO 550
540 ER=W3
550 IF X>=0 THEN P$="+" :GOTO 570
560 X=-X:P$="-"
570 EX=INT(10*EX+0.5)/10
580 ER=INT(10*ER+0.5)/10
585 R=INT(10*R+0.5)/10
586 X=INT(10*X+0.5)/10
590 PRINT "SOLUTION"
600 PRINT "RESISTANCE ",R
610 PRINT "REACTANCE ",P$;X
615 PRINT "ERRORS"
620 PRINT " R= (+/-) ";ER
630 PRINT " X= (+/-) ";EX
```

Fig 4—The TOM program. PRINT **statements are included in the program so a hard copy of the intermediate results of a calculation can be obtained. Delete the** PRINT **statements when the program works correctly.**

```
10 B=50
20 INPUT "A",A
30 INPUT "C",C
40 INPUT "D",D
50 INPUT "E",E
60 F=(B*B+C*C-A*A)/(2*B*C)
70 G=ACS F
80 H=(C*C+D*D-E*E)/(2*C*D)
90 J=ACS H
100 K=(A*A+B*B-C*C)/(2*A*B)
110 L=ACS K
120 M=(D*D+E*E-C*C)/(2*D*E)
130 N=ACS M
140 Q=ATN(B/D)
150 T=B/SIN Q
160 P=ACS((T*T+E*E-A*A)/(2*T*E))
170 S=P-Q
190 IF H>0 THEN W=D-A*SIN L
200 IF H<=0 THEN W=D+A*SIN L
210 Y=E*COS S
220 O=A*K-B
230 M=E*SIN N
240 U=E*SIN S
250 X=(W+I+Y)/3
260 R=(O+M+U)/3
270 IF X>=0 THEN GO TO 360
280 X=-X
290 Z$="-"
300 R=INT(10*R+0.5)/10
310 X=INT(10*X+0.5)/10
320 PRINT "R =";R
330 PRINT "Xj =";Z$;X
340 END
350 Z$="+"
360 GO TO 300
```

Fig 5—TOMSMALL is designed to run on a Casio PB110 pocket calculator.

```
10 CLS
20 PRINT "ANTENNA MEASUREMENT PROGRAM"
30 PRINT: PRINT
40 PRINT "TO INPUT DATA TO FILE PRESS F"
50 PRINT "TO READ DATA FROM DISK PRESS R"
55 INPUT F$
60 IF F$="F" THEN CHAIN"TOMID"
70 IF F$="R" THEN CHAIN"TOMID"
```

```
10 REM PROGRAM TOMID (DATA TO DISK DRIVE)
20 CLS
30 INPUT "WHAT IS THE FILE NAME",NF$
40 INPUT "ENTER MEASUREMENT TITLE  "TITLE$
50 INPUT "HOW MANY SETS OF DATA (MAXIMUM OF 10)",M
60 B=50
70 DIM AA(9)
80 DIM CC(9)
90 DIM DD(9)
100 DIM EE(9)
110 DIM RR(9)
120 DIM XX(9)
130 DIM ZZ(9)
140 DIM FY(9)
150 DIM EJ(9)
160 DIM P$(9)
170 OO=OPENOUT (NF$)
180 PRINT# OO,TITLE$
190 PRINT# OO,M
200 FOR Z=1 TO M
210 PRINT "MEASUREMENT ";Z
220 INPUT "FREQUENCY"FY(Z)
230 INPUT "A",AA(Z)
240 INPUT "C",CC(Z)
250 INPUT "D",DD(Z)
260 INPUT "E",EE(Z)
270 INPUT "IS THIS DATA CORRECT",C$
280 IF C$="N" GOTO 210
290 PRINT# OO,FY(Z),AA(Z),CC(Z),DD(Z),EE(Z)
300 NEXT Z
310 CLOSE#OO
320 END
```

```
10 REM PROGRAM TOMFD (READS AND PROCESSES DATA
   FROM DISK FILE)
20 ON ERROR GOTO 900
30 CLS
40 B=50
50 INPUT "WHAT IS THE NAME OF THE DATA FILE",NF$
60 DIM AA(9)
70 DIM CC(9)
80 DIM DD(9)
90 DIM EE(9)
100 DIM RR(9)
110 DIM XX(9)
120 DIM ZZ(9)
130 DIM FY(9)
140 DIM EJ(9)
150 DIM P$(9)
160 OO=OPENUP (NF$)
170 INPUT# OO,TITLE$
180 PRINT TITLE$
```

Fig 6—These programs work with data files, loading them in a matrix form, and printing the results in tabular form. **Continued on page 8.**

Fig 6—Continued from page 7.

```
190 INPUT# OO,M
200 MM=M
210 FOR Z=1 TO MM
220 INPUT# OO,FY(Z)
230 INPUT# OO,AA(Z)
240 INPUT# OO,CC(Z)
250 INPUT# OO,DD(Z)
260 INPUT# OO,EE(Z)
270 A=AA(Z)
280 C=CC(Z)
290 D=DD(Z)
300 E=EE(Z)
310 F=(B*B+C*C-A*A)/(2*B*C)
320 G=ACS F
330 H=(C*C+D*D-E*E)/(2*C*D)
340 J=ACS H
350 K=(A*A+B*B-C*C)/(2*A*B)
360 L=ACS K
370 M=(D*D+E*E-C*C)/(2*D*E)
380 N=ACS M
390 Q=ATN (B/D)
400 T=B/SIN Q
410 ZZ=(T*T+E*E-A*A)/(2*T*E)
420 P=ACS ZZ
430 S=P-Q
440 IF H>0 THEN X1=D-A*SIN L
    ELSE X1=D+A*SIN L
450 X2=E*M
460 X3=E*COS S
470 R1=A*K-B
480 R2=E*SIN N
490 R3=E*SIN S
500 X=(X1+X2+X3)/3
510 R=(R1+R2+R3)/3
520 V1=ABS(X1-X)
530 V2=ABS(X2-X)
540 V3=ABS(X3-X)
550 W1=ABS(R1-R)
560 W2=ABS(R2-R)
570 W3=ABS(R3-R)
580 IF V1>=V2 THEN GOTO 600
590 IF V2>=V3 THEN EX=V2:GOTO 620
600 IF V1>=V3 THEN EX=V1:GOTO 620
610 EX=V3
620 IF W1>=W2 THEN GOTO 650
630 IF W2>=W3 THEN ER=W2:GOTO 670
640 ER=W3
650 IF W1>=W3 THEN ER=W1:GOTO 670
660 ER=W3
670 IF X>=0 THEN P$(Z)="+" :GOTO 690
680 X=-X:P$(Z)="-"
690 ZZ(Z)=INT(10*ER+0.5)/10
700 RR(Z)=INT(10*R+0.5)/10
710 XX(Z)=INT(10*X+0.5)/10
720 EJ(Z)=INT(10*EX+0.5)/10
730 NEXT Z
740 MODE0
750 INPUT "DO YOU WANT A HARD COPY?"C$
760 IF C$="Y" THEN VDU2
770 PRINT "          ANTENNA IMPEDANCE MEASUREMENT PROGRAM"
780 PRINT
790 PRINT TITLE$
800 PRINT
810 PRINT "       INPUT PARAMETERS      RESULTS     +/-  ERRORS"
820 PRINT"FREQ     A    C    D    E    RES   JX    RES   JX"
830 PRINT"---------------------------------------------------"
840 FOR Z=1 TO MM
850   PRINT;FY(Z);TAB(9);AA(Z);TAB(15);CC(Z);
    TAB(21);DD(Z);TAB(27);EE(Z);TAB(32);RR(Z);
    TAB(38);P$(Z);XX(Z);TAB(46);ZZ(Z);TAB(52);EJ(Z)
860 NEXT
870 VDU3
880 CLOSE# OO
890 END
900 CLS: PRINT" ERROR IN DATA";GOTO 880
```

Table 1
Antenna Impedance Measurement Program
Mobile DDRR Antenna

	Input Parameters				*Results*		*± Errors*	
Freq	*A*	*C*	*D*	*E*	*Res*	*jX*	*Res*	*jX*
14	183	161	47	117	68.8	−86.2	38.7	40
14.05	169	145	47	102	63.4	−75.0	27.4	28.5
14.1	137	113	47	71	47.1	−48.2	19.2	22.8
14.13	129	99	47	63	50.8	−34.1	8.3	12.3
14.15	128	90	48	60	55.5	−23.8	2.3	3.8
14.17	135	90	48	79	77.9	+ 4.4	1.7	3.8
14.2	188	141	48	149	136.1	+69.4	6.5	34.0

Table 2
Antenna Impedance Measurement Program
G5RV With Z-Match

	Input Parameters				*Results*		*± Errors*	
Freq	*A*	*C*	*D*	*E*	*Res*	*jX*	*Res*	*jX*
14	119	101	70	34	19.4	−26.8	7.5	5.9
14.05	114	93	71	28	20.0	−19.2	1.8	1.7
14.1	109	82	70	28	26.9	− 7.4	0.3	0.3
14.13	110	77	71	38	37.4	+ 4.0	0.7	0.7
14.15	113	75	71	50	47.5	+13.4	1.0	1.3
14.2	159	110	71	106	103.8	+33.5	3.0	11.2

Table 3
Antenna Impedance Measurement Program
80-m G-Whip (Small)

	Input Parameters				*Results*		*± Errors*	
Freq	*A*	*C*	*D*	*E*	*Res*	*jX*	*Res*	*jX*
3550	120	105	52	53	20.1	−39.1	31.5	27.4
3560	115	98	52	47	23.3	−34.2	22.1	22.0
3570	109	90	52	40	22.4	−28.6	15.7	16.4
3580	102	80	51	31	18.1	−24.3	7.5	6.8
3590	95	70	51	24	17.8	−15.7	2.3	2.6
3600	89	57	51	22	21.9	− 1.6	0.2	0.2
3610	87	45	52	34	29.7	+17.8	0.8	1.1
3620	94	53	51	61	43.1	+29.5	7.8	18.1
3630	118	70	50	102	64.3	+78.2	1.0	2.8

Table 4
Antenna Impedance Measurement Program
Test Data For DDRR Antenna (Note High Q Effect)

	Input Parameters				*Results*		*± Errors*	
Freq	*A*	*C*	*D*	*E*	*Res*	*jX*	*Res*	*jX*
14	183	161	47	117	69.2	−86.7	39.2	40.5
14.05	169	145	47	102	63.8	−75.4	27.9	29
14.1	137	113	47	71	47.5	−48.6	19.7	23.2
14.13	129	99	47	63	51.2	−34.6	8.8	12.7
14.15	128	90	48	60	56	−24.3	2.8	4.3
14.17	135	90	48	79	78.4	+ 4.4	2.1	4.3
14.2	188	141	48	149	136.6	+69.9	7	34.5

Fig 7—Test data for checking the program.

A?	**126**
C?	**87**
D?	**71**
E?	**57**
F	**−0.667471264**
G	**2.30160398**
H	**0.75773029**
J	**0.710968392**
K	**0.710968392**
L	**0.857698412**
M	**8.90783296E-2**
N	**1.48159977**
Q	**0.613556146**
T	**86.8389314**
P	**2.11035353**
S	**1.49679738**
X	**5.16942091**
Solution	
Resistance	**57.2**
Reactance	**+5.2**
Errors	
R = (±) 0.8	
X = (±) 1.0	

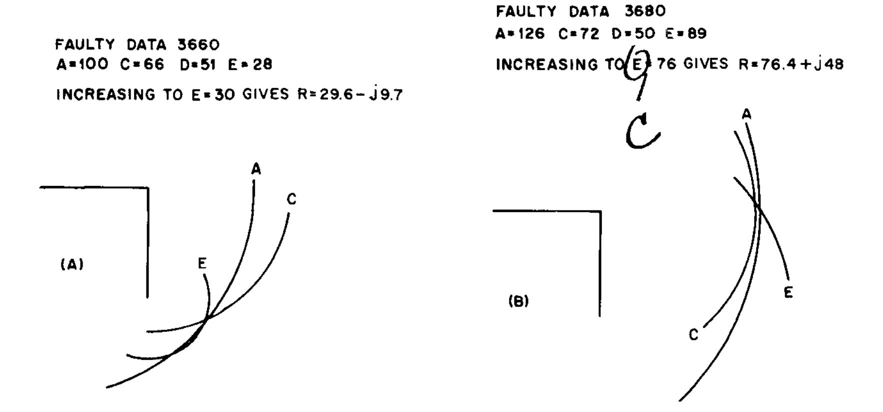

Fig 8—Graphic analysis of faulty data. The values for A, C, D, and E in both examples will not compute. Graphics reveal one of the arcs does not intersect. Increasing the arc's value forces the program to work.

Two programs are shown. The first is called TOM (Fig 4). It performs the calculations for finding the resistance and the reactive components of an impedance bridge. TOM also calculates the triangulation errors resulting from errors in measurement.

Fig 5 is TOMSMALL, our second program. It was written to perform all calculations, but not to compute errors. TOMSMALL was designed specifically for the Casio PB110 pocket calculator.

In the original article, W8CGD notes that the angles of the intersecting arcs get rather narrow with SWRs above 3:1, introducing measurement errors. A greater number of errors resulted when the SWR was high.

We devised a suite of programs, shown in Fig 6, that work with files of data, loads them in a matrix as required, and prints the results in tabular form. This is a much more convenient way of dealing with large volumes of data. The data in Tables 1-4 were derived from measurements taken with several different types of antennas and tabulated using these programs. When using these programs with your computer, remember that file handling and print formatting routines vary between different computers.

Program Peculiarities

Each program fails to operate if the argument of any arc function is greater than 1 during computation. If this occurs, data errors are present.

Fig 7 is an example of TOM's test data for checking the program. A graphic analysis of the problem is shown in Fig 8. Changing the value of C helps to minimize faulty data. The program is capable of handling other errors, provided the arguments of the arcs are less than 1.

Another program has been developed called TOMBIG. It will test the data and use only those results that are mutually compatible. In cases of ambiguity, TOMBIG will find the correct solution. It does not use the ACS function. The algorithm for this program has been devised and coded, but not fully tested.

The voltage designations called out by W8CGD have been changed in my program to read as follows: E_a = A, E_r = B, E_{cz} = C, E_c = D and E_z = F. I simplified the variables because they are used frequently in my program expressions. Also, the PB110 calculator only allows for single-letter variables.

A list of variables is used to check a program that does not run, or the results are suspect. To use the correct figure, add a PRINT variable statement in the line after the expression suspect of causing an error. Then, enter the Fig 7 values for A, C, D, and E, and compare the value of the printed test variables.

Bits

New Switched-capacitor Filters Make Their Debut

Each of eight filters in the XR-1000 family is a fourth-order, low-pass switched-capacitor filter. These components provide different responses and clock-to-corner ratios to increase and vary the number of possible applications for which they can be used. The design requires no external resistors or capacitors to create the filter function. A single external clock is all that is required to position the corner frequency of the low-pass filter. If desired, a RC oscillator or crystal can be used to obtain the clock. The XR-1001 and 1002 butterworth response low-pass filters provide maximum amplitude response flatness. The XR-1003 and 1004 fourth-order bessel response low-pass filters offer maximum flatness to the group delay response and retain the phase relationship of a complex input at the output. The XR-1005 and 1006 Chebyshev response low-pass filters feature an in-band ripple of 0.1 dB and provide more attenuation in the transition range of the filter to reduce the amplitude of undesired signals. The XR-1007, similar to the 1005, has an in-band ripple of 0.5 dB, resulting in a slightly steeper slope on the amplitude response. The XR-1008 is the same as the XR-1007 except that it has a clock-to-corner ratio of 50:1 compared to the 1007's 100:1. Prices for quantities over 100 are $1.30 for the 01, 02; $1.51 for the 03, 04, 07, 08; and $1.55 for the 05, 06. Contact the Exar Corp, PO Box 3575, Sunnyvale, CA 94088-3575, tel 408-732-7970. (This information was excerpted from the Sep 1987 issue of *Electronic Component News*.)

A 1200-Bit/s Manchester/PSK Encoder Circuit for TAPR TNC Units

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Fig 1 shows a Manchester encoder/PSK modulator circuit. It was designed to be a companion to the JAS-1 PSK demodulator circuit.[1] The design is similar to that of the Manchester encoder circuit found in the *JAS-1 Handbook*; the difference is that the 4024 ripple counter in the previous design has been replaced with a 74HC161 synchronous binary counter. The 74HC161 can be easily configured to provide a divide-by-12 function with 50% duty cycle output, and allows for the 1600-Hz carrier (needed for PSK generation) to be derived directly from the TNC transmit clock. At the flip of a switch, you can select either the Manchester-encoded output needed to drive an FM transmitter for the JAS-1/OSCAR 12 uplink, or binary PSK which is compatible with the JAS-1 PSK demodulator.

The PSK modulator can be used for loop-back testing of the demodulator. More importantly, you have a complete 1200-bit/s coherent PSK modem that can be used (with SSB equipment) for packet communications through linear transponders or for weak-signal terrestrial work. This modem should offer considerably better bit-error-rate performance than the TNCs built-in AFSK modem. Although it will be at its best in a full-duplex environment, the modem should give a good account of itself in half-duplex use as well, provided that the TNC TXDELAY parameter is set to allow sufficient time for the carrier-recovery loop to acquire lock. The circuit in Fig 1 was designed for use with TAPR TNC 2-type units, which provide a 16x clock for external modems. It should also work with the TNC 1, provided that the 32x clock available from that unit is prescaled with a divide-by-two stage (the unused half of the 4013 dual flip-flop can be used for this purpose).

A PSK modem kit, based upon the same design as the *QEX* modem, is available from TAPR.[2] The TAPR modem includes a PSK modulator, so the additional circuitry previously described is not required. James Miller, G3RUH, designed another popular PSK modem to be used with JAS-1, but it lacks a PSK modulator.[3] Fig 2 shows an adaptation of the modulator circuit for the G3RUH modem. This circuit is designed to be a plug-in replacement for U6 (a 4040); it can be

[1]Notes appear on page 11.

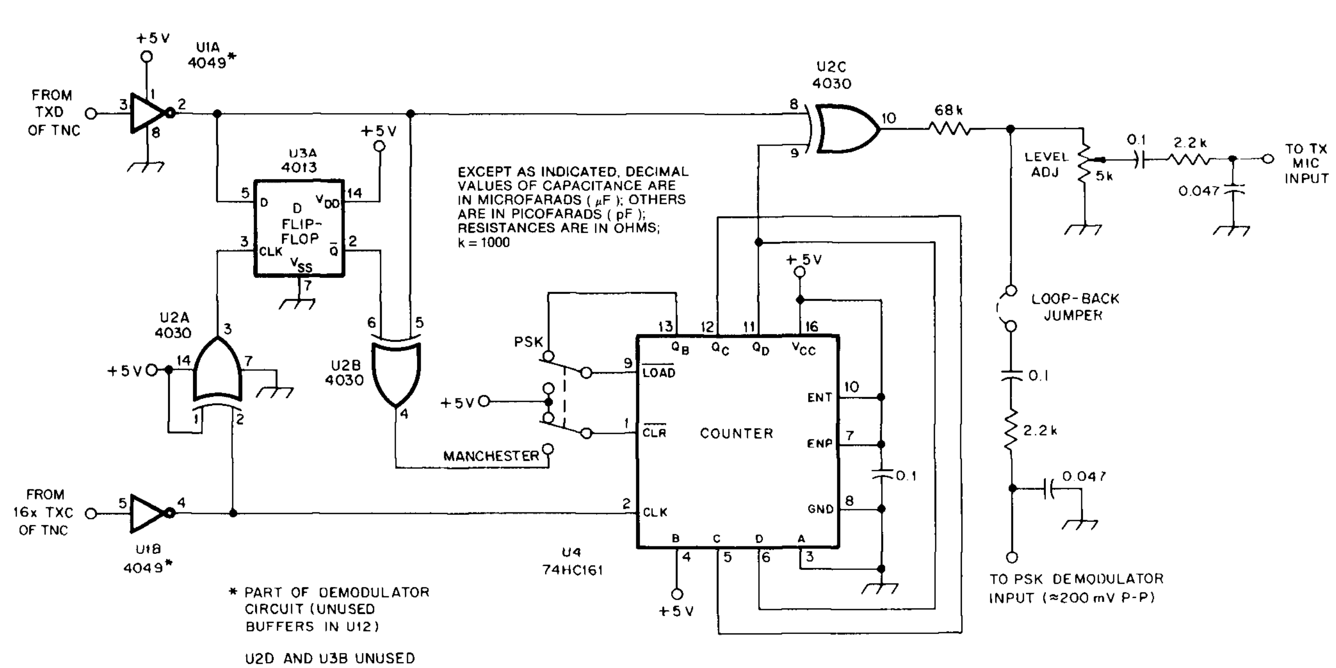

Fig 1—Schematic of the Manchester encoder/PSK modem.

constructed using a DIP socket piggybacked atop a DIP header. Some of the unused pins on the header can be used as tie points, but they must be snipped off on the underside so as not to make contact with the socket underneath. A new PSK/Manchester switch on the front panel completes the installation. The PLL in the demodulator should be retuned to produce 1600 Hz at TP1 in order to enable loopback testing; it can be left at that frequency for ordinary operation as well.

Notes

[1]Fujio Yamashita, "A PSK Demodulator For the JAS-1 Satellite," *QEX*, Aug 1986, p 3.
[2]James Miller, "A packet radio PSK modem for JAS-1/FO-12," *Ham Radio Magazine*, Feb 1987, p 8.
[3]Lyle Johnson, "The TAPR PSK Modem," *QEX*, Sept 1987, p 3.

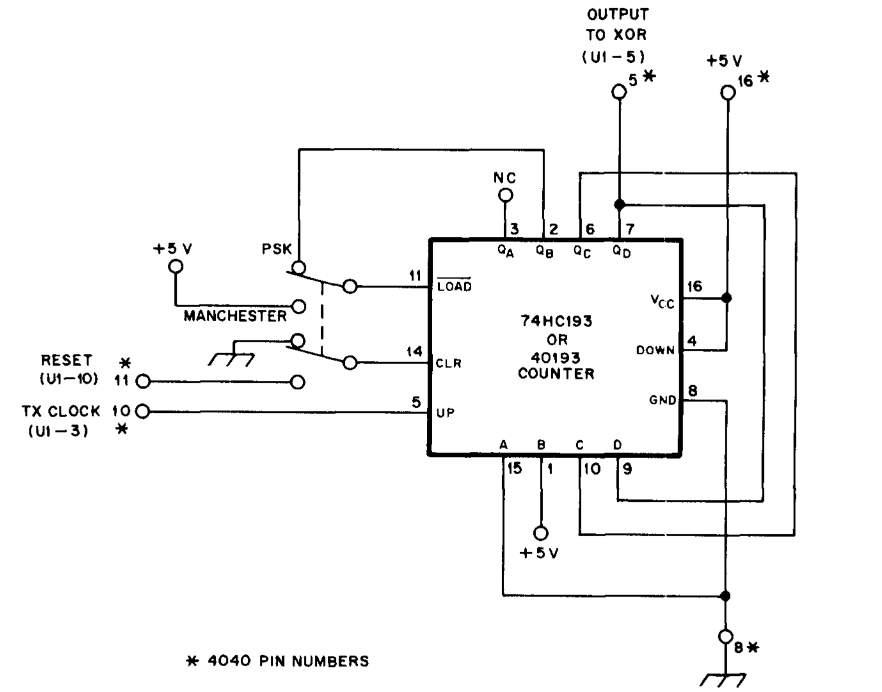

Fig 2—Schematic of the adapted modulator circuit for the G3RUH modem. It provides the PSK modem with a 1600-Hz center frequency.

Bits

Southcon/88

On March 8-10, 1988, the Orange County Convention/Civic Center in Orlando, FL will come to life with scores of professional engineers and technologists. They'll be visiting the center to hear a collection of papers on new trends and applications in electronic technology and product manufacture. Three broad fields of interest will be presented: computer based systems (artificial intelligence applications, CAE, software engineering); innovations in components and equipment (automated test systems, optical storage applications); and high tech applications (communications and networks, lightning, robotic technology and applications). For further information and a schedule of events, contact Southcon/88 Professional Program Committee, Electronic Conventions Management, 8110 Airport Blvd, Los Angeles, CA 90045.

IMARK Markets Digital ID

IMARK Pty, Ltd, an Australian company, has designed a Digital Morse Code Identification Unit suitable for use with Amateur Radio repeaters or transceivers. The Digital ID is a digital microprocessor-controlled module that includes an EPROM and state-of-the-art technology. Features include Time Out Time, ID Speed and Frequency, ID Time and ID Tone. Various parameters may be programmed and tailored to suit individual needs. Additional software features can be provided upon request.

The IMARK ID unit costs $129 US FOB Melbourne, or $134 US including air mail postage. Further details are available from IMARK Pty, Ltd, 167 Roden St, W Melbourne, Victoria, 3003, AUSTRALIA, tel 03-329-5433 or FAX 61-3-328-4431.

High-gain Modules for Cellular Radio

Motorola has developed a new MHW803 power module for portable radios. An input power requirement of only 0 dBm (1 mW) achieves an output power of 2 W (33 dB minimum gain). The modules are available in two frequency versions (806-870 MHz and 820-850 MHz). The units operate from 7.5 V, and provide 30 dB power range control. The MHW806A series is designed specifically for 6-W mobile application, is available in four frequency ranges from 820-950 MHz and offers an excellent high gain/control combination. Just 30-40 mW input provides stable, controllable output power over a 35 dB minimum range. For more information, contact Motorola Semiconductor Products, Inc, PO Box 20912, Phoenix, AZ 85036, tel 1-800-521-6274.

Lathanide Antenna May Be Broadcasting Breakthrough

NDXE Engineering's antenna division is working on a possible breakthrough for HF broadcasting. An innovative antenna design is being developed from Lathanide, a material that mobilizes electrons past the speed of light, with little heat dissipation. The material is similar to a ceramic medium, rather than metal. The antenna is expected to have a lower impedance, thus the system will dissipate more gain and be a more efficient radiation system.

NDXE Engineering hopes to patent the development and make it available to broadcasters and Amateur Radio operators. For more details on this innovative antenna, contact NDXE Engineering, PO Box 569 Opelika, AL 36801, tel 205-749-1989.

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RF Switching

I am often asked to recommend the best antenna relay for a particular power level at a particular frequency. Usually the next question is "Where can I get one?" Obviously, an RF switch suitable for handling 500 W at 1296 MHz has different characteristics than one for switching 100 mW at 28 MHz! This month's column should help you pick the right relay for the job. Finding one at a reasonable price is still often a matter of being in the right place at the right time.

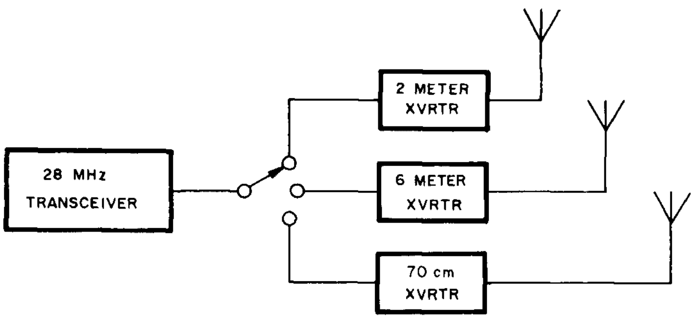

Fig 2—A manual coaxial switch can be used to drive multiple VHF transverters with a single IF transceiver.

Applications

The most familiar RF switch is SPDT antenna TR relay like that shown in Fig 1A. It switches the antenna between transmitter and receiver. At VHF and above, this is usually a coaxial relay. Often, the TR relay may have to handle more than a thousand watts at VHF and at least several hundred watts at UHF. Sometimes the relay must be mounted at the top of the tower; sometimes it is in the station.

A variation of the SPDT antenna relay is the DPDT *transfer* type. This one is used to switch around a linear amplifier or preamp so that the device is out of the circuit when it's not being used. A transfer relay is often two SPDT relays keyed together; sometimes it is a special type where one interconnection is made internally. See Fig 1B.

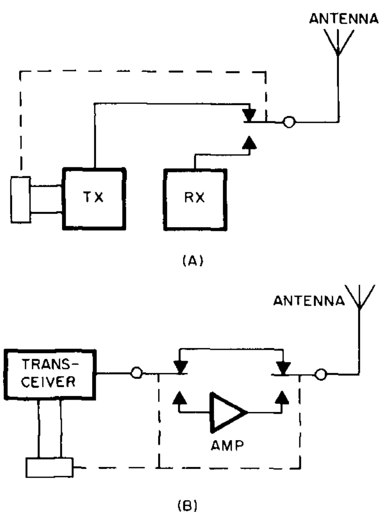

Fig 1—At A, a coaxial TR relay is used to switch an antenna between transmitter and receiver. At B, a coaxial transfer relay switches an amplifier in and out of the transmission line.

Manual switches are often used in the ham station, too. A high-power type would be used to switch different antennas to the same rig. A low-power version might switch a 10-meter IF transceiver among several VHF or UHF transverters. See Fig 2. This switch is often ganged with a dc switch to route control voltages to the appropriate transverter.

There are many other uses for RF switches. We often see solid-state (PIN diode) switches or miniature relays within a transverter to switch the IF line from the transmit mixer to the receive mixer, or even to switch a common amplifier stage between transmit and receive. In these cases, size is the major consideration as there is usually not much power present and any SWR can be tuned out.

RF Switch Specifications

The following are some of the more important specifications to look for when selecting an RF switch.

Isolation. No RF relay is perfect, so some power is always going to be present at the port(s) that are not selected. For example, in an SPDT antenna relay, some amount of transmit power is going to show up at the receive port when the relay is in the transmit position. Isolation is expressed in decibels and is important because transmit power can burn up a receiver front end if the isolation is inadequate. For example, if you use a relay with 30 dB isolation to switch the antenna between a 1-kW transmitter and a receiver, a level 30 dB less than 1 kW, or 1 W, will be present at the unused port that is connected to the receiver front end. Look for 50-60 dB isolation in a quality relay; lower isolation is acceptable for low-power applications.

Power rating. Manufacturers usually specify a maximum average power at a range of frequencies. As with coaxial cable, losses go up with frequency and consequently the power ratings go down. In addition, power ratings are usually specified at a unity SWR. A poorly matched antenna will reduce the power rating of a relay or switch because of mismatch loss.

SWR. This specification is the SWR of the switch when it is terminated with a 50-ohm load. The SWR varies with frequency; obviously the closer to 1:1 the better.

Switching time. This is the time it takes the relay to go from one position to the other. The time is usually 10 to 100 ms for a relay and up to a second for electrically activated rotary switches. Switching time is important when designing a TR sequencing scheme so that RF is not applied to the relay while it is switching.

Impedance. Coaxial relays are usually specified for a nominal characteristic impedance; 50 ohms is the magic number. Other impedances may be okay, but watch the SWR specification.

Connectors. Same old story here. The connector type should have an adequate SWR and power rating for the frequency in use. UHF connectors are probably okay below 148 MHz. Type N is a better choice and usable through 10 GHz or so. SMA types are handy at 2304 MHz and above because of their small size and low SWR.

Coil voltage. Relays with 12-V coils are handy for use with modern 12-V equipment, but 24- and 28-V relays abound in the surplus market. For these, you'll need a simple power supply that can handle the coil current—usually several hundred milliamperes. Coils that require 120 V are okay for indoor use if they are treated with care. They're not very good for mobile operation, though.

Solid-State Switching

The PIN diode has characteristics ideal for RF switching: very low impedance in the on state and very high impedance in the off state. PIN diodes are compact and nearly instantaneous in operation. They can be used at very high power levels and very high frequencies (if you have enough money!). Disadvantages are low isolation and higher loss compared to quality RF relays.

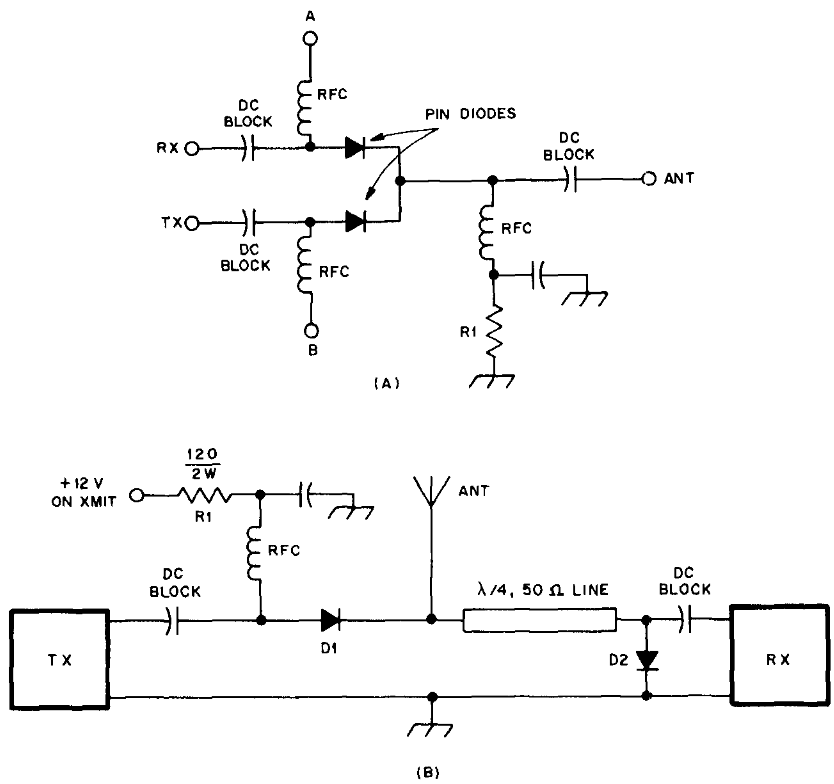

Fig 3—The circuit at A is a simple SPDT PIN diode switch. When going from transmit to receive, the appropriate diode is energized at point A or B to allow RF to pass. R1 is chosen for proper current through the diodes. The circuit at B is a series/shunt PIN diode switch. D1 and D2 are Unitrode UM9401 PIN diodes. R1 is optimized to allow 100 mA to flow through D1 and D2 on transmit.

Table 1
RF Relay Specifications

Manufacturer	*Part No.*	*Frequency (MHz)*	*Isolation (dB)*	*Power (W)*	*Insertion Loss (dB)*	*SWR*	*Connector Type*	*Notes*
Amphenol	317	2304	60	120	0.3	1.2:1	BNC	
Dow Key	DK-60	50	60	1000	*	1.1:1	UHF, N	Isol>100
		144	50	1000	*	1.3:1		dB with G
		432	40	500	*	1.5:1		option
	DK-77	432	45	400	*	1.1:1	BNC	
		1296	25	150	*	1.5:1		
EME Electronics	HF400	144	>60	1500	0.1	1.1:1	N	
		432	>60	1500	0.1	1.1:1		
		1296	45	700	0.2	1.2:1		
		2304	35	500	0.2	1.2:1		
	RK500	144	>60	1000	0.2	1.2:1		
		432	>60	500	0.2	1.2:1		
		1296	50	100	*	*		
		2304	35	50	*	*		
Omron	G4Y	900	65	15	0.25	*	None	PC-mount
		1296	40	10	0.5	*		coaxial
Transco	D	144	90	800	0.1	1.1:1	N	
		432	90	450	0.1	1.1:1		
		1296	70	300	0.1	1.2:1		
		2304	60	220	0.2	1.2:1		
		10000	60	100	0.3	1.2:1		
	DO	1296	90	150	0.1	1.1:1	SMA	
		3456	90	80	0.2	1.1:1		
		10000	90	50	0.3	1.3:1		
	Y	144	70	1600	0.1	1.1:1		
		432	60	800	0.1	1.1:1		
		1296	50	500	0.1	1.2:1		
		2304	40	300	0.2	1.2:1		
		10000	25	100	0.4	1.3:1		

*Not rated.

PIN diode switches show up most often in low-level applications where inexpensive diodes can be used without worrying about poor isolation or loss characteristics. While PIN diodes are often used in a simple SPDT configuration for low-level switching, a series/shunt configuration is the best bet for TR switching. With the proper diodes, a series/shunt TR switch can exhibit isolation greater than 30 dB and losses of only a couple tenths of a dB. See Fig 3.

Relay Types

Table 1 details some of the relays popular with amateurs. Data is extracted from manufacturers' "typical" curves and from actual measurements on some units lying around the barn here. Don't rely too heavily on this information. It's always a good idea to check your latest acquisition before wiring it into the system!

There are hundreds of different relays, and this is just a sampling of what's available. The Transco relays are military type equipment and are very conservatively rated for continuous duty. The EME Electronics relays are rated for amateur use, as are the Dow Key units. The Omron G4Y is a very compact PC-board-mount relay that would go nicely in small portable equipment. The Teledyne 411D is sort of a relay equivalent to a solid-state switch—very compact, but rated only for very low power.

Most commercial solid state "brick" amplifiers use open-frame relays for RF switching. These are often DPDT types and have poor SWR and isolation. They can obviously be made to work, and they don't cost much.

A word on surplus relays. Often found at flea markets, the D type relays (all three connectors come out on one side of a "D" shaped housing) are available from many manufacturers. Transco Y types will handle more power, but they have less isolation. Multiple pole and transfer switches are available in an endless variety. Don't overlook them for mounting on top of a tower for preamp switching or for using one feed line for different antennas. Many times these relays are in excellent condition, but often they have been sitting around a long time without use. Check before using!

Surviving in the Intermod Jungle

(continued from page 5)

Ferrite isolators (Fig 6) are effective one-way attenuators. Built around a tiny, highly-polished sphere of yttrium-iron-garnet (YIG) ferrite, isolators are routinely used in the business-band industry to forestall transmitter IM generation. With a forward insertion loss of only 0.5 dB, ferrite isolators prevent transmitter IM radiation in amateur VHF/UHF repeaters. Because of their one-way transmission properties, isolators cannot be inserted in receiver transmission lines.

What about additional receiver protection? HF/VHF crystal filters are available for insertion between the feed line and receiver input. These crystal filters are highly selective (Fig 7), affording 5-12 dB of adjacent channel attenuation (15-kHz channel spacing) and much greater attenuation beyond the adjacent channel. Crystal filters have some major drawbacks, however, because they cannot be used in transmitter lines. Their insertion loss is 4-6 dB, and they're not available for use at 220 MHz and above.

The aforementioned devices are available from a number of suppliers serving the land-mobile industry. From an amateur standpoint, they have severe shortcomings: They're often lossy (except for ferrite isolators), they're fixed tuned, and they are expensive. In short, these adjuncts are mainly useful for club-owned or subscriber-maintained repeaters.

Wrap Up

This article has suggested tools and techniques needed to survive in an intermod jungle. I thank Steve Jackson, Bill Richardson, and Mike Wortman, all of McKeever Communications, Inc, for providing essential background information.

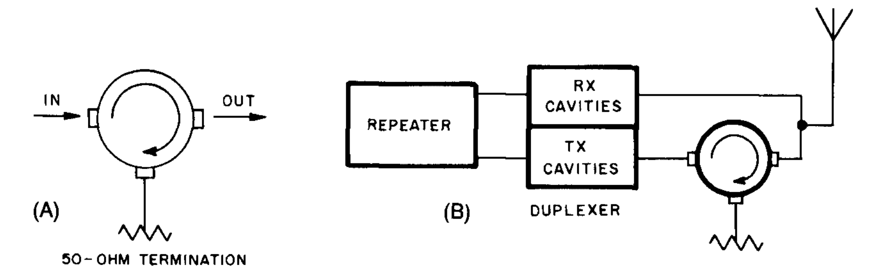

Fig 6—Circuit diagram of an isolator (A) and an isolator in the transmitter output of a repeater (B).

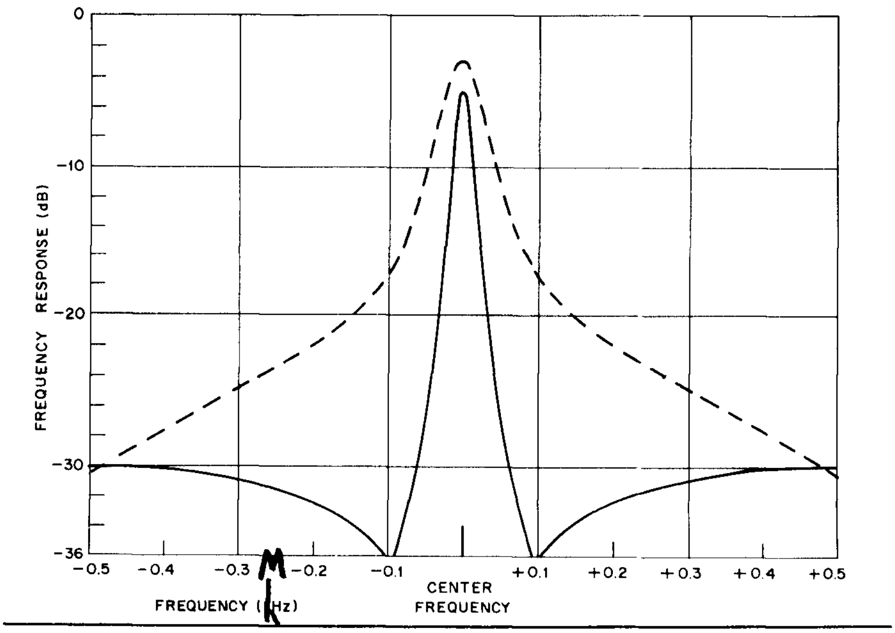

Fig 7—Frequency response curve of a 150-MHz receiver crystal filter (———). Note the steep skirts as compared with a high-Q band-pass cavity (------).

Notes

[1]C. Hutchinson and M. Kaczynski, eds., *Radio Frequency Interference*, (Newington: ARRL, 1984).

[2]D. Potter, "Intermodulation Reviewed," *QST*, May 1983, pp 17-18.

[3]B. Williams, "The Product Review Process," *QST*, Dec 1985, pp 22-24.

[4]See note 3.

[5]G. Hall, ed., *The ARRL Antenna Book*, (Newington: ARRL, 1982), p 15-22.

[6]See note 2, p 18.

13 Centimeters

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Equipment for 13 cm, Part 1

My last column was a general introduction to operation on the 13-cm band. This month, I will begin a series on 13-cm equipment. For starters, I'll describe some commercial equipment and, in succeeding columns, go into the construction of home-brew equipment.

Transverters

There are at least two 13-cm transverters available in the US. The most popular has been around for three or four years—the SSB Electronics (from West Germany) Microline 13. The basic Microline consists of three separate modules in compact tin boxes. BNC connectors are used for all RF connections on the basic unit. An optional power amplifier module is available as well. The transverter modules are:

1) SLO13 local oscillator (LO). This unit is a 2160-MHz crystal oscillator/multiplier chain with dual outputs—3 mW for the receive mixer and 5 mW for the transmit mixer. Harmonic outputs are all at least 40 dB below the carrier.

2) STM13 transmit mixer. This unit requires 5 mW of 2160-MHz LO signal and 20 to 500 mW (adjustable by internal potentiometer) of 144-MHz IF signal to produce approximately 500 mW at 2304 MHz. Spurious products are greater than 30 dB down.

3) SRM13 receive mixer. This box contains a GaAsFET preamp stage ahead of an active GaAsFET mixer. Noise figure is about 2.8 dB and overall conversion gain is about 20 dB. It requires a 2160-MHz, 3-mW LO signal, and the IF output is at 144 MHz.

4) SLA13 linear amplifier. This unit uses a single Philips BLU96 driving a Wilkinson combined pair of the same to provide close to 4 W output for 0.5-W drive. A later model using lower loss Teflon® circuit boards reportedly puts out over 5 W for the same drive level. Unlike the other modules, the SLA13 has type N connectors.

All of the Microline units run on 13.8-V dc, and the whole transverter draws only a couple of amps on transmit peaks. You must connect the modules together. The Microline 13 requires external IF switching (and possibly some IF attenuation if your IF transceiver puts out more than 0.5 W), an external antenna relay, and some dc switching. Wiring everything up is not beyond the capabilities of any ham who would want to get on this band. Four or five watts is easily capable of driving a tube-type amplifier to 30 or 40 watts output. The receive front end is adequate for local work, but a GaAsFET preamp (mounted at the antenna) should be used for DXing.

The new 13-cm transverter on the block is a unit manufactured by LMW Electronics in England. LMW has been around for a while, but has recently started exporting to the US. The LMW transverter is available in many versions. The top-of-the-line 2304TRV2D is a complete unit in an enclosure containing IF switching, relative RF output meter, TR sequencing circuitry, and an external GaAsFET preamplifier. With 0.1 to 5 W drive at 144 MHz (internally adjustable), the unit puts out close to 2 W at 13 cm. The barefoot transverter has a noise figure of around 4 dB and measures better than 1.5 dB with the preamp in the line. The internals of the LMW unit are modular in approach, and the various modules (LO, TX mixer, RX mixer, IF amp, PA) are available separately or in kit form. The basic kit (LO, transmit mixer, receive mixer and IF amp) is certainly the least expensive way to get on 13 cm. The LMW units run on 13.8 V.

Satellite Receive Operation

Because of the modular approach of the LMW and SSB Electronics transverters, the LO and receive mixer modules can easily be retuned to receive AMSAT-OSCAR Mode S at 2401 MHz. Gerry, KAØOOQ, has repeaked the SSB SLO13 and SRM13 to 2401 MHz with very little effort. In fact, using an LMW GaAsFET preamp tuned to 2320 MHz, his system noise figure is under 1.5 dB at 2401 MHz. A little further optimization could surely get the noise figure close to 1 dB.

Preamplifiers

Here is a tabulation of the presently available preamps for the 13-cm band:

Manufacturer	*Model*	*NF*	*Gain*
SSB Electronics	DX2320S	0.8 dB	22 dB
LMW Electronics	2320PP1	<1 dB	>10 dB
Angle Linear	2304	1 dB	13 dB

(The LMW unit is also available in kit form.)

Solid-State Power Amps

If you want to go beyond the basic transverter, there are a couple of choices. The SSB Electronics SLA13, mentioned previously, offers 5 W output and 10 dB gain. It requires a 13.8-V supply—ideal for portable operation. Frontier Microwave offers a 12-W-output, 10-dB-gain unit (model PA2304-12L). This unit uses a common-base transistor and requires +24 V and a separate −5 V, 1 A supply for class AB bias.

Tube-Type Power Amps

If you're looking for some righteous power, there are a couple of European-made power amplifiers for the 13-cm band. These typically use a 2C39/7289 type planar triode in a cavity configuration. These amps can put out 25 to 40 W with air cooling, with gains up to 10 dB. The most complete unit is manufactured by EME Electronics of West Germany (model PA1325) and comes complete with bias supply and blower. You need only supply the tube, filament voltage and high voltage. This amplifier is rated at 25 W output and 10 dB gain with an anode supply of 1200 V.

LMW Electronics supplies a similar unit based on the WA9HUV cavity design. This unit is a bare bones cavity amp, but with proper supply voltages will put out 25 W with air cooling and greater than 70 W with water cooling.

EME supposedly has a new amplifier out using a Siemens Y1381 tube. This unit, model EME13100, will put out over 100 W with air cooling and 1600 V on the anode.

Antennas

The 13-cm band is near the crossover frequency where dishes start to be more practical than Yagi antennas. While a few of the European companies (Parabolic in Sweden and L-Wave in England) make dish kits and dish feeds, the only commercially available 13-cm antennas in the US are the 45- and 55-element loop Yagis built by Down East Microwave. These antennas are available assembled and tested or in kit form and are cut for 2304, 2320 or 2401 MHz. In addition, power dividers and stacking frames are available for combining 2, 4, 8 or 16 antennas.

Where to Buy

SSB Electronic and EME Electronic equipment is available through Transverters Unlimited (VE3CRU), Box 6286

Station A, Toronto, Ontario, Canada M5W 1P3. Down East Microwave, LMW Electronics, and Frontier Microwave equipment are available through Down East Microwave, Box 2310 RR1, Troy, ME 04987. Hmmm. Angle Linear can be reached at 25309 Andreo Av, Lomita, CA 90717.

Conclusions

Well there you have it—13-cm appliance operation in a nutshell. While none of the equipment I've described is really "ready to go" like an HF transceiver, this stuff saves *a lot* of work for someone anxious to get on the band. It works quite well, and has been responsible for many a long-distance QSO. Next time I'll talk about modifying surplus gear, and then we'll go on to building our own.

Reader Input

The problem with reporting reader activities is that the news can be stale by the time it gets into print. For those thinking about getting on, however, this news is helpful to show what kind of work is being done and with what equipment. Even you veteran 13-cm DXers would probably be interested in new stations getting on and what the other guys are doing. Make you a deal: You write a blurb and I'll put it in at the end of the column.

My first letter comes from Jack, WB4EFZ, who reports his first 13-cm QSO from the home QTH in Newberry, South Carolina. On July 27, Jack worked Greg, KK4NO, in Greer, South Carolina, at a distance of 60 miles. While this is not exactly a new DX record, the contact was made with 32 mW from an unfinished transverter to a 1296 MHz (!) loop Yagi at 78 feet (below tree top level) and fed by 100 feet of Belden 9913. The ERP here has to be pretty low! Signals were 589 at WB4EFZ and 519 at KK4NO with no QSB. A few minutes later, KK4NO worked Jim, WA8NLC, in Columbia, South Carolina, at a distance of 100 miles. Signals were 40 dB over S9 both ways. KK4NO runs 5 W to a 2-foot dish at 47 feet, and WA8NLC runs 150 mW (home brew) to a 45-element loop Yagi at 95 feet. Jack notes that UHF TV signals were very loud that evening, as were the WD4MBK/K4MSK beacons. So there's the South Carolina report. Who's next? Reports received by the middle of December will make it into the January column. Since the Fall tropo season should be upon us by now, I hope to receive lots of reports!

Bits

Bipolar Equivalents Replaced by New CMOS RS-232-C Driver and Receiver ICs

National Semiconductor has developed a CMOS RS-232-C driver and receiver to replace its binary equivalents.[1] Engineers were able to maintain the RS-232-C standard, and the original design goals of the binary devices in the new components. The DS1488 and DS1489 ICs are the most universally used to perform RS-232-C and V.24 interface functions. Although inexpensive and designed in a low-density bipolar process, they do not fully meet the RS-232-C specification without requiring external components. They also consume a large amount of power.

The new DS14C88 RS-232-C driver and the DS14C89A receiver offer several enhancements over their binary equivalents. The components have a low-power requirement that makes them suitable for remote or portable systems. Both devices possess a fault tolerance in accordance with all requirements of the specification. The driver's slew rate limiting is provided on-chip to meet the RS-232-C specification over the entire cable capacitive load specifications. The typical low slew rate of 5-6 V/μs was chosen to minimize EMI. The receiver provides enhanced noise rejection, and its input transition voltage level is set slightly positive so that a powered-off driver is correctly interpreted as a mark condition.

In general, National's DS14C88 and DS14C89A serve to improve signal noise rejection, help to lower power and EMI, and improves data integrity. For further information on these two new CMOS ICs, contact National Semiconductor Corp, PO Box 70818, Sunnyvale, CA 94086.

[1]G. Campbell and L. Wakeman, "New CMOS RS232 Driver And Receiver Replace Bipolar Equivalents," *National Anthem*, Aug/Sep 1987, p 10.

FM Narrowband Receiver

Motorola has introduced a new low-voltage (2 V), dual-conversion FM narrowband receiver IC that can operate as a complete VHF receiver, incorporating all essential functions from the antenna input to audio preamp output. The MC3362 can be used as a utility receiver for voice and data communications. Manufactured using their patented MOSAIC process, the IC offers excellent performance for RF inputs up to 180 MHz. If the first LO signal is provided externally, the device can be used at over 400 MHz. Features include dual-conversion circuitry for improved image rejection; Received Signal Strength Indicator (RSSI) output, allowing application with a muting circuit or signal strength meter; 6-35 mW power consumption; and a data slicing comparator for FSK data recovery up to 30 kbit/s (15 kHz). The MC3362 is available in a 24-pin DIP or 24-lead wide-body SOIC (which improves RF performance), and is priced at $1.80 for orders in quantities of 100. Contact Jon Stilwell, Motorola Semiconductor, PO Box 52073, Phoenix, AZ 85072, tel 602-897-3842. (This information was excerpted from the Sep 1987 issue of *Electronic Component News*.)

New 2400-bit/s Option

Kantronics announces its newest high-speed packet modem option for the KAM and KPC-4—the 2400 Kantronics Modem™. Plug this new PC-board modem into your existing KAM or KPC-4 board for optional 2400-bit/s packet operation. The 2400 Kantronics Modem retails for $69.95. Contact Kantronics, Inc, 1202 E 23rd St, Lawrence, KS 66046, tel 913-842-7745.

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