QEX
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1985
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The ARRL Experimenters' Exchange

ARRL Spread Spectrum Committee

Are you interested in writing standards for Amateur Radio spread-spectrum communications? If so, send a letter addressed to Dr. Larry E. Price, W4RA, President, ARRL, 225 Main Street, Newington, CT 06111 outlining your qualifications. Be sure to mark the envelope "Spread Spectrum Committee" and to get it in the mail as soon as possible.

The FCC has authorized spread spectrum in Amateur Radio bands above 420 MHz. In writing the new rules, the FCC specified only what they thought necessary to guarantee their ability to monitor such transmissions. They did not provide any technical standards needed for interoperability -- that's a $10 government word for radios being able to talk to each other. They decided to delay the effective date of the rules until June 1, 1986 to give amateurs enough time to develop standards. So, at the July 1985 ARRL Board Meeting, an ad hoc committee on Amateur Radio spread-spectrum standards was established for a period of two years.

Here are the type of the standards to be considered by the committee: frequencies of operation, chip rate, the code, code rate, spreading function, transmission protocol(s) including the method of achieving synchronization, modulation type, type of information transmitted, and method/frequency(ies) for identification.

Nice Plug for Amateur Packet Radio

The August 1985 issue of **Mobile Radio Technology** magazine in its editorial and in part I of an article by John Gates, of Advanced Electronics Applications Inc., credits the contribution of Amateur Radio to packet radio in the land mobile industry.

Call for Articles

Editors are used to getting letters saying "Why don't you print more of ___?" Well, the primary answer is that we can't print what we don't get. Overall, **QEX** has a fairly steady flow of technical articles on a variety of subjects. But I, for one, would like to see more on traditional Amateur Radio subjects, such as RF design. It seems that things digital have the spotlight. That's the area of revolutionary development: computers... packet radio... digital ICs... After all, hasn't everything in analog and RF been invented already? It is true that each technology seems to find an equilibrium and stay there until the next breakthrough. Maybe we are seeing that with analog and RF design. You might get that impression by looking at the number of Electronic Engineering graduates who are prepared to do analog/RF design work. It is easy to get a feel for the scarcity of analog/RF designers if you have tried to hire one recently. Many recruiters of analog/RF designers have learned the value of Amateur Radio as a source of experienced people.

So, this is your invitation to send in your analog/RF articles on all subjects including HF QRP, VHF/UHF and microwaves.

QEX has an important advantage over Amateur Radio magazines (including **QST**): a short lead time. Most magazines take months to print an article after acceptance. **QEX** works on a faster schedule. That helps to motivate authors. If you get your ideas into print earlier, you'll get feedback sooner. Your article may stimulate a **QEX** reader to go you one better and design an improved version. **QEX**'s short lead time is great for getting answers to technical questions, too. The response to queries has been high. -- W4RI

Correspondence

Report on CCW

Mike Mideke, WB6EER, and I have been experimenting with coherent CW in the 1750-meter experimental band. My CCW beacon is located in Morro Bay, California, transmitting 10-baud CCW, while Mike is receiving with a Petit PCF-3 coherent CW filter (**QST**, May 1981). A digital dot is precisely 0.1 second, while dashes, spaces and blanks between elements are 0.3 second long. A 32-bit memory is used, making the entire ID 10.7 seconds. All experiments have been conducted on 176 kHz as sufficient RF stability occurs with ordinary crystal control. 166.66667 kHz was planned, but carrier accuracy is far less stringent than first thought!

Phase locking to 10-MHz WWV was discarded after the discovery that 100-kHz LORAN C signals were received while transmitting on the same antenna, using a simple 100-kHz tuned circuit. A basic 100-kHz receiver is now needed with only a sample and hold output such that a phase lock can be achieved with a 1-MHz crystal. A commercial LORAN C unit was used for this initial try.

It is becoming more apparent that stabilities and complexities first thought necessary are not required when the communication experiment lasts for a few hours, or can be optimized by the operator on the spot. Both Mike and I are now looking for an experimenter say, in the Hawaiian Islands, to show what coherent CW and one watt of power can really do. — Cliff Buttschardt, W6HDO, 950 Pacific St., Morro Bay, CA 93442.

Amateur Radio and EMP

Technical literature, including a **QST** article (Aug 1981, p 41), has presented the possibility of an electromagnetic pulse (EMP) attack. If such an attack were to occur, a nuclear weapon, or weapons, would be exploded in space above the United States. The electromagnetic pulse from the explosion is anticipated to burn out virtually all of the US civilian solid-state electronic equipment.

If Amateur Radio is to provide communications after such an event, a transceiver resistant to EMP will need to be designed. This transceiver would have to be designed to include at least some of the following attributes:

a. High-frequency (HF) low-power operation
b. CW capability
c. Vacuum-tube technology for all stages
d. Shielding (as close to "tempest" quality as possible)
e. Built in nanosecond transient-protective devices
f. Over-rated circuit components (to accommodate excess current and voltage)
g. Heavy point-to-point wiring instead of a circuit board
h. Circuit layout that can be serviced with a fire-heated soldering iron
i. Integration of carbon block RF absorbers into the shielding
j. Battery power operation
k. Rapidly deployable antenna system (this would be stored in a shielded container when not in use)
l. Shielded fire-resistant container for storing the transceiver
m. Shielded stock of spare parts

It would be a natural step for the readers of **QEX** to design this EMP resistant transceiver. Are there any volunteers? — Nickolaus Leggett, N3NL, 1500 Mass. Ave., N. W., Apt. 610, Washington, DC 20005.

More on Load Sharing

Concerning the recent discussions of "parallel" (load sharing) operation of power transformers and the relative merits of various connections, I have made some measurements on two nominally identical transformers.[1,2,3] The transformers were Radio Shack 273-1505 with 12.6 V, 1.2 A ratings. They were operated in parallel (primary)/parallel (secondary), series/series, and series/parallel connections. A fourth connection, parallel/series, is also possible. When paralleled, the primaries were across a 117-V line. In series, they were across an approximate 215-V line.

Parallel/Parallel

Optimum load sharing between parallel/parallel-connected transformers having the same turns ratio, but different power ratings, requires that the ratio of leakage impedances be inversely proportional to the ratio of the power ratings. Optimum load sharing between transformers with different turns ratios is not possible, but circulating current can be avoided by providing each transformer with its own rectifier (as suggested by W2MLO in his letter). The load division will still be determined by the turns ratios and leakage impedances. Reasonable operation at a fixed load can be obtained by padding the leakage reactance of the transformer delivering the higher current with an external resistance or inductance (the phase angle is not important when the secondary connection is on the dc side of the rectifier); however, the regulation will be degraded. In my measurements of the parallel/parallel connection, the open-circuit voltage between the secondaries was 0.155 volt, and the "short circuit" current was 42.1 mA. (The ammeter resistance, 0.35 ohm, was not negligible, and the true

(continued on p 10)

A Method of Frequency Control for the Converted Hygain Board

By David Donaldson, WB7DRV
1103 S. Summit, Sioux Falls, SD 57105

The HyGain Cybernet CB board has been an inexpensive way for many amateurs to use the 10-m FM subband above 29.50 MHz. Through various modifications published in **QST** and other amateur-related journals, the information available makes the conversion from CB to 10-m FM relatively easy.

Most of the boards available lack the channel select switch, thus making it difficult to switch channels. After acquiring one of these boards, I tackled this dilemma. My solution and hints on how I performed this task are stated in this article, which is based on the board conversion by Bob Heil, K9EID, in August 1981 **QST**. The circuit is divided into three sections: the Logic Reference, the Display and the Logic Switch. Each will be discussed separately.

The new circuit provides complete frequency coverage in 10-kHz steps, rather than skipping 20 kHz every fourth channel as the standard CB switch does. It displays the actual receiver frequency in use and provides repeater offset without the need for additional crystals.

Review of Board Requirements

The Cybernet board uses a 7-bit binary word to control the divide rate of the voltage-controlled oscillator (VCO) and frequency. To increase the frequency by 10 kHz or one channel, the number that is applied to the B0-B6 address lines on the board is incremented by one.

Logic Reference

The logic reference shown in Fig. 1 uses two programmable binary counters (74193). These integrated circuits are programmed to start counting in sequence from 0101110. This number is 10 counts below what would be considered the CB channel twenty or 29.50 MHz (converted). The reason for this will be discussed later.

Pins 15, 1, 10, and 9 of the 74193 IC is used to program the binary number from which the counter starts counting. U5 is a debounce circuit for the channel-select switch, a SPDT push-button type. When the channel-select button is pushed, it provides the channel-select pulse for both the logic reference and the display counters. Each pulse advances them by one until the logic reference counters reach 1001011 (equals 29.69 MHz). The leading edge of the next pulse from the channel-select circuit causes the reset circuit (U6) to provide the reset pulse. This procedure resets both counters back to channel 20 or 29.50 (0111000). With this feature, out-of-band operation is not possible.

Display

The display circuit in Fig. 2 uses a standard counter circuit. This one, however, is a binary-coded decimal (BCD). The circuit contains two common-cathode 7-segment LEDs to provide a readout of the actual receive frequency in use.

The counter uses two BCD counter chips: U3 is a programmable type (74192) in the most significant digit. The 74192 has been programmed to start counting from "5". The display counters will step through the channels in sync with the logic reference, via the channel-select line, displaying the 100 kHz and 10 kHz of the frequency in use. The display will reset itself to "50" with the next pulse after "69", by way of the reset line from U6.

Logic Switch

The actual address applied to the VCO is produced in the logic switch (Fig. 3). Two modes are possible — simplex and repeater. The transmit and receive frequency of the simplex mode is the same, but the repéater transmit frequency is 100 kHz below its receive frequency. Selection of the desired mode is made by using S1, labeled "Repeater/Simplex."

The simplex or repeat mode is dependent on the state of U9 and U10. They are Quad 2 input multiplexers. Two different inputs are applied to the chips. Depending on the state of pin 1, mode select, either input A or B is applied to the output. The first input at A is from the frequency adder (U7 and U8), and is programmed to add the equivalent of 100 kHz to the binary number on the second input at B, which comes directly from the logic reference.

U11 and U12 provide the mode select to the multiplexers. This circuit does two things. First it determines if the frequency is above 29.6 MHz. (There are no repeater inputs below 29.5 MHz.) U11A performs the task of sensing the state on pins 3 and 6 of U3, the MSD display counter. When the MSD is displaying "6", pin 4 will go low (BCD 0110), and repeater enable will go high (pin 6). Next, the circuit determines if repeater operation is desired (via S1, pin 1 of U12A). If it is, mode select will go high whenever the PTT is grounded (done through U11B). On the other hand, if simplex operation is desired, mode select will be low, independent of the state of the PTT, because of the low placed on pin 1, U12A. Depending then upon the state of mode select, the multiplexers will pass the required 7-bit number for simplex or repeater operation.

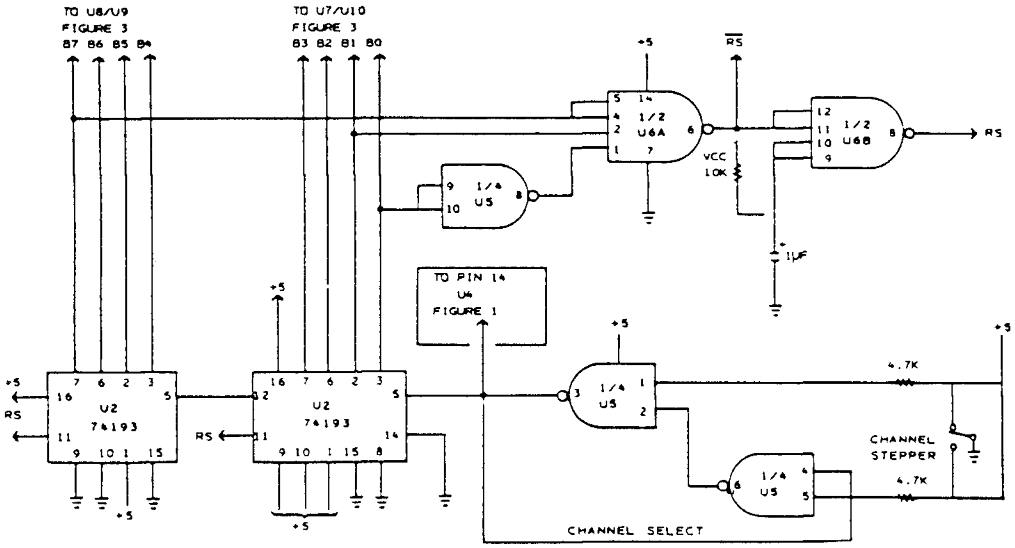


FIGURE 1: LOGIC REFERENCE

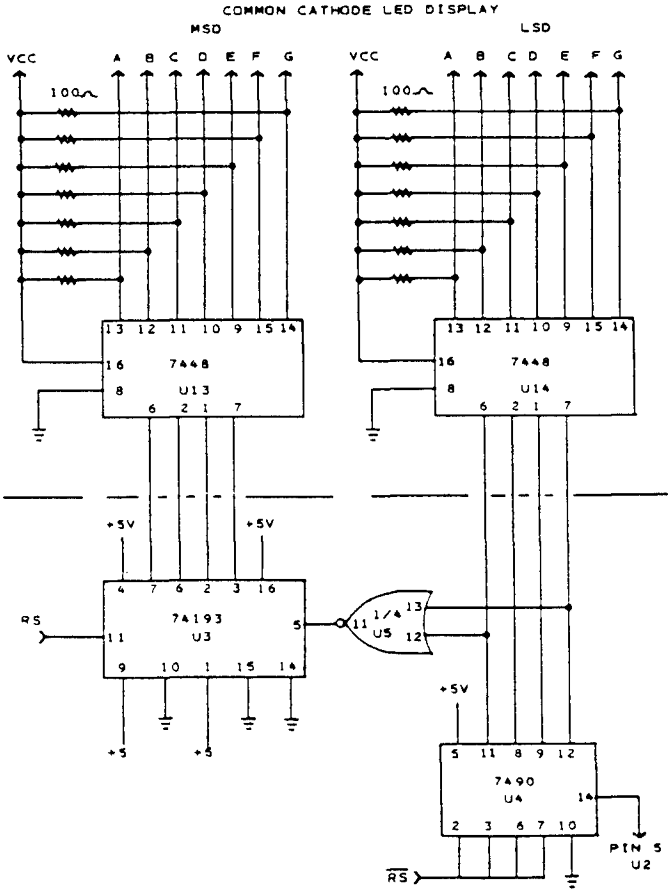


FIGURE 2: DISPLAY

During simplex operation, the mode-select line will be low and the number from the adder (U7 and U8) will be applied to the output lines. The adder uses two 7483 ICs. These chips are four-bit binary adders that have been programmed to add 001010 or 100 kHz to every number from the logic reference. So, for example, if the channel desired is 29.60 MHz, the number from the logic reference will be 0111000. The adder will add 001010, and the output of the multiplexers will be 1000010 (29.60 MHz or channel 30). This will remain the same despite the state of the PTT since mode select is always low.

If the unit is in the receive mode and repeater operation is desired, the mode select will be low and operation will be the same as simplex explained above. However, when the PTT button is pressed, mode select will go high placing the number directly from the logic reference, which is 10 channels or 100 kHz below the adders, on the output of the multiplexers. This causes the VCO to shift down 100 kHz or 29.50 MHz. When the PTT is released (going high), mode select will go low again causing the VCO to shift back up to 29.60 MHz for receive. Now we have a 100-kHz split without having to switch in additional crystals.

Construction

The main purpose of this article is to present the theory of this circuit. Therefore, only a brief description of its construction will be discussed.

The circuit was built on a 44-pin multipurpose plug-in board from Radio Shack. I used point-to-point wiring. All the necessary signals that are applied to the displays were brought to the plug (PTT, 5-V address lines and BCD addresses, and so on). This allows easy board removal for changes or modifications.

I discovered later that bypassing was important. The board's VCC lines should be bypassed at the 44-pin plug with a 0.01 uF capacitor. It is interesting to note that this was not required until some grounds were changed in the shack.

Conclusion

This circuit has worked well for two years. Though it may be more complicated than a switch, its flexibility makes the circuit practical. It can be modified later for increased frequency coverage or a different repeater split.

Parts List

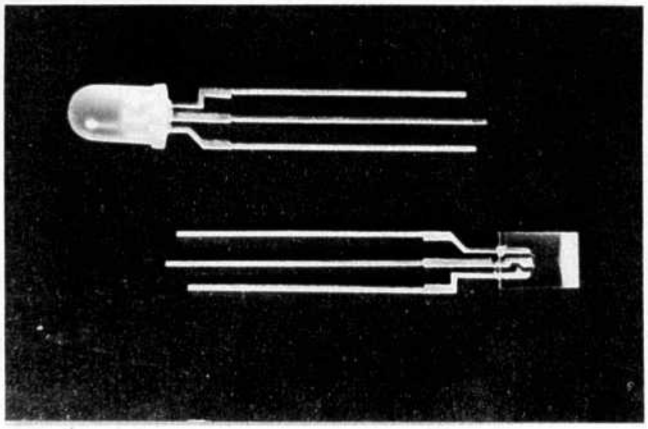
U1, U2	74193
U3	74192
U4	7490
U5, U11	7400
U6	7420
U7, U8	7483
U9, U10	74157
U12	7408
U13, U14	7448

Displays: 7-segment LED, common cathode
SPDT push-button switch
SPDT toggle switch

(Fig. 3 is on pg. 6)

Dual Color LED Indicator

Mouser Electronics has recently introduced an led that offers two colors — red and green. The color change occurs simply by reversing the polarity on the leads. Its compatibility with most DTL and TTL circuits, as well as its low-power consumption rate, makes it ideal for digital applications.



This LED operates at a forward voltage of 2 volts for the red, and 2.1 volts for the green. It has a reverse current of 5 volts at 100 uA and dissipates only 105 mW.

The Mouser dual color LED lamp is available from stock for as low as $.39 in quantities of 1000. A **free** 176-page catalog is available from Mouser on request. The address is 11433 Woodside Ave., Santee, CA 92071 tel. (619) 449-2222.

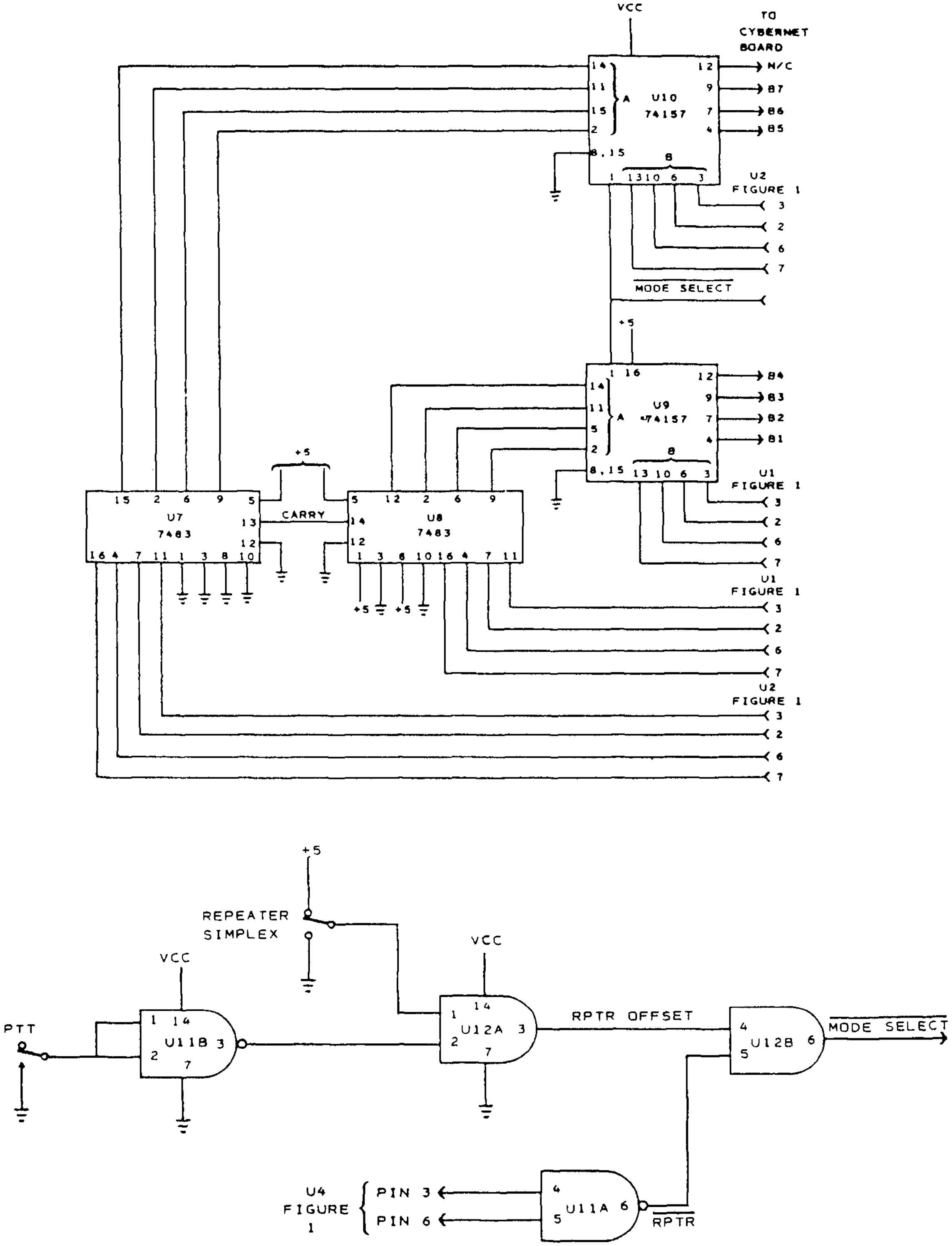


FIGURE 3: LOGIC SWITCH

Diagram drawn by Paul Donaldson

Computerized Smith Chart for Noise Bridge Applications

By Gary A. White, KO0P
1070 S. Naples Way, Aurora, CO 80017

A noise bridge can provide amateurs with valuable information on antennas and transmission lines. However, its acceptance and usage has been largely neglected because of the complex equations or graphical solutions required to translate its readings into useful data. I have developed a Commodore 64 program to help eliminate the tedious work associated with using the noise bridge. It is presented at the end of this article.

Introduction

Several years ago I was involved with antenna work and constructed a noise bridge for assistance.[1] I was surprised at the accuracy with which I could characterize the antenna and transmission line performance. At the same time, I was disappointed with the amount of time required to reduce the readings into useful parameters so I employed the Smith Chart to perform the majority of my data reductions.

The reason for the time-consuming data reductions is partly because the noise bridge circuit consists of a variable reactive element (capacitor), and a variable resistor in a parallel bridge configuration. This results in a parallel impedance model composed of parallel resistance and reactance readings. Most amateur-related articles detail a series model of the termination or load impedance. Equations 1 and 2 show that it is a time consuming, but fairly easy matter to convert the parallel readings into a series equivalent.

$$Rs = Rp * \frac{Xp^2}{Rp^2 + Xp^2} \qquad \text{(Eq 1)}$$

$$Xs = Xp * \frac{Rp^2}{Rp^2 + Xp^2} \qquad \text{(Eq 2)}$$

A popular method for graphically reducing the load impedance seen in the shack to an antenna impedance seen at the antenna is via the Smith Chart. I don't like to climb a tower with a noise bridge just to get to the termination point! Yet, I found that it takes two to three hours to compute the data from just a few minutes of using the bridge. My discussions with other amateurs have confirmed this to be the primary reason many are reluctant to employ the noise bridge. Indeed, mine has lain dormant, even scavanged for parts, since that first experience.

Thoughts about a C 64 program developed after I read an article in **Ham Radio** that featured a program for the hand-held calculator to determine antenna feed-point impedance.[2] The basic equations used in that program had to be modified so noise bridge readings could be entered directly, allowing the user to obtain the desired impedance parameters at the antenna termination point. I decided not to use a hand-held calculator for the development of this program because I wanted the option of having a hard copy of the entry data and results.

Program Equations

The fundamental problem is illustrated in Fig 1.

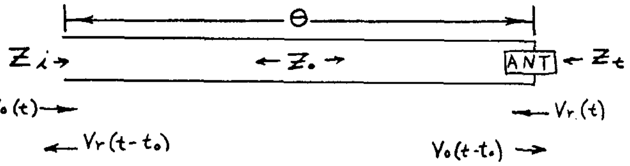


Fig 1 — Incident voltage (Vo) and reflected voltage (Vr) along a transmission line (characteristic impedance, Zo).

The noise bridge gives readings of the input impedance as seen by the transmitter or receiver at their termination point. This impedance is written as: Zi = Rs + jXs. The transmission line serves to present an antenna impedance to the bridge, which has been **rotated** through an electrical length. Eq 3 shows this.

$$\theta(\text{degrees}) = \frac{360\ L/f}{984\ \nu} = 0.3659\ \frac{L/f}{\nu} \quad (L = \text{feet}) \qquad \text{(Eq 3)}$$

As shown in Eq 3, the electrical length (θ), is a function of the physical length (L), the operating frequency (f), and the velocity factor (ν), of the feed line. In only special situations will the impedance at the end of the feed line be the same as at the antenna-termination point. Using Ohm's Law, we can write an equation for the current seen at the noise bridge (right hand side of Eq 4), as being equal to the current in the feed line terminated at the bridge (left hand side of Eq 4). The **minus** sign in front of the second term means it is a reflected voltage.

$$\frac{Vo(t)}{Zo} - \frac{Vr(t-to)}{Zo} = \frac{Vo(t) + Vr(t-to)}{Zi} \qquad \text{(Eq 4)}$$

We can now solve Eq 4 for a **modified coefficient of reflection.** This is normally defined at the antenna-termination point. However, it is just an intermediate parameter used to make the rest of the equation manipulation easier. Eq 5 defines this intermediate parameter. Using both Eq 4 and 5, the modified coefficient of reflection (ρ) is written in terms of the input resistance and reactance (Eq 6).

$$\rho \overset{\Delta}{=} \frac{Vr(t-to)}{Vo(t)} \qquad \text{(Eq 5)}$$

$$\rho = \frac{Zi - Zo}{Zi + Zo} = \frac{Rs + jXs - Zo}{Rs + jXs + Zo} \qquad \text{(Eq 6)}$$

At the termination of the antenna, another equation is written in terms of the voltage across the antenna, divided by the current in the feedline connection point:

$$Zt = \frac{1 + Vr(t)/Vo(t-to)}{1 - Vr(t)/Vo(t-to)} * Zo \qquad \text{(Eq 7)}$$

So far nothing looks good, but what we are going to do in the next few steps will simplify matters. We will solve for the ratio of reflected voltage to incident voltage at the antenna termination in terms of our modified coefficient of reflection. This can be expressed as a constant quotient. That is, the ratio is independent of time. Since our definition of coefficient of reflection contains the term Vr(t-to), we write Eq 8 as:

$$\frac{Vr(t)}{Vo(t-to)} = \frac{Vr(t-to)}{Vo(t-2to)} = \left[\frac{Vo(t)}{Vo(t-2to)}\right] * \left[\frac{Vr(t-to)}{Vo(t)}\right] \qquad \text{(Eq 8)}$$

We should recognize that the last term of Eq 8 is just the modified coefficient of reflection previously defined in Eq 5. We rewrite Eq 8 as 8A:

$$\frac{Vr(t)}{Vo(t-to)} = \frac{Vo(t)}{Vo(t-2to)} * \rho \qquad \text{(Eq 8A)}$$

Using the complex form of alternating voltage notation exp(jθt) = V(t), Eq 8a is rewritten in its final form:

$$\frac{Vr(t)}{Vo(t-to)} = \rho * \exp(j2\theta) \qquad \text{(Eq 8B)}$$

Substituting Eq 8B into Eq 7 yields the final (almost) equation necessary to develop the program.

$$Zt = \frac{1 + \rho * \exp(j2\theta)}{1 - \rho * \exp(j2\theta)} * Zo \qquad \text{(Eq 9)}$$

It should be noted that Eq 9 contains the desired information of what is the antenna characteristic input impedance based on the values of impedance measured in the shack at a particular operating frequency, line length, and velocity factor. In addition, I have assumed a perfect transmission line (i.e., no loss). When a loss factor (d), is introduced in terms of dB/(100 ft), at the operating frequency, Eq 9 can be rewritten in the form given in 9A:

$$Zt = \frac{1 + \rho * \exp(j2\theta) * k}{1 - \rho * \exp(j2\theta) * k} * Zo; \qquad \text{(Eq 9A)}$$

$$k = 10^{L*d/1000}$$

For further information, I suggest that you consult the article in ref 2, or any good introductory text (such as **Engineering Electromagnetics**, by W. H. Hayt), on antennas and tranmsission lines. In order to use these equations, they must be converted into a form which can be easily manipulated by the computer. The use of the following equation ("Euler's Formula"), allows the manipulation of Eq 9A so that it can be easily entered into the computer.

$$\exp(j\theta) = \cos\theta + j\sin\theta \qquad \text{(Eq 10)}$$

A good reference for complex number manipulation is, **Calculus and Analytic Geometry**, by Thomas.

Program Operation

A listing of the prototype program is shown in Table 1. The constants of the equation are first entered. This allows the user to restart the program at line 39 (with a GOTO 39), for successive passes with different noise bridge readings. Many of the popular bridges on the market use a range expander (typically a 100-ohm resistor in series). If your noise bridge does not have this feature, or if you are not using the range expander, be sure to answer **No** or the output values will be incorrect.

For example, an 80-m antenna is fed with 60 ft of RG-8 (50-ohm characteristic impedance; velocity factor 0.66). At 3.65 MHz, the noise bridge obtains a null with dial settings of resistance = 240 ohms and capacitance = -98 pF. We can assume that the attenuation or loss is zero. In addition, the range extender is being used. Running the program with these inputs should yield a SWR of 4.41859309:1 and an antenna series resistance/reactance of 24.0716376/-50.1107286 ohms. Other intermediate results are also displayed.

Summary

This program has been written as an aid in encouraging the use of the noise bridge in amateur antenna experimentation and development. It was also written with a minimum of **computer unique** language and commands. Therefore, it should lend itself to an easy conversion to other home computers. Please feel free to copy and pass this program to your friends, user groups and so on. However, marketing of this program is reserved by the author under existing copyright laws.

References

[1] Hubbs and Doting, "Improvements to the RX Noise Bridge," **Ham Radio**, February 1977, p 10.
[2] MacCluer, "Numerical Smith Chart," **Ham Radio**, March 1978, p 104.

Table 1

```
10 REM ***** SMITH CHART *****
20 REM *****      BY       *****
25 REM ***  GARY A. WHITE  ***
30 PRINT"⊐"
31 INPUT"▓ENTER LOSS(DB/100 FEET)";DB
33 INPUT"▓ENTER LINE LENGTH(FT)";L
34 AA=10↑-(L*DB/1000)
35 PRINT"ATTENUATION FACTOR=";AA
36 INPUT"▓ENTER VELOCITY FACTOR";VF:IF VF=0 THEN GOTO 36
38 INPUT"▓ENTER LINE IMPEDANCE";ZO:IF ZO=0 THEN GOTO 38
39 INPUT"▓ENTER FREQ(MHZ)";F:IF F=0 THEN GOTO 39
40 INPUT "▓ENTER BRIDGE RESISTANCE";RL
45 PRINT"BRIDGE RESISTANCE=";RL;"OHMS"
49 INPUT "▓ENTER BRIDGE CAPACITANCE";XJ
50 PRINT"BRIDGE CAPACITANCE=";XJ:IF XJ=0 THEN XJ = 1E-10
51 XJ=(-159000)/(F*XJ)
52 R=RL:RL=RL*(XJ↑2)/(RL↑2 + XJ↑2)
53 XJ=XJ*(R↑2)/(R↑2 + XJ↑2)
54 INPUT"▓RANGE EXTENDER USED (Y/N)";RE$:IF RE$= "Y" THEN RL=RL-100
56 PRINT"SERIES RESISTANCE/REACTANCE AT SHACK",RL;XJ
75 LDEG=0.3659*L*(F/VF)
80 PRINT"LINE LENGTH (DEGREES) =";LDEG
100 REM COMPUTE REAL AND IMAGINARY PART
101 REM OF LOAD NORMALIZED AGAINST LINE
102 REM IMPEDANCE
103 RL=RL/ZO
104 XJ=XJ/ZO
105 D=((RL+1)↑2)+(XJ↑2)
110 REM NOW COMPUTE REAL AND IMAGINARY
115 REM PARTS OF COEFFICIENT OF REFLECT
120 RP=(RL-1)*(RL+1)+XJ↑2
121 RP=RP/D
125 IP=(RL+1)*XJ-(RL-1)*XJ
126 IP=IP/D
160 P=SQR((RP↑2)+(IP↑2))
170 PRINT"COEFFICIENT OF REFLECTION=";P
180 VSWR=(1+P)/(1-P)
190 PRINT "VSWR AT SHACK =";VSWR
191 PRINT
192 AA=10↑(DB*L/1000)
200 KK=(2*π)/360
210 LDEG=LDEG*KK*2
220 RE=COS(LDEG)*AA
230 IE=SIN(LDEG)*AA
240 RN=1+RP*RE-IP*IE
250 IN=RP*IE+IP*RE
260 RD=1-RP*RE+IP*IE
270 ID=(-IP*RE)-(IE*RP)
280 DD=RD↑2+ID↑2
290 RO=ZO*((RN*RD+IN*ID)/DD)
300 IO=ZO*((IN*RD-ID*RN)/DD)
301 P=P/AA
302 VSWR=(1+P)/(1-P):
303 PRINT"VSWR AT ANTENNA =";VSWR
304 PRINT"ANTENNA RESISTANCE/REACTANCE",,RO;"/";IO
```

The program is fairly straightforward, and the only special characters that prevent it from running on other computers are contained in lines 30, 31, 33, 36, 38, 39, 40, 49, and 54. The first character in line 30 provides a "clear screen." The other character in the remaining lines provides "reversed characters" for all the input data. These could easily be removed and the program should run with almost any version of BASIC.

(continued from p 2)

short-circuit circulating current must have been noticeably greater than this measured value.) With an ammeter in the secondary of each transformer, the following currents were measured as the load on the secondary was increased.

Parallel/Parallel Connection

Ia	Ib	It	Ia/Ib
0.01	0.01	(0.00)	1.00
0.742	0.673	1.415	1.102
0.883	0.840	1.723	1.051
1.110	1.040	2.15	1.067

The first line represents no load; the currents were the circulating current. Note that the addition of the resistance of a second ammeter noticeably reduced the circulating current.

Parallel/parallel operation of transformers is addressed in most AC machinery texts.[4] The testing procedures described in such texts make interesting reading and experimenting.

Series/Series

Optimum load sharing between series/series connected transformers having the same current rating requires that the ratio of the turns ratios (primary to secondary) be inversely proportional to the ratio of the power ratings and that the primary magnetizing currents be identical. Optimum load sharing between transformers with different secondary current ratings is not possible. In the series/series connection, the most informative test is the voltage division under load, with the test preferably made in the primary circuit. If the voltage division between the two transformers differs from 0.5 by not more than 10 percent, successful operation is probable. This division between the primaries is determined almost entirely by the magnetizing impedances. Because the magnetizing impedances are nonlinear functions of the magnetizing current, it is necessary to perform this test under load: The voltage drop in the primary leakage impedance may change the magnetizing current, and thus the magnetizing impedances significantly. The following measurements were obtained.

Series/Series Connection

I	Va	Vb	Va/Vb
0.0	113.8	103.3	1.102
0.479	112.8	102.6	1.099
0.616	112.1	102.2	1.097
1.1	108.7	101.8	1.068
1.24	108.4	101.6	1.067

Here, V is the primary voltage and I is the secondary current.

The series/series connection requires that power be delivered to the load by each secondary on both half cycles. A "full-wave" rectifier with the secondary connection as a center tap will not work.

Series/Parallel

Finally, the following measurements were made in the series/parallel connection.

Series/Parallel Connection

It	Va	Vb	Va/Vb
0.0	107.5	108.1	0.9944
0.608	106.9	107.5	0.9944
1.073	106.8	107.3	0.9953
1.77	106.2	106.7	0.9953
2.41	105.7	106.2	0.9953

Notice that in the series/parallel connection the connection of the secondaries forces the primaries to divide the source voltage equally. (The ratios 0.9944 to 0.9953 can be considered 1.000 within the accuracy of the measurements.) As the primaries were excited by equal voltages, the secondary currents should be in the same ratio as for the parallel/parallel connection. For the cautious, measure the circulating current at no load when the transformer has a parallel connected secondary. If this is not more than 10 percent of the rated load current, no significant problem should be encountered in parallel operation.

Conclusion

In each of the three connections, transformer A appears to have supplied, at nominally full load, 6.7 percent more voltamperes than transformer B. At very light loads, transformer A supplied about 10 percent more voltamperes than transformer B.

The type of interconnection thus has little effect on the load sharing of the transformers: The load is split in accordance with the characteristics of the transformers regardless of the type of connection.

For these two transformers, which would probably not be regarded as "high quality," load sharing appears acceptable without the addition of external resistors or inductors. I would expect that any two nominally identical transformers (same manufacturer, same ratings), can be used in any of the four (includes parallel/series) possible interconnections without special precautions to force load sharing. -- Albert E. Weller, WD8KBW, 1325 Cambridge Blvd., Columbus, OH 43212.

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Bits

11537A — The Voltage-Controlled Attenuator

The 1537A is a junction isolated, high-precision AGC/voltage-controlled attenuator that features a proprietary supermatched gain-cell structure. The large geometry structure allows an 18 dB improvement in noise performance, a 30 dB reduction in 2nd order distortion products, and a 60 dB reduction in 3rd order distortion products. The supermatching also reduces control feedthrough by an order of magnitude in balanced configurations. The 1537A is especially suited to high-speed precision control of level, dynamic range, phase and amplitude equalization.

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Prices for the component begin at $7.50 for quantities 1 through 99. A complete data sheet on the 1537A, with price information, is available from Aphex Systems, Ltd., 13340 Saticoy St., No. Hollywood, CA 91605, tel. (818) 765-2212.

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For more information on the DTMF receiver kit, contact Teltone Corporation, 10801 120th Ave., N.E., Kirkland, WA 98033, tel. 1-800-227-3800, ext. 1130.

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