QEX 61

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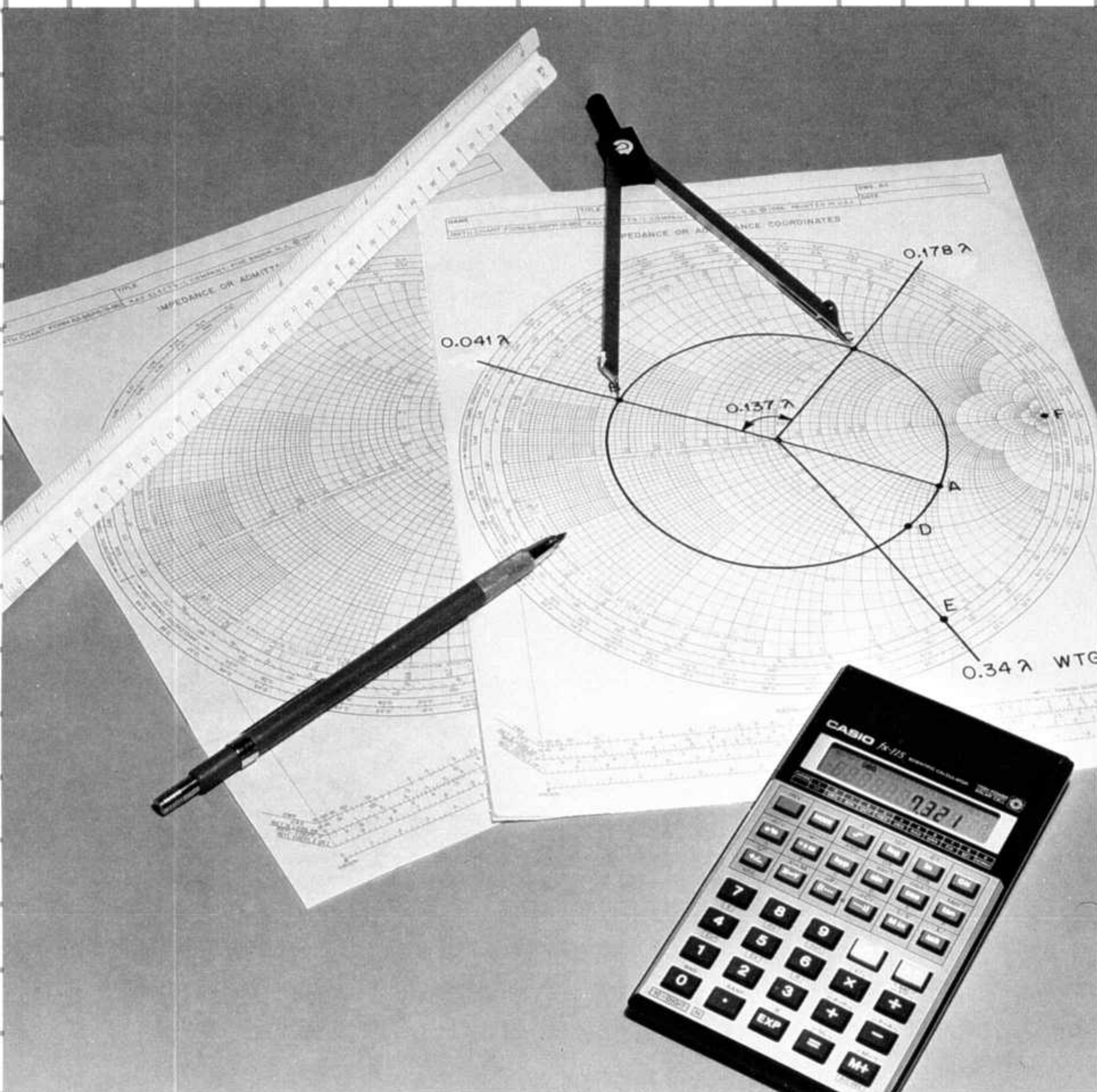
ARRL Experimenters' Exchange and AMSAT Satellite Journal



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ABOUT THE COVER

The Smith Chart is widely used for determining transmission line parameters. Using available drafting tools, and the Smith Chart fundamentals presented on page 4, impedance and admittance plots are easily charted.

THE AMERICAN RADIO RELAY LEAGUE, INC

The American Radio Relay League, Inc, is a noncommercial association of radio amateurs, organized for the promotion of interest in Amateur Radio communication and experimentation, for the establishment of networks to provide communications in the event of disasters or other emergencies, for the advancement of the radio art and of the public welfare, for the representation of the radio amateur in legislative matters, and for the maintenance of fraternalism and a high standard of conduct.

ARRL is an incorporated association without capital stock chartered under the laws of the State of Connecticut, and is an exempt organization under Section 501(c)(3) of the Internal Revenue Code of 1954. Its affairs are governed by a Board of Directors, whose voting members are elected every two years by the general membership. The officers are elected or appointed by the Directors. The League is noncommercial, and no one who could gain financially from the shaping of its affairs is eligible for membership on its Board.

"Of, by, and for the radio amateur," ARRL numbers within its ranks the vast majority of active amateurs in the nation and has a proud history of achievement as the standard-bearer in amateur affairs. As its membership journal, ARRL publishes *QST* monthly.

A bona fide interest in Amateur Radio is the only essential qualification of membership; an Amateur Radio license is not a prerequisite, although full voting membership is granted only to licensed amateurs in the US and Canada.

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Purposes of *QEX*:

1) provide a medium for the exchange of ideas and information between Amateur Radio experimenters
2) document advanced technical work in the Amateur Radio Field
3) support efforts to advance the state of the Amateur Radio art.

All correspondence concerning *QEX* should be addressed to the American Radio Relay League, 225 Main Street, Newington, CT USA 06111. Envelopes containing manuscripts and correspondence for publication in *QEX* should be marked: Editor, *QEX*.

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*.

Any opinions expressed in *QEX* are those of the authors, not necessarily those of the editor or the League. While we attempt to ensure that all articles are technically valid, authors are expected to defend their own material. Products mentioned in the text are included for your information; no endorsement is implied. The information is believed to be correct, but readers are cautioned to verify availability of the product before sending money to the vendor.

Empirically Speaking. . .

220: The Good News is. . .

QST goes to press during the first few days of the month before the cover date. It was the second day of February when Dave Sumner wrote his March *QST* "It Seems to Us" announcement that Novice Enhancement was coming. We had just a general idea of what the FCC PR Docket No. 86-161 *Report and Order* would say but had not seen the actual text. Often, the final wording carries a surprise or two; it was logical to anticipate that some of the specific new privileges that the League asked the FCC for might not be granted, or there might be some strings attached. Not true. The FCC came through with all of the enhanced operating privileges the ARRL sought for Novices in their *Report and Order* released February 10.

There was a surprise, however, and a second point that caused the raising of an eyebrow. The surprise was that there would not be a 6-month period in which to phase in new exam question pools but that the new exams and privileges would go into effect on March 21 at 0001Z UTC. That caused ARRL HQ to go on Red Alert to get the question pools updated, coordinated with other VECs, and into effect by the effective date. We also did a massive mailing of information to about 7000 people the next day to spread the good news of Novice Enhancement.

The eyebrow raiser was that Novices would get only 222.1-223.91 MHz of the 1.25-cm band. The part between 223.91 and 225 MHz was somewhat understandable as these are repeater output frequencies, and Novices are not permitted to be control operators or licensees of repeaters.

The missing 220-222.1 MHz: Hmmm! What did it portend, if anything? Was this the result of the longtime 220-MHz band joint FCC-NTIA study? The answer came swiftly. Indeed the FCC had plans for the bottom two megahertz of the 220-MHz band. These were revealed in their *Notice of Proposed Rule Making* under PR Docket No. 87-14, released on February 12, which announced the FCC's intention to allocate the 2 MHz to the land mobile services. There will be details in April *QST*, but you can obtain a verbatim copy of the 87-14 *R&O* from ARRL HQ if you mail an SASE with a 22-cent US stamp.

One can sympathize with the plight of the land mobile services: There is no question that in some parts of the country, they need more channels. What they have asked for, however, is for more channels in someone else's frequency allocations rather than first putting their own house in order. Their rationale is that: (a) dropping in ACSSB channels between existing FM channels doesn't work too well, (b) kicking someone off an existing FM (15-kHz-wide) channel to make room for three (5-kHz-wide) ACSSB channels for a 300% expansion of channels in their own bands is not convenient, and (c) these narrow-band technologies need some "virgin" frequencies, meaning someone else's. Anyone who is intimately familiar with land mobile frequency utilization will tell you that it is not state-of-the-art. There is much known about the science of spectrum management that has yet to be applied to land mobile communications. It is an open secret that it is a 4-dimensional problem being worked with 2-dimensional management tools.

The proposed deallocation of 220-222 MHz couldn't have come at a worse time from our perspective. This is prime VHF spectrum that digital experimenters have been planning for high-speed packet radio relay. Presently, 220 MHz is the lowest frequency on which we can operate at a speed up to 56 kilobauds with bandwidths up to 100 kHz. There has been a dialog with some repeater coordinators about reserving up to five 100-kHz channels in this band for high-speed packet, particularly for intercity trunks. The equipment needed for high-speed packet operation has been hard to come by to date. This was due in part because of the uncertain status of the 1.25-meter band allocation, which caused manufacturers to be reluctant to build a variety of radios for this band. We also lacked high-speed modems, but this is about to be corrected in that at least two manufacturers have firm plans to announce 9600-baud or higher-speed modem/radios this spring. Because the modems cannot be used with off-the-shelf radios, the two must be tailored as mates. So loss of this frequency space would cause these small-business manufacturers to "eat" these designs and either redesign for a less-satisfactory higher-frequency band or consider tossing in the towel.

Continued on next page.

Correspondence

EMP Petition Dismissed

During the past several months, a petition regarding a controversial subject was circulated through FCC offices. The petition suggested a study be made of how the US civilian economy could be protected from an electromagnetic pulse (EMP) generated by a high-altitude nuclear explosion. The two individuals responsible for asking the FCC to open a Notice of Inquiry on the subject of EMP and possible countermeasures were Nickolaus Leggett, N3NL, and Donald J. Schellhardt.

How did the FCC respond? The petition was considered and given a docket number (RM-5528). Both Leggett and Schellhardt filed the petition as an individual party, with no association with a corporation. In turn, GTE Service Corp notified the FCC that, "While the problem identified by the Petitioners is real, the industry and government are already addressing it, and, thus, there is no need for an FCC Inquiry at the present time." On December 5, 1986, the petition for Notice of Inquiry to consider requirements for shielding and bypassing civilian communications systems from electromagnetic pulse effects was dismissed without prejudice by the FCC.

Leggett and Schellhardt are currently in the process of appealing that decision. Their beliefs remain that, "while the individuals who makeup the FCC are briefed about EMP protection policies, who will give everyday citizens the right to see, evaluate and comment on the timeliness and adequacy of whatever standards are being developed?"

In the spirit of Amateur Radio, operators concerned with properly protecting their electronic communications equipment from EMP should reference a series of *QST* articles on, "Electromagnetic Pulse and the Radio Amateur," by Dennis Bodson, W4PWF. Parts 1 through 4 appear in August, September, October and November 1986 issues, respectively. The information appearing in the *QST* articles was excerpted from an unabridged report prepared by Dennis Bodson, Acting Assistant Manager, Office of Technology and Standards, National Communications System, Washington, DC 20305-2010. The report is available free of charge to anyone interested. Thus far, in excess of 1,000 copies of the report have been mailed to interested parties.—*Maureen Thompson, KA1DYZ, Assistant Editor, QEX*

ASR Feedback

Subscription information for the *Amateur Satellite Report* was erroneously reported in note 1 of the RUDAK article (Jan 1987 *QEX*, p 13). ASR is the official newsletter of AMSAT, written by AMSAT members involved with space-related activities, for the AMSAT membership. The newsletter is published biweekly and is inseparable from AMSAT membership ($24 annually). Further information on membership fees and benefits can be obtained by writing to AMSAT, PO Box 27, Washington, DC 20044.—*Tnx Vern Riportella, WA2LQQ*

Bulletin Board Changes User Schedule

The Timex Sinclair Amateur Radio Users Group (TSARUG) has a new telephone number for accessing their main bulletin board. The new number is 505-522-7081. An East coast bulletin board has been set up in North Carolina and can be reached after 5 pm and before 9 am, and all day on the weekends (704-547-4185). TSARUG is composed of users who are interested in putting their Timex or Sinclair computers to use in Amateur Radio operations. For more information about TSARUG and the bulletin boards, send a large SASE to Alex F. Burr, K5XY, 2025 O'Donnell, Las Cruces, NM 88001.—*Tnx Alex F. Burr, K5XY*

Call For Papers For The ARRL Packet-Radio Conference

The Sixth ARRL Amateur Radio Computer Networking Conference will be hosted by the TRW Amateur Radio Club, Redondo Beach, CA, on Saturday, August 29, 1987. The Conference will feature technical papers presented by internationally known packet-radio pioneers.

Papers are invited on Amateur Radio digital communication, in particular packet radio, in the following subject areas: transmission technologies, networking, network expansion and development, applications, operations, message handling, international matters, spectrum management, and integration of data, voice and images.

Prospective authors are requested to contact Mrs Lori Weinburg, ARRL HQ, 225 Main St, Newington, CT 06111, tel 203-666-1541 for an author's kit. Camera-ready originals are due at ARRL HQ no later than July 27, 1987.—*Paul Rinaldo, W4RI, Editor, QEX*

National Committee Hosts Space Development Conference

The L-5 Society is the largest organization of its kind responsible for uniting scientists, engineers and others involved in the future of manned space exploration and development. During March 27-29, 1987, the Pittsburgh Hilton, Pittsburgh, PA, will host the L-5 Society's Sixth Space Development Conference. The theme, "Return to the Vision," will probe the future of manned space travel. Distinguished participants will explore the challenges and opportunities of the next 50 years.

Seminar and workshop presentations feature innovative space systems, basic space flight, space education and defense, and arts related to the space age. For more information on this Conference, contact David L. Veres, 340 Amabell St, Pittsburgh, PA 15211, tel 412-841-4491.

220: The Good News is...

Continued from previous page.

Isn't the FCC being shortsighted? It can be argued that the land mobile service may be better off leaving these two megahertz in the hands of the amateur R&D caldron. Haven't we taken packet radio, once the province of the military-industrial complex, and made it practical and economical for anyone to use—including the very land mobile service that would like to do their spectrally efficient radio experiments on *our* band, not their own? Do land mobile people think that *they* developed the packet-radio equipment that is advertised in their trade publications?

High-speed packet radio is not the only current use for the 220-222 MHz band. There are numerous repeaters and auxiliary links, not to mention EME and weak-signal operations that will be disenfranchised. Many of these uses do not appear in the *ARRL Repeater Directory*. So they are not readily apparent to the FCC or perhaps the average ham. In fact, in order to find space for up to five 100-kHz packet channels in the 220-MHz band, we have considerable band planning ahead of us. We are confident that hams will do the requisite spectrum management to accommodate new technology within *our own* bands. We suggest that the land mobile service do their R&D in *their own* bands.—W4RI

Smith Chart Fundamentals

By R. Sherman Banks, N4CXF
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Kingston, GA 30145

"Why learn how to use the Smith Chart? Didn't that go out with the slide rule? Computers do that stuff now!" These are typical responses of many radio amateurs when the subject of the Smith Chart is discussed. In 1939, *Electronics Magazine* published articles about the Smith Chart written by its developer, Philip Smith.[1] In his articles, Smith described a new graphical technique for solving transmission line problems. With the advent of the computer, today's engineer has access to various computer systems that can calculate an accurate answer to a transmission line problem in minutes. An engineer who uses a graphics terminal can get both a graphical and numerical representation of possible network topologies and choose the best technique to use in a circuit. A numerical printout does not give such insight. If you want to know what a Smith Chart is and how it can be used, this article will give you the basic fundamentals of using the chart in the design of simple transmission line problems. In the process, you will acquire a better grasp of transmission line theory.

Review

Before the Smith Chart is discussed, a review of basic transmission line definitions is in order. These terms are given as a reference and provide a more complete description of the material presented here. These same definitions also appear on amateur exams administered by the Volunteer Examiner Coordinator.

An *impedance* is a voltage-to-current ratio at a given point on a transmission line or circuit. Impedances are usually written in the form

$$Z = R + jX \qquad \text{(Eq 1)}$$

where
- Z = the impedance in ohms
- R = the resistive component in ohms
- X = the reactive component in ohms.

This is a complex number. The magnitude of Z is

$$Z = \sqrt{R^2 + X^2} \qquad \text{(Eq 2)}$$

where
- R = the resistor
- X = the reactance value of a capacitor or inductor.

The *j* in front of the X says that the two numbers cannot be added together directly. Fig 1 shows a simple RC circuit that we will convert to the form $R + jX$.

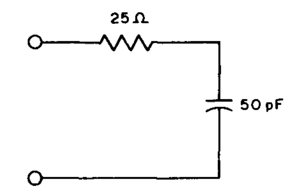

Fig 1—A simple R-C circuit.

For capacitors,

$$X = j\frac{1}{2\pi fC} \qquad \text{(Eq 3)}$$

where
- f = frequency in hertz
- C = capacitance in farads.

If we make R = 25 Ω, and C = 50 pF, and since X is frequency dependent, the circuit appears as an open at dc. At extremely high frequenices, X is a short. Suppose f = 146 MHz, then

$$jX = \frac{1}{2\pi(146 \times 10^6)(50 \times 10^{-12})}$$

$$= -j21.8 \text{ ohms} \qquad \text{(Eq 4)}$$

Thus, at 146 MHz, the circuit in Fig 1 has an impedance of $Z = 25 - j21.8$ ohms.[2] While solving Eq 4, the *j* was brought up to the numerator from the denominator to give it a negative value. It is important to note the sign of the reactance. Capacitive reactance is negative and inductive reactance is positive.

The *characteristic impedance* of a system, Z_0, is defined as the voltage-to-current ratio at a specific point on the transmission line with *no* reflected waves present. This impedance is not the resistance measured between the two leads of the transmission line with an ohmmeter. Fig 2 helps to illustrate this point and is a graph of voltage and current on a transmission line with respect to position on the line. At d_1, $Z_0 = V_z/I_z$.

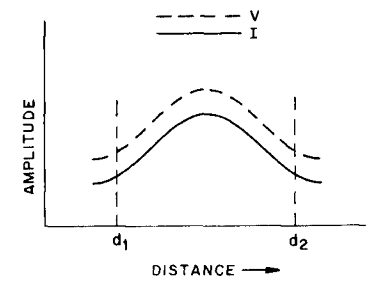

Fig 2—Graph of voltage and current on a transmission line as a function of position.

At d_2, the numbers for V_z and I_z change, but the ratio V_z/I_z stays the same. This is true no matter where the ratio is taken on the line. In these equations, V and I are called *complex quantities*.

To plot an impedance on a Smith Chart, the impedance must first be *normalized*. Normalizing an impedance usually involves dividing the $R + jX$ value by the characteristic impedance of the line. By using the impedance calculated earlier and by letting Z_0 of our line equal 50 Ω, we obtain a normalized value of

$$Z_N = \frac{Z}{Z_0} = \frac{25 - j21.8}{50}$$

$$= 0.5 - j0.436 \text{ ohm.} \qquad \text{(Eq 5)}$$

To unnormalize the equation and get the original value, multiply Z_N by Z_0.

The *reflection coefficient* is defined as

$$\Gamma_L = \frac{V-}{V+} \qquad \text{(Eq 6)}$$

where
- V− = voltage of the reflected wave
- V+ = voltage of the incident wave.

When Γ equals zero, it represents a case where all of the incident wave is absorbed by the load.

The *standing wave ratio* (SWR) of a system is defined as

$$SWR = \frac{V_{max}}{V_{min}} = \frac{1 + |\Gamma_L|}{1 - |\Gamma_L|} \qquad \text{(Eq 7)}$$

Smith Chart

The Smith Chart is a projection of Γ

[1]Notes appear on page 7.

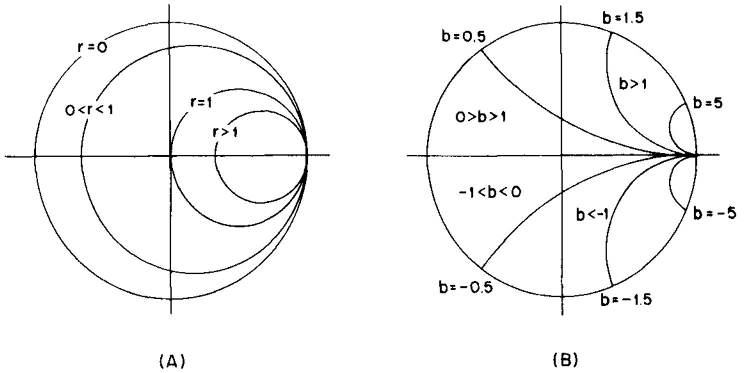

Fig 3—The data on a Smith Chart are represented by a system of lines. The circles shown at A represent constant resistance and B shows the contours of constant reactance.

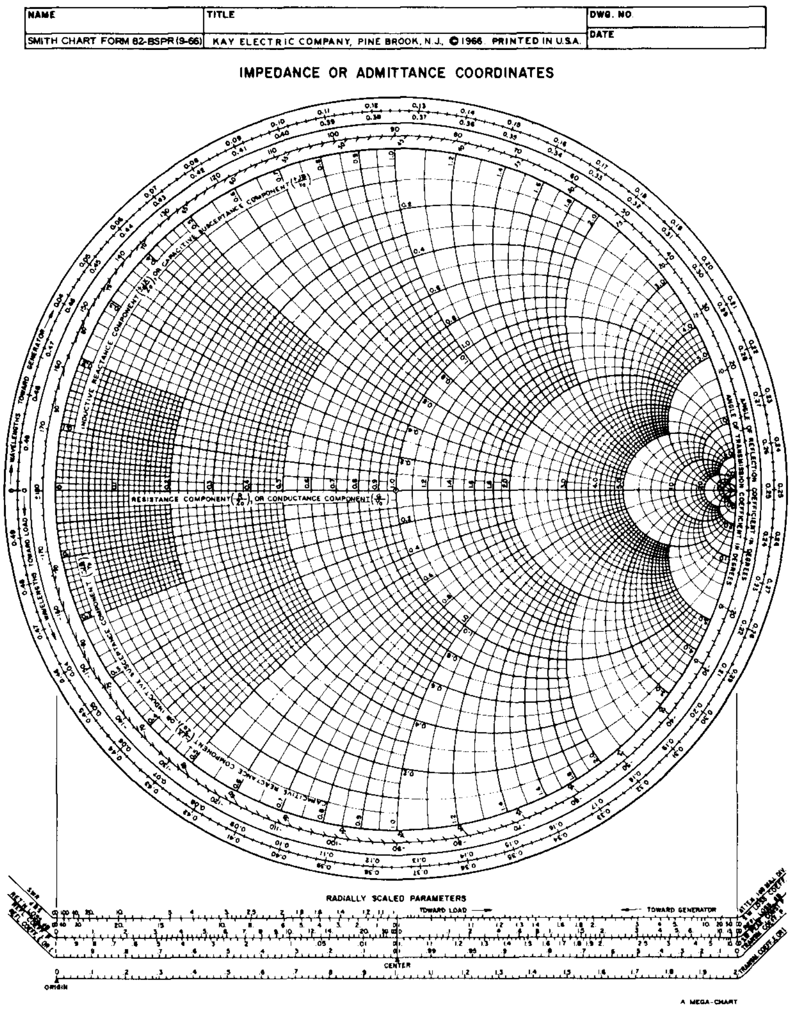

Fig 4—When the two types of circles shown in Fig 3 are superimposed on each other, the result is a Smith Chart.

where the distance from the center of the chart to any point is the $|\Gamma|$. Its angle is measured from a scale on the outside of the chart. Figs 3A and 3B show what the different lines on the Smith Chart represent. Fig 3A shows circles of constant resistance, and Fig 3B shows lines of constant reactance. Superimposing these two graphs yields the Smith Chart shown in Fig 4. In Fig 3, note that the R = 1 circle (G = 1 if we use admittance, Y, the reciprocal of impedance) passes through the center of the chart. It is the only resistance circle to pass through the center point at 1 + *j*0. An impedance plotted at this point would be matched if it was normalized to the Z_o of the line. This matched condition will be our goal in an upcoming example. But let's first use the impedance we calculated earlier. We will plot that value on the Smith Chart and calculate several quantities directly from our data.

Using the normalized quantity, Z_N, we can obtain a plot with a higher degree of accuracy (Fig 5). The radius from the chart's center to another point represents $|\Gamma|$. The angle of Γ is read from the scale labeled *angle of reflection coefficient* in degrees. The outermost circle of the Smith Chart represents $|\Gamma| = 1$ and the center of the chart is $|\Gamma| = 0$. For Z_N, $\Gamma = 0.42 \angle -123°$. The radius can be calculated by measuring the distance from the center of the chart to Z_N with a compass and transferring that to the scale at the bottom of the chart labeled *transmission coefficient E or I*. Measure this distance from 0. To calculate the SWR, use the same distance for the scale labeled SWR. This time, however, measure the distance from the center (SWR = 1).

Let's think about what we did. If the radius was 0, or the center of the chart, a reflection coefficient of 0 and an SWR of 1 would be obtained. Measure out from these limiting case values when calculating the appropriate quantity. As will be shown later, it is sometimes easier to work with admittances, the mathematical inverse of impedance. (The unit of admittance is the siemen, the reciprocal of the ohm.) Admittance is written in the form

$$Y = G + jB \qquad \text{(Eq 8)}$$

where

Y = admittance in siemens
G = conductance in siemens
B = susceptance in siemens.

Unless you own a calculator that computes complex numbers, this formula is not easy to work with. Using the Smith Chart, the problem can be evaluated in seconds.

The normalized admittance, Y_N, is a point on the Smith Chart of equal radius $|\Gamma|$, but opposite of Z_N across the origin. Fig 5 shows a plot of both Y_N and Z_N. Reading the chart,

$$Y_N = 1.1 + j0.99 \qquad \text{(Eq 9)}$$

To unnormalize this *admittance*, divide by the Z_o of the system. For example, if Z_o = 50 ohms for our system, then

$$Y_N Y_o = Y_N\left(\frac{1}{Z_o}\right) = (1.1 + j0.99)\left(\frac{1}{50}\right) = 0.022 + j0.0198 \text{ siemen.} \qquad \text{(Eq 10)}$$

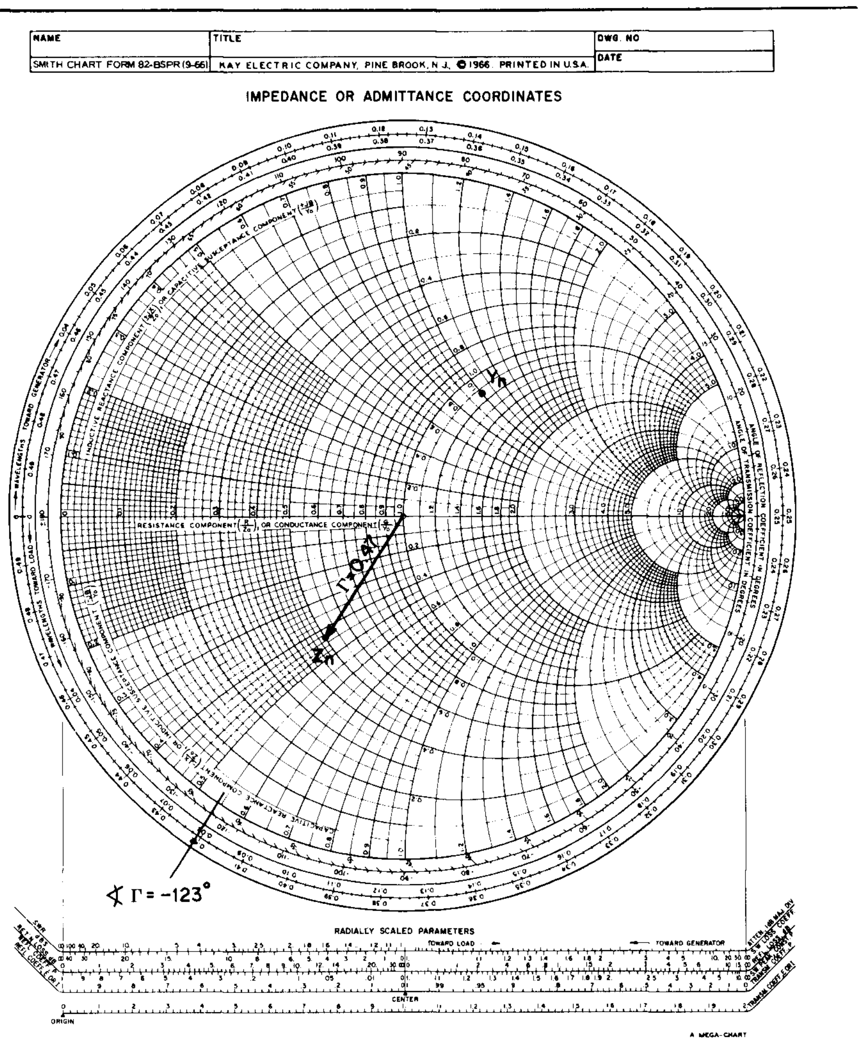

Fig 5—Z_N is called the normalized quantity and is plotted here. By using Z_N in our calculations, a more accurate plot can be charted. Point Y_N is the inverse of Z_N.

This calculation may appear backwards from that of Eq 5 because we are now working in admittances, *not* impedances. When working in admittances, multiplying by Z_0 is equivalent to dividing by Y_0, since $Y_0 = 1/Z_0$. So, if all the units are the same, the procedure for normalizing as described in an earlier section will stay the same.

Impedance Matching by Shunt Admittance

Let's look at a transmission line application using the Smith Chart. Our goal is to take an arbitrary load and cancel its reactive component while transforming the real component to the characteristic impedance of the transmission line. Assume we discover, by using a noise bridge, impedance meter or the like, that the load at the end of the transmission line, Z_L, is equal to 200 − *j*200 Ω with the Z_0 equal to 100 Ω. $Z_{LN} = 2 - j2$ and is represented by point A in Fig 6. If we use impedances, we add elements in series with the transmission line. If we work with admittances, we add them in parallel and we can calculate a transmission line *stub* that can be added in parallel to the existing transmission line. This is the preferred method and will be the way we match our system. Point B in Fig 6 shows Y_L, the inverse of Z_L. Remember our goal is to move on the Smith Chart and land on the G = 1 circle.

When using a transmission line to match the load, its corresponding movement on the Smith Chart is in a circle about the center. On our chart, we move clockwise about the origin because we are starting at the load. The only movement we can make is toward the generator. Note that on the Smith Chart the wavelengths toward the generator (WTG) is clockwise. Moving clockwise, we pass through the G = 1 circle in two places (C and D). To get to point C we moved 0.178 - 0.041 λ or 0.137 λ away from the load. Point D is 0.321 - 0.041 λ or 0.28 λ away from the load. Point C is closer to the load and its admittance is 1 + *j*1.57.

Since we now know where on the line we need to put the stub (0.137 λ), let's calculate the length it should be. If a shorted stub is used, a short in admittance corresponds to ∞ or point F on Fig 6. Point E corresponds to −*j*1.57 and 0.34 λ off the WTG scale. Since we start at 0.25 λ (point F) this must be subtracted from the previous value. So, the length of the shorted stub is 0.34 − 0.25 λ = 0.09 λ long.

If an open stub is used, its length is calculated by starting at Y = 0. We would move clockwise to 0.34 λ. This is much longer than the shorted stub and would not be the better choice.

There are other configurations which would match this system to the 100-Ω line impedance. We could have started at point D and chosen between the open and shorted stub. If we had started at point D, a +*j*1.57 value would be necessary to cancel the reactive component. Using a shorted stub, we would add 0.25 λ. Its length would be 0.25 + 0.178 λ = 0.428 λ. This is further away from the load than the value calculated previously. The final configuration using the shortest values is drawn in Fig 7.

In a vacuum, a radio wave propagates at the speed of light. Radio waves travel slower in a transmission line. To account for this, the cable manufacturer usually provides a number called the *velocity factor* (VF) for a particular line. In free space

$$\lambda = \frac{c}{f} \quad \text{(Eq 11)}$$

where

c = 3 × 10^8 meters per second
f = frequency in hertz.

To account for the VF, the equation changes to

$$\lambda = \frac{VF \times c}{f} \quad \text{(Eq 12)}$$

As an example, let us calculate the actual length of the line from the load to the stub as shown in Fig 7. This length was calculated to be 0.028 λ. Assume that for the line we have a VF of 0.7 and our design frequency is 146 MHz. Plugging these values into Eq 12 we get

$$\lambda = \frac{(0.7)(3 \times 10^8)}{146 \times 10^6} = 1.438 \text{ m};$$

$$0.028\ \lambda = (0.028)(1.438) = 0.040 \text{ m} \quad \text{(Eq 13)}$$

Our results show that the stub would need to be placed 4 cm or 1.58 inches away from the load. The length of the stub should be calculated in the same manner.

Conclusion

A more in-depth discussion on Smith Charts in transmission line applications can be found in *The ARRL Antenna*

Book.[3] A large amount of material has been presented here. Don't feel left out if you did not digest everything at once. With experience, you will learn to use the Smith Chart for solving transmission line problems. The material covered in this article is intended to be a starting point for learning how to design circuits that use capacitors and inductors to transform the impedance of transistors to any source or load. If you understand how to plot points and move on the Smith Chart, the hard part is over and it is downhill from here.

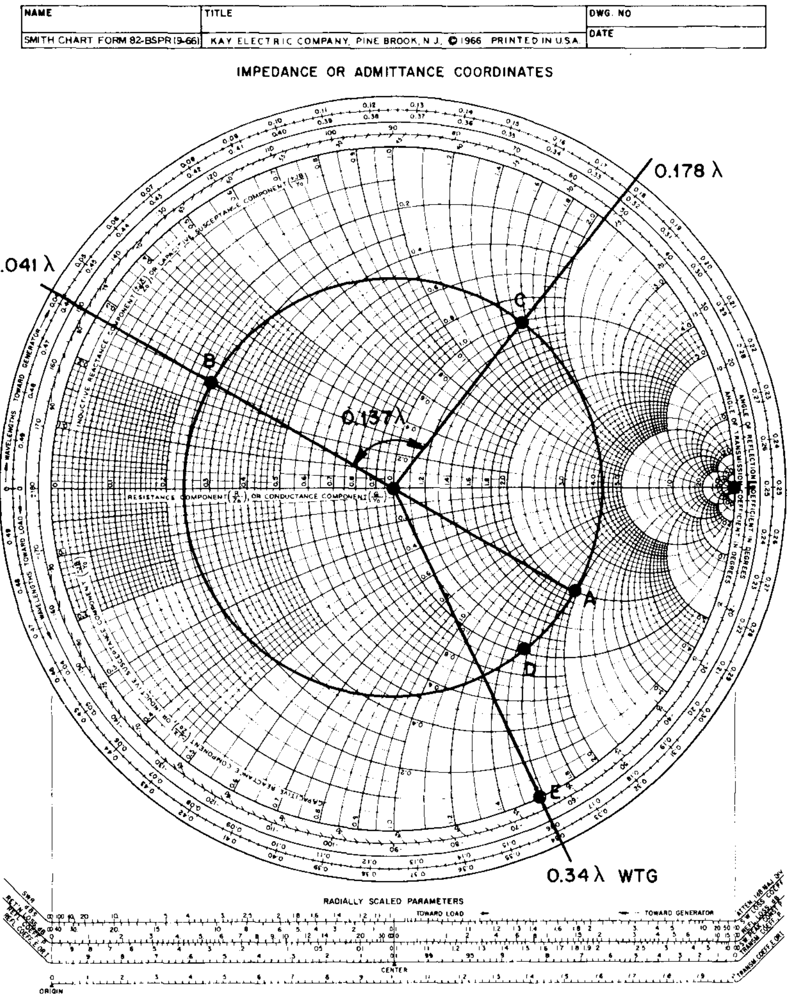

Fig 6—By using the Smith Chart's admittance coordinates, a transmission line stub can be calculated and added in parallel to the existing transmission line. How these values were obtained is explained in the text.

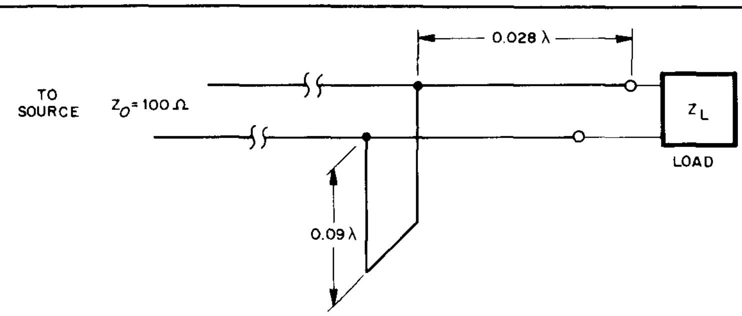

Fig 7—This schematic of our final configuration uses a shorted rod in parallel. Twin-lead is shown in this example, but coaxial cable could have been used, too.

Notes

[1]P. H. Smith, "Transmission Line Calculator," *Electronics*, Jan 1939, vol 12, p 29.

[2]F Napurano, "How to Perform AC Circuit Analysis," *QST*, May 1985, p 19.

[3]J. Hall, ed., *The ARRL Antenna Book*, (Newington: ARRL, 1982), pp 3-7 to 3-11.

Bits

New Single Chip Modem Meets Three Standards

The TSG7515 CMOS modem was recently introduced by Thomson Components-Mostek Corp. The device is a single chip solution for full-duplex operation according to three-pin selectable standards: Bell 212A, Bell 103 and CCITT V22 A-B. The TSG7515 is capable of generating and receiving both PM and FM signals. This dual capability allows the designer to achieve up to four different operating modes with data rates from 300-1200 bps.

The new chip uses differential phase shift keying to alternatively modulate two independent carriers. A data buffer converts variable rate asynchronous character data to an equivalent bit-oriented synchronous data stream. During PM a scrambler is used to ensure the transmission of a continuously changing pattern. On-chip switched capacitor filters perform filtering functions for frequency generation, out-of-band noise rejection and demodulation. A 4.9152-MHz crystal is used as the frequency reference for all internal frequencies.

To eliminate parasitic sampling effects, the modulated output signal is passed through a continuous time filter. An additional low-pass filter is provided to filter and add dual-tone, multi-frequency signals to the transmitted signal information. The TSG7515 modem chip is fabricated using an advanced double-poly CMOS process and consumes 100 mW from a ±5 V power supply. For further information on the TSG7515 modem chip, write Thomson Components-Mostek Corp, 1310 Electronics, Carrollton, TX 75006; tel 214-466-6178.—*KA1DYZ*

How to Measure Transceiver TR Switching Times

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When using an HF SSB transceiver for AMTOR[1] Mode-A (ARQ) communications, the radio must be capable of switching from transmit to receive and back again, quickly. Most manufacturers do not report switching times, and, those that do, often use differing test procedures to measure those times. The following information is offered to those amateurs interested in a consistent and repeatable method for testing radios to determine switching times. This test procedure is also suitable for determining just how "QSK" a CW transceiver is. If you have any comments or suggestions for improving this procedure, please send them to me at the address listed above.

Test Fixture

The test fixture for determining a transceiver's switching time is shown in Fig 1. The RF signal generator produces an unmodulated CW signal with an output nominally of −30 dBm or greater at the test frequency. An adjustable RF attenuator is used to control the signal generator's output and it should be able to dissipate ¼ W at any attenuator setting. The fixed attenuator has a loss of approximately −40 dB and is used to isolate the RF generator and the adjustable attenuator from the transmitter's energy. Any 50-ohm, 100-W resistive dummy load can be used to provide a 1:1.3 or lower SWR at the desired frequency. A relative RF output indicator is formed by the 1N60 diode and the RC filter at its cathode. TP2 provides a relative RF output signal for oscilloscope display.

An audio oscillator set for 2200 Hz (1700 Hz could be an alternate choice) is connected to the microphone input of the transceiver. The level of this oscillator should be adjusted, along with the microphone gain control, such that maximum RF output power is obtained without audio distortion. Use an additional HF receiver to monitor the quality of the transmitted audio. The receive audio is terminated with either an 8-Ω resistor or a speaker (a speaker is recommended). TP1 is an audio output point for oscilloscope display. The advantage of connecting a speaker at TP1 is that it allows you to hear any chirp on the received signal. Chirp might be caused by a local oscillator (LO) that is sliding onto frequency following a transmit condition, such as might be found with a poorly designed synthesizer. Transmitter push-to-talk (PTT) control is provided by a 10-Hz oscillator with 50% duty cycle (an example circuit is shown in Fig 2). The output of

[1]AMTOR is a multi-mode (either ARQ or FEC) low-speed teleprinter error control protocol (as defined in CCIR Recommendation 476-3) designed for use on HF radio.

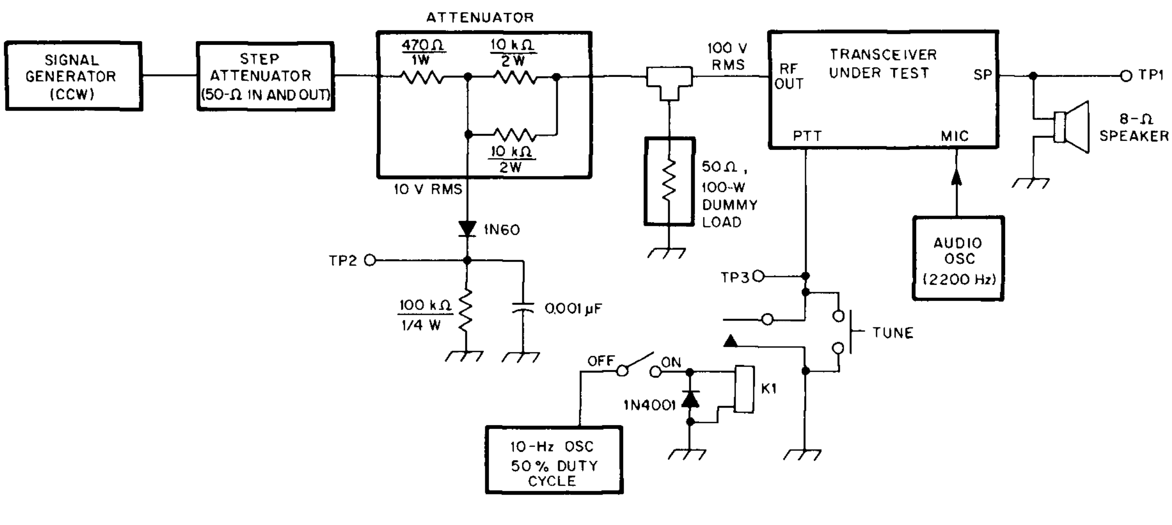


Fig 1—The test fixture for evaluating a transceiver's ability to operate on Mode-A AMTOR. The CW signal generator should be well shielded, and the step attenuator should be adjustable with a 250-mW rating. Operation of the fixture is explained in the text.

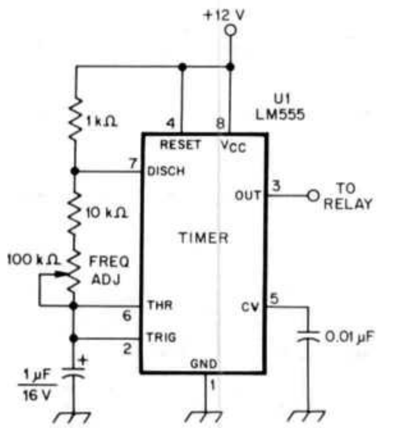


Fig 2—A 10-Hz oscillator with 50% duty cycle provides transmitter PTT control.

this 10-Hz oscillator is connected to a relay that drives the radio's PTT lead. TP3 provides a digital output for oscilloscope display to show the state of the PTT lead. In parallel with the PTT relay contacts is a momentary-contact, normally-open switch. Closing this switch forces the radio into a continuous transmitter on condition; this is useful for transmitter tune up.

Test Procedure

To correctly evaluate your radio's switching time, follow the procedure outlined in steps 1 through 10:

1) Set the transceiver to the desired operating frequency. Select SSB; tests will be done using AFSK (audio frequency shift keying). If the radio offers FSK (frequency shift keying), do a separate test using that mode and report those results as well. Select lower sideband, if possible. *Never test a radio for AMTOR operation in the CW mode.* Because some radios select different AGC time constants for CW and SSB, CW results will not always be the same as those found with SSB.

2) Open the PTT oscillator control switch so that the relay is isolated from the oscillator. Press the manual TUNE button on the PTT and tune the transmitter for maximum RF output. Note on the oscilloscope that the voltage at TP2 is about 10 V for an output of 100 W. Adjust the oscilloscope such that the trace associated with TP2 moves 2 divisions when the PTT is open, then closed.

3) Adjust the RF generator's frequency for a 2200 Hz (±100 Hz) note at the receiver's speaker. Adjust the oscilloscope such that the trace associated with TP1 moves 2 divisions when the signal generator is switched from off to on.

4) Adjust the oscilloscope such that the trace associated with TP3 moves 1 division when the PTT switch goes from open to closed.

5) Turn off the receiver's AGC, if possible. Set the adjustable step attenuator such that the receiver's audio output has a (S + N)/N = 20 dB (ie, the peak receiver audio output voltage with the signal generator turned off is about 1/10 of that when the generator is on). Don't worry about getting this level exact, a few dB error is acceptable. You are only trying to create a qualitative "low-level" signal for the receiver.

6) Close the PTT oscillator control switch so that the relay is connected to the oscillator. Adjust the oscilloscope's timebase to 5 ms per horizontal division. Adjust the oscilloscope's TRIGGER (and DELAY, if any), as required, to observe the envelopes of TP1 and TP2 as TP3 rises. Take a photo. The transmit-to-receive (TR) turnaround time is the time from TP3 rising until the audio output envelope at TP1 measures 50% (-6 dB) of its final value.

7) To observe the envelopes of TP1 and TP2 as TP3 falls, adjust the oscilloscope's TRIGGER (and DELAY, if any), as required. Take a photo. The receive-to-transmit turnaround time is the time from TP3 falling until the RF output envelope at TP2 is 50% of its final value. (Note any chirp on either transmitted or received signals by listening to the signals on a monitor receiver and the test fixture's speaker).

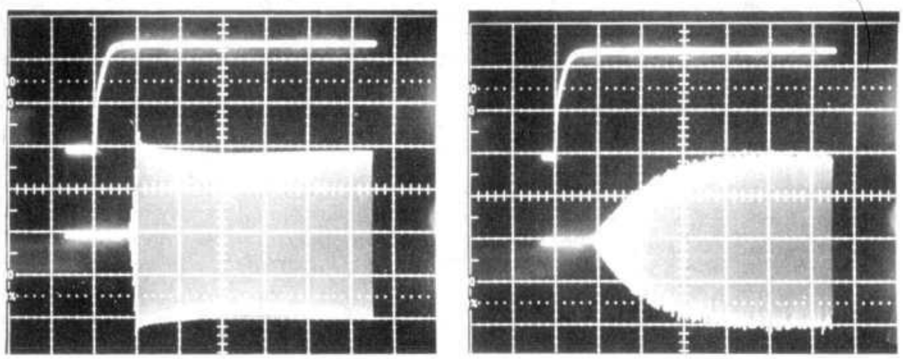
8) Turn on the receiver's AGC, if possible. Remove 50 dB of attenuation from the RF step attenuator (ie, increase the signal level to the receiver by 50 dB). With the receive signal much stronger, the AGC should now be effective.

9) Adjust the oscilloscope's TRIGGER (and DELAY, if any), as required, to observe the envelopes of TP1 and TP2 as TP3 rises. Take a photo. The TR turnaround time is the time from TP3 rising until the audio output envelope at TP1 measures 50% of its final value.

10) Adjust the oscilloscope's TRIGGER (and DELAY, if any), as required, to observe the envelopes of TP1 and TP2 as TP3 falls. Take a photo. The receive/transmit turnaround time is the time from TP3 falling until the RF output envelope at TP2 is 50% of its final value. (Again, note any chirp on either transmitted or received signals).

That completes the testing procedure. The four recorded times, two with AGC effective and two without, should always be listed as part of any test report. The values with AGC effective and ineffective should be within a few milliseconds of each other.

If your test results are similar to that of Fig 3, then your transceiver is adequate for Mode-A AMTOR under strong signal conditions. Transceivers that report all times of less than 20 ms may be justifiably referred to as "AMTOR capable." Those manufacturers whose radios have a switching time greater than 30 ms should consider redesigning the product and should certainly *not* claim or suggest that the radio is suitable for AMTOR Mode-A operation.



(A) (B)

Fig 3—Receiver turnaround-time waveforms for a modern transceiver. Each horizontal division is 20 ms. The top trace shows the key closure. The lower trace shows audio output. Upon key opening, the delay from opening to 50% audio output is measured. Receiver turnaround time with an S9 signal input is shown at A. The turnaround time is 20 ms, suitable for Mode-A AMTOR. At B, receiver turnaround time with an S1 signal is shown at a level greater than called for in our test procedure. The turnaround time is approximately 40 ms, which most operators may find unacceptable for weak-signal AMTOR Mode-A operation.

Transferring C64 Program Files With AMTOR

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With hams the world over using the Commodore 64® computer for Amateur Radio applications, programs and programming techniques are often the topic of discussion. I had successfully transferred program files across town and into the next county on VHF using packet and ASCII, but on 20 m, a clean transmission is rare. Since packet and ASCII fall victim to QRM, QRN and QSB, receiving an error-free program over the air is next to an impossible achievement.

During an AMTOR QSO, I have often been approached by other operators looking for a program or simple routine to accomplish some task. From my own experience, I surmise that this person has been searching back issues of computer-related literature without luck, and has turned to the radio for help. I may have the program at hand, but because of poor band conditions, I cannot use packet or ASCII to transmit the program error-free. This led to my evaluation of AMTOR capabilities.

The error-correcting system of AMTOR is near perfect for transmitting programs, except for one small failing—it will not operate in the *transparent* mode like ASCII or packet. AMTOR will not handle all the codes necessary for sending a program. After a program is stored in the message buffer of the PAKRATT™ model PK-64 (an all-mode data controller), and it is being transmitted in AMTOR's standard form, some of the characters are dropped. This shortcoming makes the program useless.

The solution to the aforementioned problem is to make the program transparent to the AMTOR system. That is, build a file using only codes that the AMTOR system can recognize. The program presented here performs this task for you. It converts the program into an *image* (transparent) file by changing every *byte* of the original program into a two-character hexadecimal string. (A hex file contains only the numbers 0-9 and the letters A-F.) The AMTOR system uses the image file written to disk as though it were a text or message file.

During transmission of a file, familiar BASIC commands such as GOSUB, PRINT A$, and so on, are not visible. Instead, BASIC commands are represented by a token number. For example, GOSUB's token number is 141. The BASIC operating system of the computer turns this token into the word GOSUB. The conversion program then converts the number into its hexadecimal equivalent, 8D, which AMTOR will recognize as a command.

The Image File

Fifteen two-element hex strings are combined to form a string 30 characters long. Ten of these are formed into one *frame* of the hex-image file (see Fig 1). Frame numbers and line numbers are added to the file to easily locate errors that may have crept into the received file.

Because each byte of the original program is represented by a two-element string, the image file is longer than the original program. Thus, three times as much information is produced.

Some files may take 10 minutes or more to transmit. Because FCC rule 97.84 states that the corresponding stations must identify every 10 minutes or less, call sign identification must be included in the file sent. This is accommodated for by the program.

Program Analysis

The station's call sign is entered in line 305. Line 335 builds ID$. The ID$ uses a PK-64 (and MBA-TOR) feature that automatically transmits the other station's call, the CONTROL X buffer. Once the other station's call sign is placed in the buffer, each time the system sees a CONTROL X or CHR$(24), it sends the call. W$ in line 395 enables other stations to monitor what is being sent. If frame transmission takes longer than 3 minutes, check to see that the stations are properly linked and on the same frequency. If poor band conditions exist, setting ARQTMO to 60 or more at both stations may help.

Lines 450-465 print a closing for the file. The CHR$(4), CONTROL D, at the end of line 465 is the "end-of-transmission" character. When the AMTOR system sees CHR$(4), it immediately stops transmitting and returns to the standby mode. At this time, the receiving station must *immediately* save the QSO buffer on disk.

As the file is converted from a program to its hex-image form, it is displayed on the screen. Obtaining a printer dump after the conversion process is complete is valuable. The receiving station can look at the file and request retransmission of only one line, if necessary.

```
//  DE N9FHO //
//HEX FILE FOR TEST PRGM//
<<FRAME 1>>
-0-0108270864008F202A2A2A2A2A2A2A
-1-2A2A2A2A2A2A2A2A2A2A2A2A2A2A2A
-2-2A2A2A2A2A2A2A2A004D0869008F
-3-202A20202020202020202048455849
-4-444543494D414C2020202020202020
-5-202A0073086E008F202A2020204649
-6-4C4520434F4E56455253494F4E2052
-7-4F5554494E455320202A0099087300
-8-8F202A2020202020464F5220432D36
-9-3420434F4D50555445522020202020
//  DE N9FHO //
//HEX FILE FOR TEST PRGM//
<<FRAME 2>>
-0-20202A00BF0878008F202A20202020
-1-2020202056455253494F4E20332E32
-2-412020202020202020202A00E5087D
-3-008F202A2020202020202020202020
-4-204259202020202020202020202020
-5-2020202A000B0982008F202A202020
-6-202048415256204E454C534F4E202D
-7-204E3946484F20202020202A003109
-8-87008F202A2020202020202020502E
-9-4F2E424F582037333620202020202020
//  DE N9FHO //
//HEX FILE FOR TEST PRGM//
<<FRAME 3>>
-0-202020202A0057098C008F202A2020
-1-53544556454E5320504F494E542057
-2-4953432E2035343438312020 2A007D
-3-0991008F202A202020202020202020
-4-202020202020202020202020202020
-5-20202020202A00A30996008F202A20
-6-20202048455820494D414745204649
-7-4C452043414E2042452020202A00
-8-C90998008F202A2020584D49544544
-9-20425920414D544F52204F52204241
//  DE N9FHO //
//HEX FILE FOR TEST PRGM//
<<FRAME 4>>
-0-55444F5420202A00EF09A0008F202A
-1-202020202020202020202020202020
-2-20202020202020202020202020202A
-3-00150AA5008F202A20202046524545
-4-20544F20434F5059204E4F5420544F
-5-2053454C4C20202A003B00AA008F20
-6-2A2A2A2A2A2A2A2A2A2A2A2A2A2A2A
-7-2A2A2A2A2A2A2A2A2A2A2A2A2A2A2A
-99-2A000000
//END//END//END//
//HEX FILE FOR TEST PRGM//
//SAVE QSO-BUFFER IMMEDIATELY//
//  DE N9FHO...LINK DOWN//
```

Fig 1—Fifteen two-element hex strings are combined to form a string 30 characters long. Ten of these are formed into one frame of the hex-image file.

Converting Hex to Program

The hex-image-to-program file is part two of the program. Once the name given to the received QSO buffer is entered, line 675 of the program initializes a search through the file for a series of two slash marks ("//"). The slash marks appear at the end of the string. When the marks are located, the program goes to line 685 and the file-conversion process begins. This scheme should eliminate the need for any editing of the file by hand. The program ignores extraneous remarks that precede the hex-image file. Information such as, "Good afternoon Harv, a fine day at the Copa here in Rio. . . Temp 35°C. .," may be of great importance to a displaced Carioca like me who is trying to survive the rigors of a Wisconsin winter. However, the data could cause problems within the file. Therefore, the program is written to eliminate and ignore ID$, W$ and frame numbers embedded in the file. Only the hex data is converted to a usable program (lines 705-715).

Error Trapping

When the program finds a line containing hex data (line 715), it goes to an error-trapping routine (line 775). There, it removes the line number and checks that the remainder of the string has the required 30 characters. (Only the last line of hex data can be less than 30 characters long.) Next, the program checks the line to make sure that all the characters are either 0-9 or A-F. If other data that are not hex numbers or letters exist, the error routine eliminates them. Once these two tests are complete, the hex-to-decimal conversion begins at lines 815-830. The resulting numbers are PRINTed to disk to reconstruct the program in usable form.

If one of the two tests had failed, an EDIT routine is available at line 860. The program gives an indication of the failure. . . too many or too few characters in a line. At times, characters may be transformed (ie, an "A" becomes a "K").

The EDIT routine goes through the image file twice. During the first pass, erroneous data can be singled out and correct information resent by the person who initiated the transmission. On the second pass, corrections can be made on the screen. Be sure to remove the first program file the conversion program made. The DOS does not allow two programs to share the same name on one disk.

Additional Program Notes

The FOR/NEXT loops in lines 425, 665 and 690 use the C64's reserved system variable ST. ST, or status, gives information on how the last input/output operation occurred. The ST value changes constantly as the program is run, and enables you to read a file of unknown length. As long as ST = 0 (everything okay), X also equals 0, and the loop continues. When the "end-of-file" marker is encountered on disk, the ST value changes to 64, X becomes greater than

```
100 REM ******************************
105 REM *          HEXADECIMAL          *
110 REM *   FILE CONVERSION ROUTINES   *
115 REM *      FOR C-64 COMPUTER       *
120 REM *         VERSION 3.2A          *
125 REM *              BY               *
130 REM *     HARV NELSON - N9FHO      *
135 REM *         P.O.BOX 736           *
140 REM *  STEVENS POINT WISC. 54481   *
145 REM *                               *
150 REM *    HEX IMAGE FILE CAN BE     *
155 REM *  XMITED BY AMTOR OR BAUDOT   *
160 REM *                               *
165 REM *   FREE TO COPY NOT TO SELL   *
170 REM ******************************
175 :
180 POKE 53280,0:REM BLACK BORDER
185 POKE 53281,0:REM BLACK SCREEN
190 POKE 646,1  :REM WHITE PRINT
195 DIMC$,C,Z$,Y$,X,Y,L,L%,L$,Q,Z,R
200 DIMA$(255)
205 S$=CHR$(147):REM CLEAR SCREEN
210 D$=CHR$(17) :REM CURSOR DOWN
215 U$=CHR$(145):REM CURSOR UP
220 R$=CHR$(18) :REM REVERSE ON
225 V$=CHR$(146):REM REVERSE OFF
230 :
235 PRINTS$D$D$"AMTOR FILE CONVERSION ROUTINES"
240 PRINTD$D$"1. PROGRAM TO HEX IMAGE"
245 PRINTD$"2. HEX IMAGE TO PROGRAM"
250 PRINTD$"3. VIEW DISK DIRECTORY"
255 PRINTD$"4. HEX PRINTER DUMP"
260 PRINTD$D$"ENTER A NUMBER"
265 GETK$:IFK$=""THEN265
270 IFVAL(K$)<1ORVAL(K$)>4THENPRINTR$" 1 TO 4 ONLY ":GOTO260
275 ONVAL(K$)GOTO295.590,1040,1270
280 :
285 REM *** CONVERT PROGRAM TO HEX ***
290 :
295 PRINTS$D$"CONVERT PROGRAM TO HEX IMAGE FILE"
300 PRINTD$"ENTER YOUR STATION CALL"D$
305 INPUT CL$
310 PRINTD$"ENTER NAME OF PROGRAM TO CONVERT:"D$
315 GOSUB1180
320 PRINTD$"WANNA MAKE ANY CHANGES?  Y/N"
325 GETK$:IFK$=""THEN325
330 IFK$="Y"THEN295
335 ID$="// "+CHR$(24)+" DE "+CL$
340 PRINTS$D$"BUILDING LOOK-UP TABLE... STANDBY"D$D$D$
345 FORX=0TO255:C$=""
350 L=X/16:FORI=1TO2:L%=L:L$=CHR$(48+L%-(L%>9)*7):C$=C$+L$:L=16*(L-L%):NEXT
355 A$(X)=C$:PRINTU$X"   "A$(X):NEXT
360 CLOSE8:CLOSE9:CLOSE15
365 OPEN15,8,15
370 OPEN8,8,8,P$+",P,R"
375 INPUT#15,E1$,E2$,E3$,E4$
380 IFVAL(E1$)<>0THEN1225
385 HX$=LEFT$(P$,12)
390 HX$=HX$+"-HEX"
395 W$="//HEX FILE FOR "+P$+" PRGM//"
400 OPEN9,8,9,HX$+",S,W"
405 PRINT#9,ID$" //"
410 PRINT#9,W$
415 F=0:GOSUB550
420 Q=0:C$="":Z$="":Z=0
425 FORX=0TO1:GET#8,C$:X=ST
430 C=ASC(C$+CHR$(0))
435 Z$=Z$+A$(C):Z=Z+1
440 IFZ>14THENZ=0:GOSUB515
445 NEXT:Q$="-99-":GOSUB520
450 PRINT#9,"//END//END//END//"
455 PRINT#9,W$
460 PRINT#9,"//SAVE QSO-BUFFER IMMEDIATELY//"
465 PRINT#9,ID$"...LINK DOWN//"CHR$(4)
470 CLOSE8:CLOSE9:CLOSE15
475 PRINTS$D$D$"THE PROGRAM - "P$
480 PRINTD$"HAS BEEN CONVERTED TO"
485 PRINTD$"A HEX IMAGE FILE - "HX$
490 PRINTD$"AND IS NOW READY FOR TRANSMISSION"
495 PRINTD$D$D$"PRINTER DUMP OF THE HEX FILE?   Y/N"
500 GETK$:IFK$=""THEN500
505 IFK$="Y"THENGOSUB1290
510 END
515 Q$="-"+RIGHT$(STR$(Q),1)+"-"
520 PRINTQ$Z$
525 PRINT#9,Q$Z$:Z$=""
530 Q=Q+1:IFQ>9THENQ=0:GOSUB540
535 RETURN
540 PRINT#9,ID$" //"
545 PRINT#9,W$
550 F=F+1:F$="((FRAME"+STR$(F)+"))"
555 PRINTS$"CONVERTING "P$" TO HEX IMAGE FILE"D$
560 PRINTTAB(16)"FRAME"F:PRINTD$"LINE #"D$
565 PRINT#9,F$:F$=""
570 RETURN
575 :
580 REM ** CONVERT HEX TO PRGRM FILE **
```

1 (X = ST), and the input loop is terminated. Thus, we need not concern ourselves with how many elements the file contains.

Lines 345-355 build a look-up table of hexadecimal strings to represent the numbers 0-255. Lines 425-445 GET the individual characters from the original program, reading the program file as though it were sequential. The character will always be a number from 0-255. The hex-image string of that particular number is found in the look-up table array and PRINTed in the image file. Certain computers (IBM® PC, PCjr and TRS-80® IV) have a HEX$ function as part of their BASIC software that will return the hexadecimal form of most numbers. The C64 does not have this feature. If you convert the program for use on one of these other machines, use the HEX$ function; it saves time. Lines 815-840 convert the hex data back to decimal on the receiving end.

Lines 1040-1160 display the disk directory without affecting program operation. This feature has been included because I have a problem remembering the names assigned to different files on disk. If your memory is better than mine, this routine can be eliminated.

When the program converts a received file, hex data is displayed on the screen. The program may appear to be hung up, with no activity, and the disk drive will run intermittently. This occurs because the write buffer is being loaded with data that will only be printed to disk when the buffer is full or the file is closed. Be patient while running this program. It is short and the process takes but a few minutes at most.

Interpreting Received Data

If the initial hex string of the received program is 01, then it is a BASIC program. If it is 00, you are receiving a machine-language file. After the program is converted back into its original form, load it to the buffer as any C64 program would be.

Transmitting Data

The size of the program that can be transmitted is limited by the size of your computer's message buffer and the QSO buffer of the AMTOR system the receiving station uses. It takes a little longer than one minute to send one block of a disk file. So, if your hex-image file occupies 45 blocks on the disk, it will take about 50 minutes to transmit the file on a perfect-running AMTOR link.

To reduce transmit time, break the data of a large program into several parts and send each part separately. Then, on the receiving end, use a merge system to reconstruct the program into a whole unit. Use of buffer space is also reduced by *crunching* the program before it is con-

```
585 :
590 PRINTS$D$"CONVERT HEX IMAGE TO PROGRAM"
595 PRINTD$D$"ENTER NAME OF HEX IMAGE FILE"D$D$
600 GOSUB1180
605 HX$=P$
610 CLOSE9:CLOSE8:CLOSE15
615 OPEN15,8,15
620 OPEN9,8,9,HX$+",S,R"
625 INPUT#15,E1$,E2$,E3$,E4$
630 IFS=0THENS=1:IFVAL(E1$)=62THENHX$=HX$+"-HEX":GOTO610
635 IFVAL(E1$)<>0THEN1225
640 PR$=HX$
645 IFLEN(PR$)>4THENPR$=LEFT$(PR$,LEN(PR$)-4)
650 PR$=PR$+"-PRG"
655 OPEN8,8,8,PR$+",P,W"
660 C$=""
665 FORX=0TO1:INPUT#9,C$:X=ST
670 IFC$=""THEN680
675 IFRIGHT$(C$,2)="//"THENX=2
680 NEXT
685 C$=""
690 FORX=0TO1:INPUT#9,C$:X=ST
695 IFC$=""THEN720
700 IFASC(C$+CHR$(0))=10THENC$=RIGHT$(C$,(LEN(C$)-1))
705 IFASC(C$+CHR$(0))=47THEN720
710 IFASC(C$+CHR$(0))=40THENGOSUB755
715 IFASC(C$+CHR$(0))=45THENGOSUB775
720 NEXT
725 CLOSE9:CLOSE8:CLOSE15
730 PRINTS$D$"THE HEX IMAGE FILE - "HX$
735 PRINTD$"HAS BEEN CONVERTED TO"
740 PRINTD$"THE PROGRAM - "PR$
745 PRINTD$"AND IS NOW READY TO RUN"
750 END
755 Z$=RIGHT$(C$,(LEN(C$)-7)):F=VAL(Z$)
760 PRINTS$"CONVERTING "HX$" TO PRGM FILE"D$
765 PRINTTAB(16)"FRAME"F:PRINTD$"LINE #"D$
770 RETURN
775 LN=VAL(RIGHT$(C$,(LEN(C$)-1)))
780 Z$=RIGHT$(C$,(LEN(C$)-3))
785 PRINTC$
790 IFLEN(Z$)<>30THEN860
795 FORR=1TOLEN(Z$):L%=ASC(MID$(Z$,R,1))
800 IFL%<48ORL%>70THEN885
805 IFL%=>58THENIFL%=<63THEN885
810 NEXT
815 FORY=1TOLEN(Z$)STEP2
820 Y$=MID$(Z$,Y,2)
825 L=0:FORI=1TO2:L%=ASC(Y$):L%=L%-48+(L%>64)*7:Y$=RIGHT$(Y$,1):L=16*L+L%:NEXT
830 PRINT#8,CHR$(L);
835 NEXT
840 RETURN
845 :
850 REM *** DATA ERROR ROUTINES ***
855 :
860 IFLN<>99THEN890
865 Z$=RIGHT$(Z$,(LEN(Z$)-1))
870 IFZ$=""THEN840
875 ER=LEN(Z$)/2
880 IFER=INT(ER)THEN795
885 ER$="ILLEGAL CHARACTER ERROR"
890 IFLEN(Z$)>30THENER$="TOO MANY CHARACTERS IN:"
895 IFLEN(Z$)<30THENER$="NOT ENOUGH CHARACTERS IN:"
900 PRINTS$#A DATA ERROR HAS OCCURRED'"
905 PRINTD$ER$
910 PRINTD$"LINE #"LN"  OF FRAME"F
915 PRINTD$C$
920 PRINTD$D$"PRESS:"D$
925 PRINT"F1 EDIT THIS LINE ON SCREEN"
930 PRINT"F3 SKIP THIS LINE/BYTE & CONTINUE"
935 PRINT"F5 ABORT & SCRATCH "PR$" FILE"
940 PRINT"F7 DUMP HEX FILE TO PRINTER"
945 PRINT"   (ALSO SCRATCHES "PR$" FILE)
950 GETK$:IFK$=""THEN950
955 K=ASC(K$)-132
960 IFK<1ORK>4THEN950
965 ONKGOTO970,840,1015,1010
970 PRINTS$"EDIT LINE #"LN" OF FRAME"F
975 PRINTD$"TYPE YOUR CORRECTION DIRECTLY ON THE LINE DISPLAYED BELOW. ";
980 PRINT"THE "CHR$(34)"-#-"CHR$(34)" IS THE  FRAME LINE NUMBER AND MUST BE ";
985 PRINT"INCLUDED  IN YOUR CORRECTION. 0 TO 9 ARE VALID.   THE LAST";
990 PRINT" LINE OF THE FILE SHOULD BE -99-"
995 PRINTD$D$"  "C$U$
1000 INPUTC$
1005 PRINTS$:GOTO780
1010 GOSUB1285
1015 CLOSE8:CLOSE9
1020 PRINT#15,"S0:"+PR$:CLOSE15
1025 END
1030 REM **** READ DISK DIRECTORY ****
1035 :
1040 OPEN15,8,15:R=0
1045 PRINT#15,"I"
1050 PRINTS$
1055 C=0
1060 OPEN2,8,0,"$0:*"
1065 GET#2,C$,C$
```

```
1070 GET#2,C$,C$,C$,B$
1075 A=ASC(C$+CHR$(0))+256*ASC(B$+CHR$(0))
1080 IFSTTHEN1160
1085 E$=""
1090 IFCTHENE$=MID$(STR$(A)+"    ",2,3)
1095 GET#2,C$
1100 IFC$<>CHR$(34)ANDC$<>"B"THEN1095
1105 GOTO1125
1110 GET#2,C$
1115 IFC$=""THEN1135
1120 IF(ASC(C$)AND127)<32THEN1110
1125 E$=E$+C$
1130 GOTO1110
1135 E$=LEFT$(E$,25)
1140 IFR=0THENE$="0 "+R$+E$+D$
1145 PRINTE$:R=1
1150 C=C+1
1155 GOTO1070
1160 CLOSE2:CLOSE15:GOTO1235
1165 :
1170 REM *** CHECK FILE NAME STRING ***
1175 :
1180 INPUTP$:IFP$=""THENPRINTU$U$:GOTO1180
1185 FORI=1TOLEN(P$)
1190 P2$=MID$(P$,I,1)
1195 IFP2$="*"THEN1215
1200 NEXT
1205 RETURN
1210 REM *** DISK ERRORS ***
1215 PRINTR$"  NO WILD CARD LOADS!!  "
1220 GOTO1235
1225 PRINTS$D$D$"CAN'T LOCATE FILE NAME. CHECK DIRECTORY"D$D$
1230 PRINTE1$R$"  "E2$"  "V$E3$" "E4$
1235 PRINTD$D$R$" PRESS A KEY TO CONTINUE "
1240 GETK$
1245 IFK$=""THEN1240
1250 RUN
1255 :
1260 REM *** PRINTER ROUTINES ***
1265 :
1270 GOSUB1275:RUN
1275 PRINTS$"ENTER NAME OF HEX IMAGE FILE:"D$
1280 INPUTHX$
1285 CLOSE8:CLOSE9
1290 PRINTD$"TURN YOUR PRINTER ON, THEN HIT "R$" RETURN "
1295 POKE198,0:WAIT198,1:POKE198,0
1300 CLOSE4:OPEN4,4
1305 CLOSE15:OPEN15,8,15
1310 CLOSE9:OPEN9,8,9,HX$+",S,R"
1315 INPUT#15,E1$,E2$,E3$,E4$
1320 IFVAL(E1$)<>0THEN1225
1325 PRINTS$D$D$"PRINTER DUMP IN PROGRESS...."
1330 FORX=0TO1:INPUT#9,C$:X=ST
1335 IFASC(C$)=10THENC$=RIGHT$(C$,(LEN(C$)-1))
1340 PRINT#4,C$
1345 NEXT
1350 PRINT#4:CLOSE4:CLOSE9
1355 RETURN
```

verted to a hex-image file.

Program Compatibility

I have been working with several hams to experiment with similar file transmissions using AMTOR on 20 m. The group has been successful in converting, transmitting and reconverting, BASIC and machine-language files without error. Sometimes the path was 5400 miles long! Transmissions were sent at different times of each day, including weekend afternoons when QRM and QSB are most noticeable. Each station used less than 150-W power output, and antennas included everything from dipoles to five-element beams. High power and elaborate antenna systems are not required for perfect copy on AMTOR.

The program presented here is for the C64 computer. However, Apple® and IBM owners can modify it for use with their systems. The programs can be held on disk for store and forward by *any* message-storage operation system, regardless of computer model.

The programs sent between the group members were up and running within one half hour. The process may at first seem tedious and slow, but when considering that it takes a mailman 10-14 days to accomplish the same task, AMTOR is a vast improvement.

Program Uses

Attempting to transmit a game program you wrote to your buddy in Tanzania is probably a waste of time because the band will close before you finish. But, if you should want to forward a 5- to 15-kbyte program across country, there should be no problem.

It should also be possible to use this same system to transmit programs using BAUDOT. The group has not tried it yet. BAUDOT does not have the error-correcting features of AMTOR, and near-perfect conditions may be necessary to copy a complete and functional program.

Another use for this program might be in the transmission of bit-mapped graphics, similar to the SSTV mode, where perfect copy is necessary. A complete multicolor bit map of 8000 bytes would require transmission of a 24,000-character hex-image file. If a monochrome bit map is sent, as in a line drawing, graph, schematic or cartoon, only the bytes that represent ink (their memory locations and values) are sent.

Conclusion

With a little time and effort, this program can be modified to work with any computer system. If you are not fond of typing, a copy of the program for the C64 computer is available from the author free of charge. Send a disk and an SASE return disk mailer to Harv Nelson, PO Box 736, Stevens Point, WI 54481.

Acknowledgements

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Bits

Tekdraw for the Apple® II Computer Family

Tekdraw is designed for anyone requiring a quality, inexpensive, easy and flexible drawing system. Circuit schematics, robotic systems, architectural layouts, charts, graphs and much more can be designed. Several hundred computer predrawn technical symbols and shapes are included with each Tekdraw package. Rotate and position objects on the computer screen as necessary. Joysticks or game paddles can be used an inexpensive, but effective controllers.

Tekdraw also contains a utility program section. Included programs are a memory reader, ASCII keyboard decoder, picture reconstruct, easy printer interface and a Page II to Page I HGR graphics converter.

The program requires 48-kbyte RAM, one disk drive and is compatible with the Apple II computer family. Tekdraw sells for $69.95 and is available from Computer Aided Instructional Systems, Box 177, Bldg 5, Service Dr, Holly, MI 48442—*KA1DYZ*

>50

Focus on technology above 50 MHz

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Solid-State Construction Practices, Part 3

In the past two columns I have covered components, circuit layout and enclosures and connectors for use in construction projects at VHF and above. This month I will cover some loose ends that add to the overall picture: thermal considerations and transistor handling.

Thermal Considerations

Since transistors do not run at 100% efficiency, they dissipate heat. For the designer/builder, this means figuring a way to get the heat out of the transistor and into the air. The higher we go in frequency, the more inefficient things get. At the frequencies most of us are interested in, getting the heat out can be a real headache at times. Remember that a transistor junction has a recommended maximum operating temperature. The idea is to provide a heat-sinking system for the device that will keep the junction below the maximum.

I will not go into an actual design here; rather, I will present some general guidelines. You can find a detailed analysis of thermal design in Chapter 6 of *The 1987 ARRL Handbook* (starting on p 6-18) and in a recent *QST* article.[1]

When you're trying to find the right heat sink for a device, first go to the data sheet and look at the collector efficiency specs. A little math will get you to a number for the maximum dissipated power. The data sheet also gives a number for thermal resistance between the junction and the case (θ_{jc}), usually specified in degrees Celsius per watt (°C/W).

The situation is analogous to current flowing through a resistor. Heat flow is equivalent to current flow, thermal resistance is equivalent to resistance and temperature is equivalent to voltage. What we want to do is keep the thermal resistance between the transistor junction and the outside air low enough that the temperature of the junction stays below the recommended maximum (usually 200°C).

Heat sinks are rated in terms of their thermal resistance to ambient air. The rating often applies to a specific orientation of the heat sink, usually vertical. Remember: we want convection to take the heat away. If you have heat sinks in your junk box, consult a manufacturer's catalog and find one that is similar to what you have. This will give you a rough idea of the thermal resistance number to crank into your design. Choose a heat sink that is right for the job. Better too big than too small!

While we usually think of heat sinks and power dissipation in the context of power devices, all the same rules apply to small-signal devices too. Usually, convection off the case and conduction out the leads is enough to keep the junction at the right temperature. Sometimes, however, a clip-on heat sink is in order. Look at the data sheets and go through the calculations, especially on a new circuit or new device.

On high-power devices, the thermal resistance between the transistor case and the heat sink can be significant. Make sure the flange is flat and mates with the heat sink surface perfectly, then a little thermal grease will make everything nice and cool.

In most mobile-type transistor packages, the flange or stud is electrically insulated from the device. Microwave-type devices often have the flange or stud act as not only the heat-sink junction, but also the electrical return path for the circuitry. This is why you often see microwave circuits built onto a one-piece brass or copper carrier. Sometimes, the circuit boards and transistors are actually soldered down to the carrier, which in turn is bolted to a heat sink. This technique affords both a good electrical and a good thermal circuit.

When it's all done, remember you want the heat sink mounted with the fins up, or at least vertical, so natural convection will carry the heat away. If you mount the heat sink horizontally, you will impair natural convection, and the θ_{jc} numbers you worked so hard on will no longer be valid. See Fig 1.

It really is worth getting familiar with the fundamentals of thermal design and taking the time to build it right. If you don't, Murphy's Law says that your newest project will work flawlessly until you're in the middle of the next big band opening or contest—thermal stress time. . .

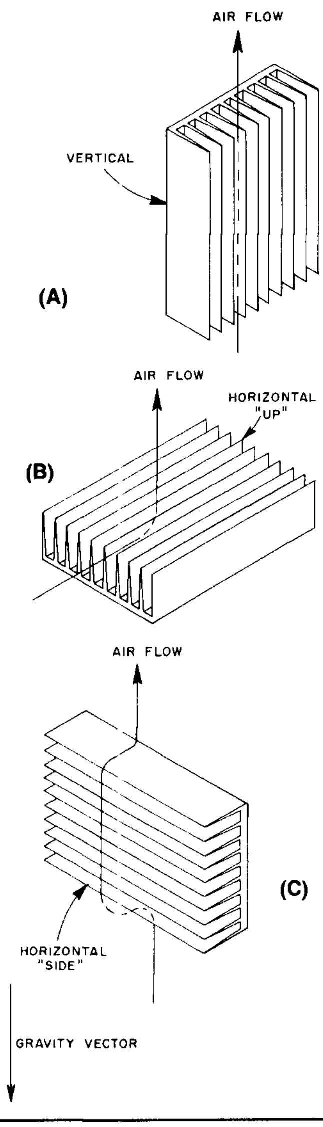

Fig 1—Possible heat-sink orientations. The orientation at A is best. Used in many commercial applications, the orientation at B is acceptable as long as you don't stack other equipment on top of the heat sink. The orientation at C should be avoided if at all possible. In all cases, allow sufficient room for airflow around the heat sink.

Transistor Handling

Small-signal devices are usually supported by their leads in a circuit, so you must take care to see that the leads stay on the device after it is installed. This is usually not a problem with most modern transistor packages, but should certainly be kept in mind when trying to stretch a transistor to fit. Use a minimum of heat when soldering, and use a pair of

[1]D. Jansson, "Keeping Cool: A Thermal Design Primer," *QST*, Jun 1984, pp 11-14.

needle-nose pliers to heat sink the lead if possible. Mount all the other components into the circuit first, and solder the transistor in last. This helps to avoid placing undue stress on the device.

GaAsFETs and some MOS devices are static sensitive because of their very delicate geometries and subsequent low current-handling capability of their gate structures. Though in recent years with gold-metallized gates the static problem is not as prevalent as it once was, it's still a good idea to use a grounded tip on your soldering iron when soldering in these devices. Avoid picking GaAs devices up with your fingers, especially on one of those clear, dry static-electricity-generating days!

Power devices are not usually static sensitive, and they are relatively rugged mechanically. The beryllium-oxide insulator that the leads are mounted on is brittle, however. When mounting these devices, screw down the stud or flange first, making sure there is no stress on the package or leads, and *then* solder it into the circuit. The leads should not bend away from the package to contact the circuit board. If you bend them too far, you risk breaking the package. You'll know if you do. The quiet "crack" sound

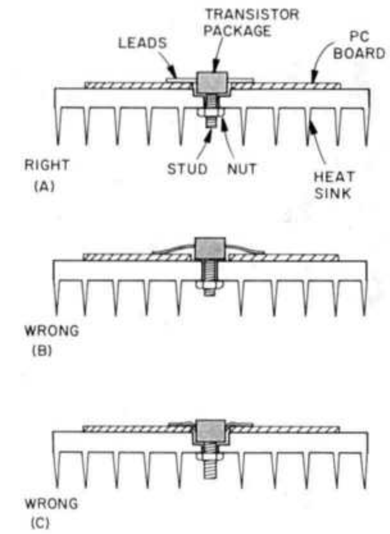

Fig 2—Power devices should be mounted with the leads flush with the circuit board, as shown at A. You might have to place shims under the board or mill out the heat sink to get the correct spacing. If the transistor is mounted incorrectly as shown at B and C, you risk bending the leads too far and breaking the device.

of the beryllium-oxide insulator or ceramic package breaking is generally accompanied by a bad feeling in the pit of your stomach. See Fig 2.

One other caution: Make sure you have the input and output leads aligned correctly before soldering. It's a lot easier to solder one in than to take one out. Where's that roll of Solder-Wick? Usually the collector is indicated by a cut lead, but on Japanese devices, it's often the base lead that is cut. Check the data sheet; don't make potentially costly assumptions.

Microwave power devices are usually treated like their lower frequency cousins. Since the packaging is often more sophisticated, they can be more delicate (that is to say the leads can break off more easily). They also cost a lot more, so be careful—protect your investment!

Next month, I will finish up the construction techniques series with some information on microstriplines. After that, there will be a real project to test your new skills. Thanks to everyone who heard my plea for feedback and wrote letters of encouragement and sent suggestions. It's nice to know someone *is* reading this! Till next month, time to throw another log in the stove and keep shoveling...

Bits

Surface Mount Repair

When automatically assembled surface mount boards develop a defect, making repairs using conventional soldering tools is difficult. High density packaging and unique lead configurations on the PC boards require special tools to avoid damaging neighboring components and the board.

Hexacon Electric has designed a new family of soldering tips that are shaped and sized to match the dimensions of currently available surface mount components. They permit safe hand soldering and desoldering of devices.

Hexacon Electric has also developed a new line of surface mount device stations and a subminiature soldering iron with a very short reach for precise positioning on crowded boards. These products have a thermal compensating element that holds a steady work temperature. For a catalog of available soldering and desoldering tools for surface mount devices, write to Hexacon Electric Co, 161 W Clay Ave, PO Box 36, Roselle Park, NJ 07204; tel 201-245-6200. *—KA1DYZ*

EIA Publishes Two Electronic Documents

The EIA has published JEDEC Standard No. 24, Power MOSFETs. This document contains a listing of terms, definitions, letter symbols, established procedures followed in the assignment of semiconductor-industry-type designations to power transistors, electrical verification tests, thermal characteristics and a user's guide. The price is $18 and is available by writing the EIA at the address below.

JEDEC Standard No. 21-A, *Configurations for Solid State Memories*, consists of a compilation of all memory device standards developed by the JC-42 Committee on Semiconductor Memories. The standards were approved by the JEDEC Council through the end of 1983. The Committee configured the various device types to allow the use of a progression of devices with varying degrees of data permanence (and ease of alteration) as the system design progresses. This publication sells for $21 and is available from EIA, Standards Sales Office, 2001 Eye St, NW, Washington, DC 20006. [This information was excerpted from *Test & Measurement World*, Jan 1986, pp 17-18.]*—KA1DYZ*

Convert A Mechanical Force To An Electrical Response

KYNAR® Piezo Film, a versatile new transducer material, transforms a mechanical force to an electrical response and conversely, transforms an electrical signal to a mechanical motion. The Pennwalt Corp has developed a specialty film available in various thicknesses for application as transducers for many industrial devices. The base resin used in the development of the film is polyvinylidene fluoride (PVDF), a polymer which shows the highest piezo- and pyroelectric activity.

Uses of the KYNAR Piezo Film include audio applications, switching components, heat sensors and more. A KYNAR Piezo Film technical manual and sample kit is available from Pennwalt Corp, PO Box C, King of Prussia, PA 19406, Attn: Piezo Film Dept; tel 215-337-6710. Price: $45.*—KA1DYZ*