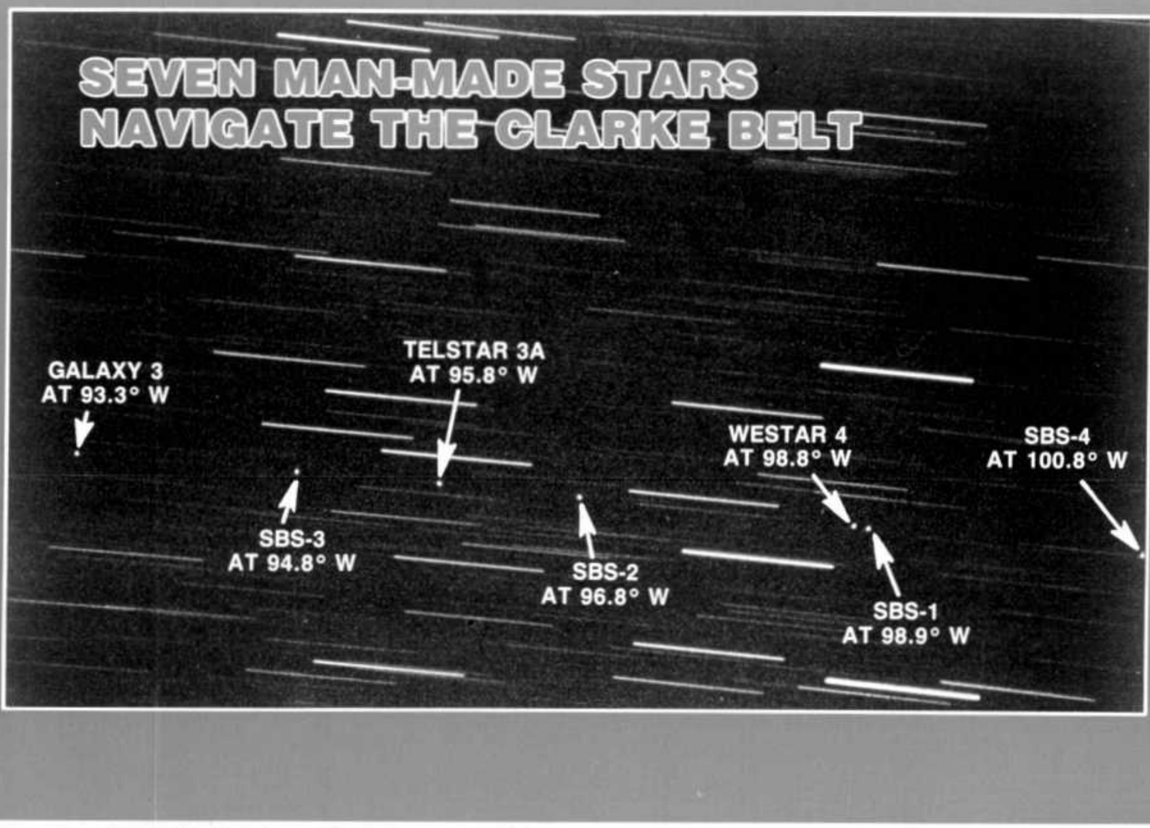
QEX 77

$1.75

JULY 1988

ARRL Experimenters' Exchange and AMSAT Satellite Journal



QEX: The ARRL
Experimenters' Exchange
American Radio Relay League
225 Main Street
Newington, CT USA 06111

Non-Profit Org.
US Postage
PAID
Hartford, CT
Permit No. 2929

TABLE OF CONTENTS

COLUMNS

ABOUT THE COVER

Seven heavenly travelers (geosynchronous satellites) are captured in this photo by Paul D. Maley, of Houston, Texas. The streaks are stars, and the streaking is caused by the rotation of the Earth during the five-minute photographic exposure. *(Reprinted with permission.)*

QEX (ISSN: 0886-8093) is published monthly by the American Radio Relay League, Newington, CT USA.

David Sumner, K1ZZ
Publisher

Paul L. Rinaldo, W4RI
Editor

Paul Pagel, N1FB, Mark Wilson, AA2Z
Senior Assistant Technical Editors

David Newkirk, AK7M, James W. Healy, NJ2L
Assistant Technical Editors

Mark Forbes, KC9C
Geoffrey H. Krauss, WA2GFP
Bill Olson, W3HQT
Contributing Editors

Lisa Tardette
QEX Circulation

Michelle Chrisjohn, WB1ENT
Production Supervisor

Alison Halapin
Layout Artist

Sue Fagan
Graphic Design Supervisor

David Pingree
Technical Illustrator

Bruce O. Williams, WA6IVC
Advertising Manager

Technical Department

Charles L. Hutchinson, K8CH
Manager

Gerald L. Hall, K1TD
Deputy Manager

Production Department

E. Laird Campbell, W1CUT, *Manager*

Joel P. Kleinman, N1BKE, *Deputy Manager*

Circulation Department

Debra Jahnke, *Manager*
Kathy Fay, *Deputy Manager*

Offices

225 Main St, Newington, CT 06111 USA
Telephone: 203-666-1541
Telex: 650215-5052 MCI
Electronic Mail: MCI MAIL ID:215-5052 (user name ARRL)

Subscription rate for 12 issues:
In the US by Third Class Mail:
ARRL/AMSAT Member $8, nonmember $16;
US by First Class Mail:
ARRL/AMSAT Member $13, nonmember $21;
Elsewhere by Airmail:
ARRL/AMSAT Member $23, nonmember $31.

QEX subscription orders, changes of address, and reports of missing or damaged copies may be marked: *QEX* Circulation.

Members are asked to include their membership control number or a label from their *QST* wrapper when applying.

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.

Officers

President: LARRY E. PRICE, W4RA
PO Box 2067, Statesboro, GA 30458

Executive Vice President: DAVID SUMNER, K1ZZ

AMSAT®

RADIO AMATEUR SATELLITE CORP

President: VERN "RIP" RIPORTELLA, WA2LQQ

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 06111 USA. 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 recent editions of *The ARRL Handbook*. 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. . .

Phase 3C Launch ~~Imminent~~ Successful!

More next month—W4RI

As this is written, the AMSAT Phase 3C satellite launch is scheduled for June 15, 1988, according to Arianespace—the management arm of the European Space Agency. Assuming this schedule holds, you will probably have heard by now whether the launch was successful as there will be C-SPAN cable and widespread Amateur Radio bulletin coverage of the event.

A joint AMSAT-NA/AMSAT-DL/BRAMSAT team has been on hand at the launch facility in Kourou to monitor the final preparations until launch day.

Phase 3C will be launched aboard an Ariane 4 rocket, which is capable of launching 2 to 4.3 tons into geostationary orbit. The method of installing the satellite within the payload is new. A fixture, called SPELDA (Structure Porteuse Externe pour Lancements Doubles Ariane) makes simultaneous satellite launch possible. Phase 3C has 50 liters of toxic propellant to shift the satellite from geosynchronous transfer orbit to the final elliptical orbit. Both the fueling and the installation in the SPELDA was tricky. For one thing, the installation of three satellites was done in the following order: first Panamsat, then Meteosat, followed by AMSAT Phase 3C wedged between the other two. The weather satellite, Meteosat, will be the first to be separated from the SPELDA. Then the middle portion with AMSAT Phase 3C inside will be explosively separated from the lower portion of the SPELDA. After that part is at a safe distance from the remainder of the SPELDA, the upper and lower halves of this lower part will separate, and the communication satellite, Panamsat, will be ejected from the lower half shell of the SPELDA.

If all goes well, the beacon will be switched on to signal the birth of AMSAT OSCAR 13 (AO-13) about 60 minutes after separation. The first apogee will be reached 5 h 30 min after launch. The subsatellite point (SSP) will be 85° E, 0.3° S, at an altitude of 36,223 km. The following two apogees are at 15 h 15 min after launch (above Quito, Ecuador) and 26 h 55 min after launch (above Borneo), accordingly to calculations by ESOC in Darmstadt, West Germany.

The beacon will be on either 145.812 or 145.985 MHz. You may need a low-noise preamp and directional antenna to hear the bird's PSK telemetry. Daily bulletins will be issued, at least until after the first kick-motor burn about one week after launch. The beacon transmission starts a period of intense activity for the German command stations. Initially, all values in the PSK telemetry must be analyzed. Of particular importance is information from the sensor electronic unit (SEU), which allows the ground stations to determine the attitude of the satellite. Next comes the measurement of the orbit. Only after all these data are known is it possible to determine when the apogee engine should be ignited. After a successful burn, the spacecraft should be in its intended elliptical orbit.

Even after the spacecraft's orbit has been corrected, transponder operation will still not be possible. That will have to wait another four weeks. This amount of time is necessary in order to reorient the satellite towards the earth by means of the magnetorquing system. Since considerable electrical power is required for this maneuver, the transponder cannot be operated. Only after a successful reorientation and complete checkout by command stations can the transponders be used by amateur stations for general operations.

We wish to thank all those within AMSAT and supporting organizations for their part in the design, construction, launching and maintenance of AMSAT Phase 3C. Thanks also to Vern Riportella, WA2LQQ, Rolf Niefind, DK2ZF and Don Moe, DJØ/HC/KE6MN for this information.
—W4RI

Correspondence

Mir Pamphlet Available from AMSAT-UK

The Mir *(Peace) Satellite Special,* a 16-page supplement to March 1988 *OSCAR News,* is now available from AMSAT-UK. Its highlights include:

- "Some Soviet Frequencies for Use in Space Communications"
- "Living and Working in Space—The *Mir* Space Station" by David L. Skinner
- "A *Mir* Spacecraft Downlink Converter" by R. H. Pearson, G3CAG
- "Some Thoughts of a '*Mir*' Mortal" by G. Perry

The 5¾- x 8¼-inch pamphlet is free to AMSAT-UK members and $2 (US notes) for AMSAT-UK nonmembers. *The* Mir *(Peace) Satellite Special* is available from the Secretary, AMSAT-UK, 94, Herongate Road, Wanstead Park, London E12 5EQ, England.—*David Newkirk, AK7M, ARRL HQ*

Some Thoughts About SMT

A lot has been written about surface-mount technology (SMT)—but not from a *practical* standpoint! What are the advantages of SMT? Generally, the surface-mount devices (SMDs) are smaller and lighter, having the shortest possible lead length. (This *may* allow the construction of physically smaller circuits providing "dead-bug" construction methods are employed.) Soldering SMDs hasn't been a problem for me, although I have had a lot of experience with soldering. I use a big, chisel-shaped tip and work fast to tack the part in, then go back to finish up the joints.

If you use a PC board, there usually isn't much choice as to where or how a surface-mount device is placed. The short lead lengths allow even beginners a chance to successfully build microwave circuits. With the use of SMT, UHF circuits become less touchy and are often easy to tune with good instrumentation.

The biggest disadvantage of SMT? Fragility. The last thing you want to do to a board with SMDs on it is to bend it. Sometimes an ohmmeter and an appropriate value capacitor can be used to find the hairline cracks than can result from such flexing—sometimes not.

How can manufacturers sell fragile electronic equipment? Easy. The average consumer now *expects* his expensive equipment to be fragile. It's a surprise when a piece of equipment is dropped and *doesn't* break!

Amateurs should probably be using SMT up (down, for old-timers) into the microwave region, and in tiny circuits where ruggedness isn't required. In other cases, standard-size components are easier to work with and more reliable. Because high-volume parts consumers will invariably go to SMT, it might be wise to stock up on standard-size components before prices rise.—*Zachary Lau, KH6CP, ARRL Lab Engineer*

Impedance-Measuring Hybrid Comments

The graphical data-reduction step in the impedance-measuring technique described by Caron[1] can be simplified.

The Smith chart is a wonderful thing—in its place! But the Smith chart can also complicate the analysis of circuit response. In this application, the use of rectangular R-X coordinates is simpler. In some cases, the use of rectangular coordinates also allows greater accuracy, as you are not restricted to the fixed scales of the Smith chart.

Fig 1 is Caron's example plotted on rectangular paper. The two SWR circles represent loads with the same value of X and values of R differing by 27 ohms. If circle no. 2 (Caron's notation—unknown plus the 27-ohm series resistor) is shifted to the left by 27 ohms, the two circles intersect at the common value of X and at the unknown's resistance, R. Because the R and X scales are linear, no change in the radius of circle no. 2 is caused by this shift. In fact, there is no need to draw circle no. 2. Circle no. 3 can be drawn directly. Fig 2 shows the solution to the example.

In the R-X plane, the center of a constant SWR circle is located at $Z_0(S^2 + 1) / 2S$, and its radius is $Z_0(S^2 - 1) / 2S$, where S is the SWR.

An analytical solution for the data reduction is given by the equations

$$R = \frac{r_3^2 - C_3^2 - r_1^2 + C_1^2}{2(C_1 - C_3)} \qquad \text{(Eq 1)}$$

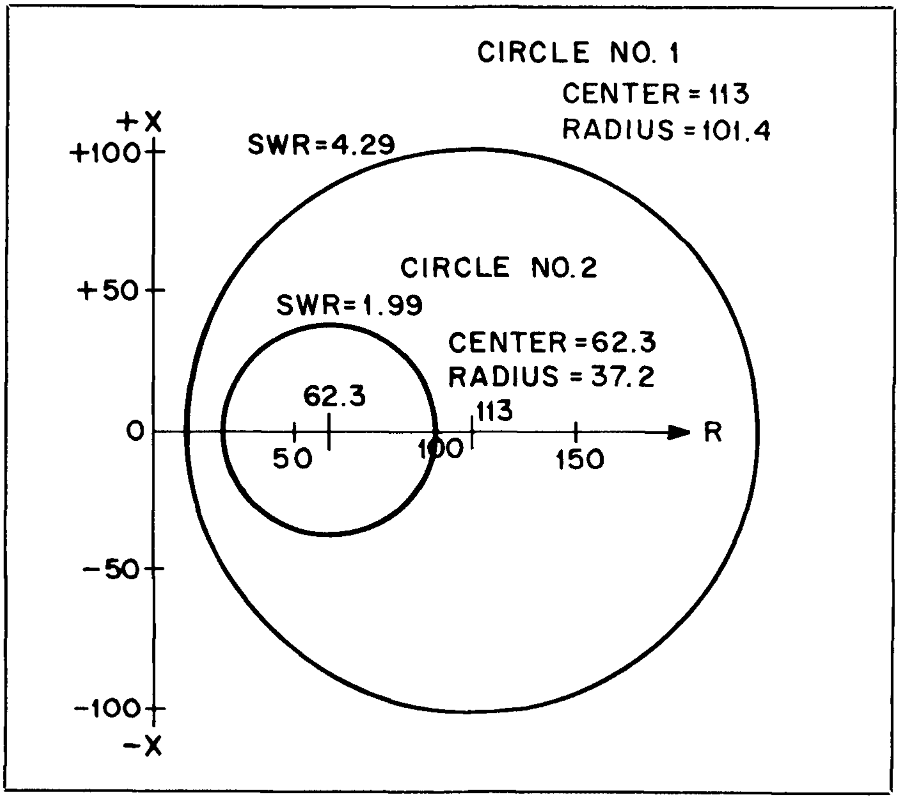


Fig 1—SWR circles in R-X coordinates.

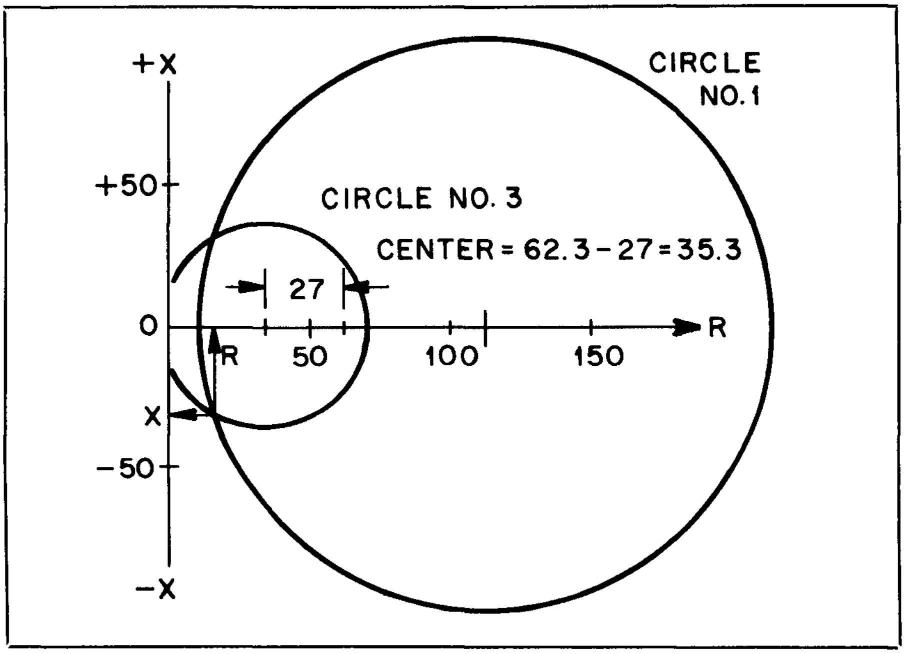


Fig 2—Solution for the example.

$$X = \pm \sqrt{r_3^2 - (R - C_3)^2} \quad \text{(Eq 2)}$$

where r_i and C_i refer to the radii and center coordinates of the appropriate circles. When applied to Caron's example, the result is R = 16.99 and X = 32.38.

In common with similar methods, this one is rather sensitive to errors in the measurements. In particular, the measurements of unknowns with either large or small values of X or R tend to be inaccurate for the minor component.

Readers may recognize that this technique is based on SWR measurement. Hence, with the addition of the sense capacitor, C3, it can be used with any device or devices capable of accurately measuring SWR. The primary limitation may be power dissipation in the auxiliary series resistor. Thus, the technique might be used at VHF/UHF with a Bird wattmeter, but the lack of low-power slugs for the HF bands prohibits use in those bands.

This limitation can be relaxed by measuring in terms of admittance rather than impedance. This can be done by attaching a dummy load of appropriate rating in parallel with the unknown by means of a coaxial Tee. The data-reduction procedure is unchanged if all parameters are expressed as admittances rather than impedances.—*Albert E. Weller, Jr, WD8KBW, 1325 Cambridge Blvd, Columbus, OH 43212.*

Suggestions For Building and Using the W8CGD Impedance-Measuring Box

The following suggestions can improve the performance of, and increase your satisfaction with, the W8CGD impedance-measuring box[2] recently updated and described by G3LDO and G3TML.[3] The nomenclature used here is that of note 3.

Place the voltmeter components and circuits inside the box and mount the RF jacks, C6 and R8 above the box on an L- or U-shaped bracket. Bring the three voltmeter leads inside the box through clearance holes. If you need a power attenuator, place it in a separate box. Note that without the attenuator, dc continuity through the RF source is required.

Go to extremes to reduce stray capacitance to ground from the RF-carrying conductors and components (this applies to the voltmeter circuits, too). Do not use terminal strips. Provide necessary support with thin plastic strips, or use PC board with all but small pads of the foil removed, cemented to the metal structure. Keep overall lengths of RF conductors to a minimum.

To keep the series inductance associated with R8 small, attach the voltmeter leads as close as possible to the resistor body. Use a ½-W metal-film resistor for R8. Leave ¼-inch wire stubs extending from R8 and the UNKNOWN jack. C1-C5, inclusive, should be increased in value to 0.005 μF for use on the lower-frequency amateur bands. R1-R5, inclusive, can be reduced in value to 150 kΩ to 220 kΩ to make matching less critical.

The reactance of C6 should be numerically at least as large as the magnitude of the load impedance. Values in the range of 50 Ω to 150 Ω are appropriate for general use. If the unknown impedance has a capacitive reactance, better accuracy can be obtained by substituting an inductor for C6. The inductive reactance should be in the range of 50 Ω to 150 Ω for general use. The reactance does not need to be known accurately as it is calibrated in use. The Q should be reasonably high—at least 10. When an inductive standard is used, the sign of the reactance returned by the Dodd/Lloyd programs will be incorrect and must be reversed.

If you do not have a computer and don't want to reduce the measurements graphically, the following equations can be used:

$$X = \pm \frac{R8}{2}\left[\frac{C^2 - D^2 - E^2}{BD}\right] \quad \text{(Eq 3)}$$

$$R = \frac{R8}{2}\left[\frac{A^2 - B^2 - C^2}{B^2}\right] \quad \text{(Eq 4)}$$

In equation 1, the plus sign is used if C6 is an inductor. If C6 is a capacitor, the negative sign is used.

For voltmeters using 1N34A diodes, increase the measured dc output voltage by 0.11 V. This approximately corrects for the relative (not absolute) error of the voltmeters. If any of the measured dc voltages is less than about 2.5, increasingly large errors will occur. Increase the input voltage (consistent with the component ratings), or change the reference impedance (C6) to a more appropriate value. Adjusting the Dodd/Lloyd programs for values of B other than 5 V is straightforward.—*Albert E. Weller, WD8KBW, 1325 Cambridge Blvd, Columbus, OH 43212.*

[1]W. Caron, "A Broadband VHF Impedance Measuring Hybrid," *QEX*, May 1988, pp 3-7 and 11.
[2]D. Strandlund, "Amateur Measurement of R + *jX*," *QST*, Jun 1965, pp 24-27.
[3]P. Dodd and T. Lloyd, "Measurement of Antenna Impedance," *QEX*, Nov 1987, pp 6-9 and 11.

Feedback

Please refer to "Designing LC Filters Using SVC Filter Tables," *QEX*, Jun 1988. On pp 8 and 9, there are missing radical signs in equations 1, 2, 4 and 5. In each case, the parenthetical expression should appear beneath a radical sign.

In the first column on p 9, beneath the heading "Example of the Standard-Value LC Filter Design Procedure," the tenth line should read:. . . level of 500 Ω . To get an understanding..." *(Tnx Ed Wetherhold, W3NQN)*

Your Window For Visually Observing Satellites

By Vern Riportella, WA2LQQ
PO Box 177
Warwick, NY 10990

A surprising number of earth satellites can be seen—*with your eyes*—using little or no equipment. Even very small satellites can be seen through binoculars under favorable conditions. AMSAT OSCAR 6, for example (a small box about a 1½ feet long) was visually observed in 1973 using small telescopes.[1] OSCAR 6's brightness flashed to about 5th magnitude[2]—just visible to the naked eye. At the other extreme, the large Russian space station, *Mir*—more than 100 feet long—is one of the current favorites for casual observers.

Although it may not be a surprise to think that an object the size of *Mir* could been seen at a distance of 220 miles or more, it probably *is* a surprise to learn that even satellites at geosynchronous altitudes (22,300 miles) can be observed given well-chosen observational conditions! Through careful planning, Paul D. Maley obtained a dramatic photograph of *seven* geosynchronous satellites in a single frame! (See Fig 1 and the cover photo.) Paul used a 35-mm camera equipped with a 200-mm telephoto lens and a 5-minute exposure of ASA 1000 film.[3]

How can *you* know where and when to look to appreciate these man-made stars? Knowing *where* to look is a problem that has been largely solved by personal computers and tracking software available from AMSAT and elsewhere.[4] Using your computer, and the information that follows, will be enough to help you define the *where* and *when* of satellite spotting. I'll focus on telling you how to determine when it's possible to spot the Low Earth Orbiting (LEO) satellites.

Visual observation of a satellite depends on the following conditions:

A. The satellite is sufficiently reflective in the preferred direction.
B. Visible-light attenuation is sufficiently low.
C. The sky is sufficiently dark.
D. The satellite is above the observer's horizon.
E. The satellite is illuminated by the sun.

The *size* of the satellite, its *reflectivity* and its motion determine the fulfillment of condition A. If the satellite is tumbling, the brightness can vary widely—perhaps 3 or 4 degrees of stellar magnitude. A sudden glint from a large solar panel can yield a brightness impulse over a millionfold.[5]

[1]Notes appear on page 8.

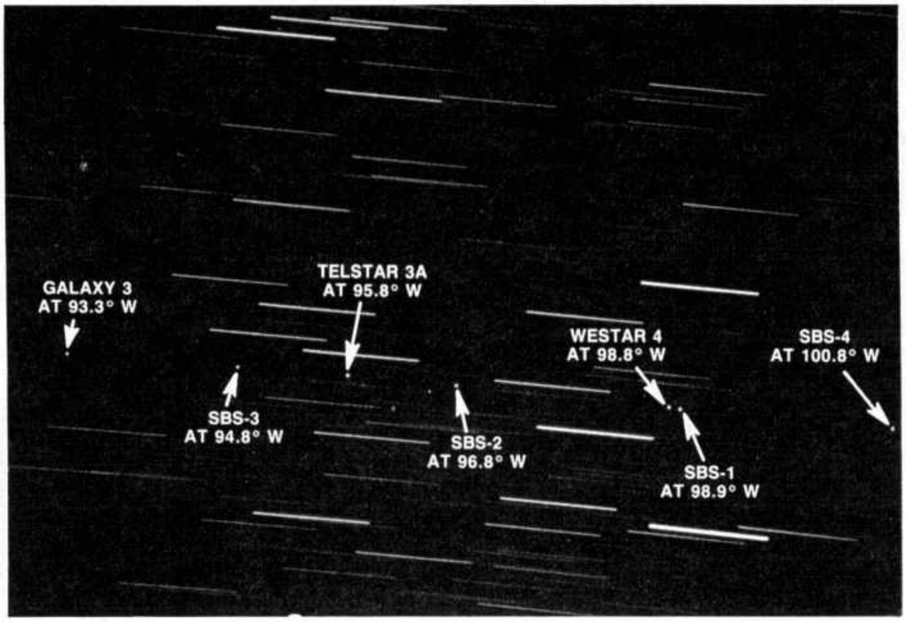


Fig 1—Part of the "Clarke Belt" showing seven geosynchronous satellites as photographed by Paul D. Maley on October 4, 1985, at Brazos Bend, Texas. The satellites are situated 22,300 miles over the Equator at the longitudes shown below. From left to right, they are: (A) Galaxy 3, at 98.3 degrees W; (B) SBS-3, at 94.8 degrees W; (C) Telstar 3A, at 95.8 degrees W; (D) SBS-2, at 96.8 degrees W; (E) Westar 4, at 98.8 degrees W; (F) SBS-1, at 98.9 degrees W; (G) SBS-4, at 100.8 degrees W.

The estimated apparent magnitude of the satellites is +10.5. The streaks are stars, and the streaking is caused by the rotation of the earth during the five-minute photographic exposure. *(Copyright 1985 by Paul D. Maley, Houston. Reprinted with permission.)*

Condition B addresses the light attenuation along the column of the atmosphere between the satellite and the observer as well as path losses outside the atmosphere. Condition C requires a dark sky background in order to establish the required contrast ratio between the satellite and its background. Conditions A, B and C taken together simply establish a usable "signal-to-noise ratio" requirement. Since we're dealing with the timing of events, let's assume conditions A and B are satisfied.

For condition C to be met, obviously the sun must be sufficiently below the observer's horizon so that the twilight period has passed. Usually, if the sun is at least 10 degrees below the horizon, the twilight period has ended. On a typical clear evening, twilight ends between 45 and 60 minutes after sunset. So, the beginning of the observer's satellite-spotting window is defined by the end of twilight, ie, dusk plus 45 minutes.

Your computer and software can tell you whenever condition D is met. Anytime the satellite has a positive elevation—voila!—it's above your horizon. The overall problem then resolves to determining when condition E is met concurrent with the other four conditions.

To review: A satellite is potentially observable when it's above your horizon beginning not earlier than 45 minutes after dusk, and conditions A, B and C remain true.[6] But for how long is this window of potential viewing open? In other words, suppose a satellite shows up above your horizon four hours after dusk. Can you see it?[7]

The answer to that depends on whether the satellite is still in sunlight four hours after dusk; and that depends (perhaps obviously) on the particular satellite's altitude. For instance, although *Mir,* at an altitude of 335 km, is in sunlight only up to 3.2 hours after dusk at 40 degrees latitude, the Japanese "Mirror Ball," *Ajisai,* 1500 km high, is in sunlight for up to six hours after local sunset at 40 degrees latitude.

To understand how to estimate when the observation window closes, it's helpful to phrase the question relatively, rather than absolutely. Just as you find the window opening in relation to dusk (dusk plus 45 minutes), it's helpful to be able to specify the window closing in relative terms, ie, dusk plus N hours. How long after local sunset will a given satellite at a known height remain illuminated by the sun, as seen from a given location? Specifically, what is the boundary condition where the sun *just barely* illuminates the satellite? If you know the boundary condition, you can give a "not-later-than" time that comprises the window closing. You'll then have bounded the observational window and can look carefully at specific conditions that may permit observation within that window. That is, it's *not certain* the satellite can be seen within the window; it *is certain* the satellite cannot be viewed outside it!

If you shift your perspective on the problem from that of the observer's location to that of the point of view of the satellite, a helpful insight results. From the satellite's perspective, conditions D and E mean both the observer and the sun must be in view. Conditions D and E taken together reflect a common radio-satellite consideration: the satellite footprint. Observers at any and all points within the footprint can "see"[8] the satellite. Conversely, the satellite can see any and all points within its footprint. Fig 2 shows a different perspective with the terminator and the observer located at opposite boundaries of the footprint.

In Fig 2, I've arranged the essential elements for the desired boundary conditions. There are four zones defined in Fig 2 where conditions D and E are satisfied, or not satisfied, in the four possible combinations of the two conditions.

Now that you have a feel for the geometry of the window-closing instant, it remains only to determine exactly the time at which the sun moves to the western edge of the footprint. This can be done easily by figuring the diameter of the footprint and calculating how long it takes the terminator[9] to cross the footprint, if the footprint is static.

In Fig 3, the perspective and projection have changed. This is essentially a projection to a plane that you can use to model the problem in two dimensions. The moment of dusk (the passage of the terminator across your location) is deter-

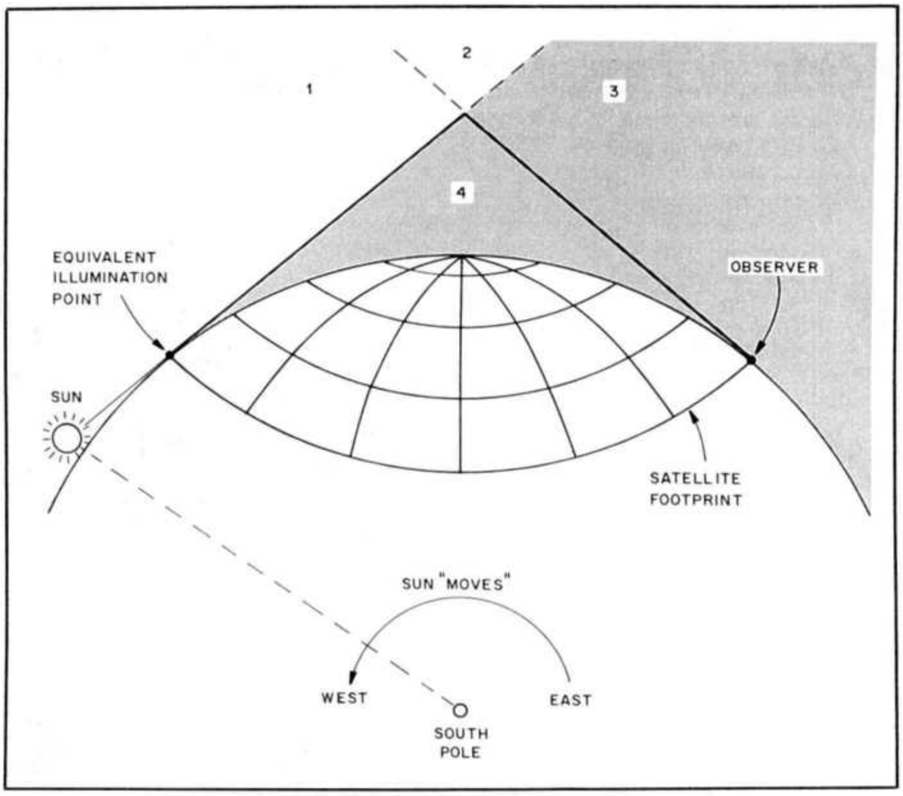


Fig 2—Boundary-condition configuration. The required boundary conditions are illustrated looking at Earth from above the South Pole. With the satellite footprint illustrated, and the observer and an equivalent-illumination point positioned on the footprint's periphery, four zones are defined. These zones enclose regions wherein one or both of two conditions (referred to as D and E in the text) are satisfied: D, the satellite is above the observer's horizon; E, the satellite is illuminated by the sun. In zone 1, the satellite is in sunlight, but not above the horizon; in zone 2, the satellite is in sunlight and above the horizon; in zone 3, the satellite is above the horizon, but not in sunlight; in zone 4, the satellite is not above the horizon and is not in sunlight.

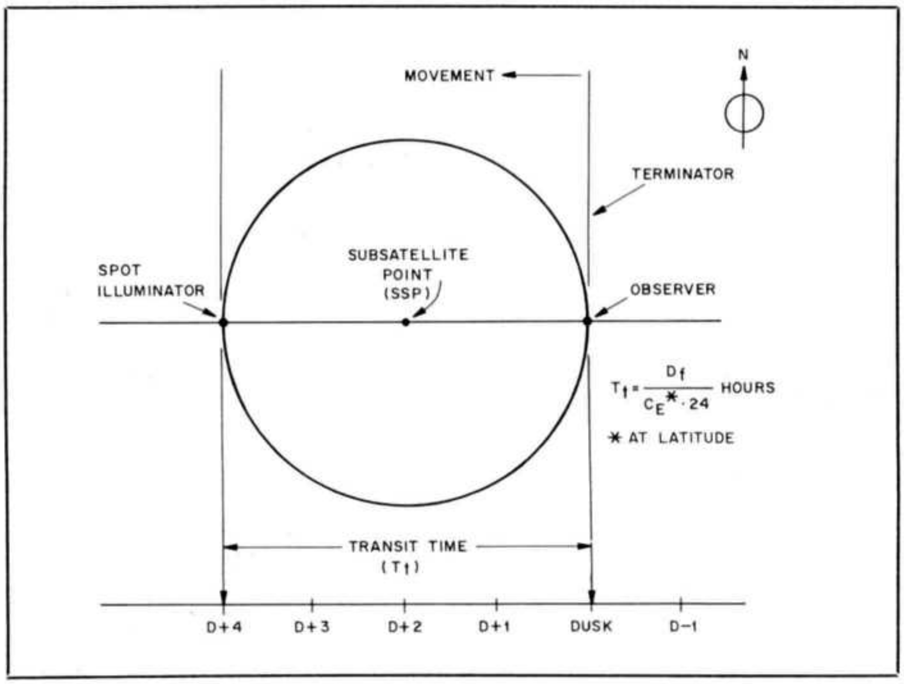


Fig 3—A simplified plot of terminator movement across the satellite footprint.

mined easily by observation. Knowing the *time* of the terminator's passage across your location, the *diameter of the footprint* and the *velocity of the terminator* across the footprint are sufficient to determine when the terminator will cross the western edge of the footprint. The passage of the terminator across the western edge of the footprint signifies the observations window's *closing*. This is the event we sought because—assuming the satellite is still above your horizon—condition E is negated when the terminator crosses the footprint boundary.

The footprint diameter is:

$$D = 2R \arccos [R/(R + h)] \qquad \text{(Eq 1)}$$

where

D = distance across the footprint in km
R = radius of the earth (6371 km)
h = height of the satellite in km
and
arccos is expressed in radians.[10]

For example, if the satellite is *Mir* (335 km high), then the footprint diameter is:

$$D = 2 \times 6371 \arccos [6371/(6371 + 335)] = 4045 \text{ km} \qquad \text{(Eq 2)}$$

You could, in theory, see *Mir* at zero elevation when the terminator was 4045 km west of you.[11] But how long did it take the terminator to go from your location to a point 4045 km west of you?

The terminator velocity is determined easily. A day is about 24 hours long. In that time, the terminator moves 360 degrees of longitude. The velocity of the terminator is then simply:

$$(360 \text{ degrees/day}) \div (24 \text{ hours/day}) = 15 \text{ degrees/hour} \qquad \text{(Eq 3)}$$

How long it takes to cross the footprint depends on how wide the footprint is in the east-west direction in terms of its longitude; this is illustrated in Fig 3. The longitudinal width of the footprint (in degrees) depends on the latitude. Fig 4 provides a graphical approximate solution. An example of the graph's use for *Mir* is shown in Fig 5.

To use the graphs of Figs 4 and 5, enter the graph at the bottom with the altitude of the satellite. Move vertically until the curve is intersected. Move horizontally to the left to determine the satellite's footprint diameter. Move horizontally to the right to intersect the line representing your latitude. Then move vertically up to read the terminator transit time at the top.

For example, *Mir's* footprint diameter of 4045 km represents 47.5 degrees of longitude at 40 degrees North latitude. The terminator will thus cross the *Mir* footprint in:

$$(47.5 \text{ degrees}) \div (15 \text{ degrees/hour}) = 3.2 \text{ hours} \qquad \text{(Eq 4)}$$

If dusk were at 1900 local time, the observation window would open at roughly 1945, and close not later than 2212 (1900 + 3.2 hours). If your computer indicated *Mir* was above your horizon in that 2-hour, 27-minute (1945 to 2212) window, there's a chance you'd see it.

Whether or not the satellite is actually visible depends on how near to the window closing time the satellite rises above your horizon. The later in the window the satellite rises, the more restrictive are the conditions under which it can be seen. If it rises early in the window chances are very good; if late, very poor.

I've assumed the terminator sweeps from east to west and is parallel with the meridians and perpendicular to the equator. But in fact, the terminator paral-

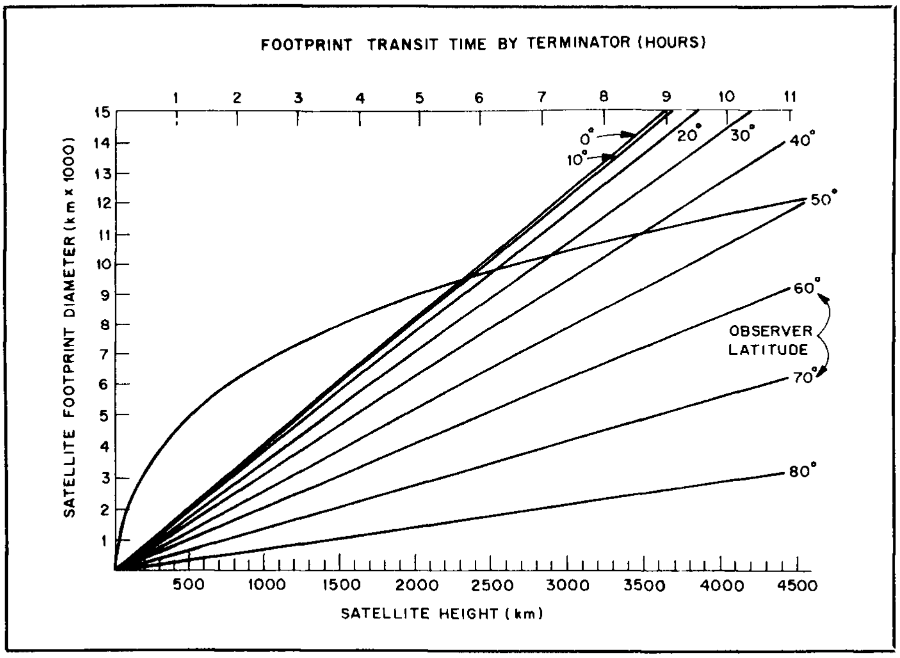


Fig 4—A graphical solution for finding satellite footprint diameter and terminator transit time at observer's latitude (see text).

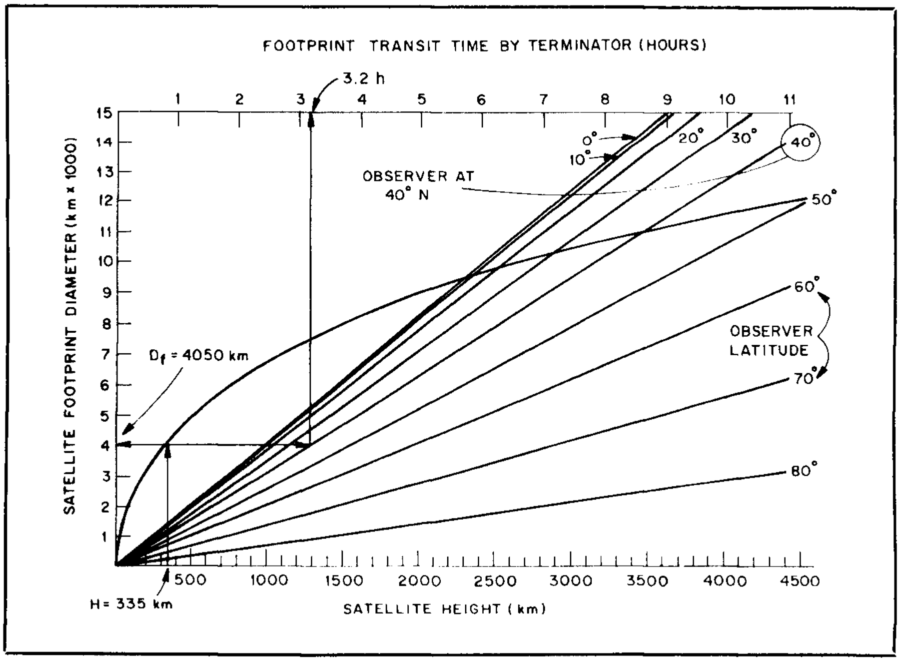


Fig 5—An example of using the graph of Fig 4 to find the footprint diameter and terminator transit time of the *Mir* satellite (see text).

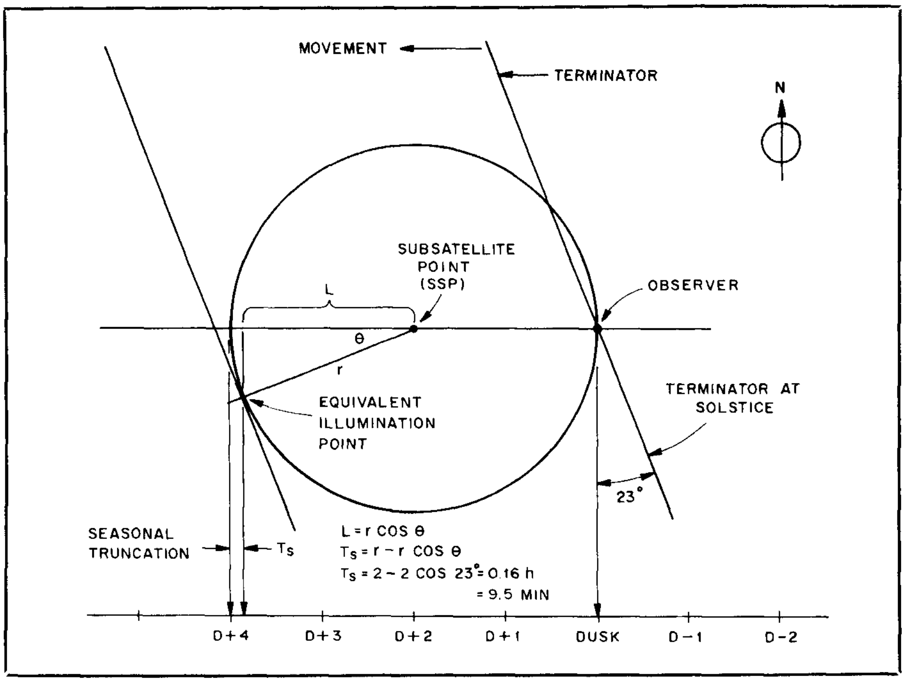


Fig 6—A simplified schematic of the terminator movement across the satellite footprint, including an approximate compensation for seasonal effects on the terminator angle with respect to meridians.

lels the meridians only *twice per year:* at the vernal and autumnal equinoxes. On the first day of spring and the first day of autumn (approximately March 21 and September 21, respectively) the sun is over the equator, causing the terminator to parallel the meridians. The 23-degree inclination of the Earth's spin axis to the plane of its orbit causes the terminator's angle to vary continuously with respect to the meridians.

This slightly complicates the estimate of the terminator's transit time across the footprint. Although the terminator still moves at 15 degrees per hour from east to west, the terminator exits the satellite footprint earlier than it had when its exit point was diametrically opposed to the observer. In this simplified model, the truncation is only 9.5 minutes (see Fig 6). This would be the approximately the case for a *Mir* observer (4000-km footprint) at the equator at the winter solstice (declination −23 degrees). On the other hand, for latitudes at which the terminator angle is radically different, the window closing can be extended indefinitely. Thus, without further corrections, this method is best used at latitudes up to about 50 degrees. Beyond that latitude, seasonal adjustments for window closing needs be proportionately quite large.

Summary

I've qualitatively described the conditions necessary and sufficient to see LEO satellites. I've presented a simple method for defining the opening and closing times of observational windows for LEO satellites at known altitudes and provided a graphic solution. Given clear skies, sound computers and tractable software, the rest should be easy.

Notes

[1]R. Cumrine, "AMSAT OSCAR 6 Visual Observation Report", AMSAT Newsletter, Volume V, Number 4, Dec 1973.

[2]Visual magnitude is based on a logarithmic scale devised by Ptolemy 2000 years ago. Ptolemy placed all stars into one of six classes according to their brightness: 1 (brightest) through 6 (dimmest). Later, it was determined that the apparent range of brightness was approximately 100. So, a scale was devised wherein a second magnitude star is 2.512 times dimmer than a first-magnitude star, and a third-magnitude star is 2.512 times dimmer than a second, and so forth. On this scale, the brightest visible star, Sirius, is −1.46, and Polaris, the North Star, is +2.0. Venus, at its brightest, is −4.4. A 5th-magnitude star is close to the lower limit of unaided visibility, 6th magnitude. The full moon can be as bright as −12.5, and the sun −26.6.

[3]Amateur Satellite Report (ASR), Number 120/121, April 3, 1986. Photo is copyrighted by Paul D. Maley, Houston, Texas; reprinted with permission.

[4]AMSAT Software Exchange, PO Box 27, Washington, DC 20044.

[5]J. King-Hele, *Observing Earth Satellites* (New York: Van Nostrand Reinhold Co, 1983), p 104.

[6]In this discussion, I focus on the dusk case. However, for obvious symmetry reasons, the same arguments can be applied (albeit with appropriate sequence inversions) to the dawn case.

[7]It's fair to ask why the tracking programs don't provide the answer here. In fact, the more sophisticated programs do provide a means of graphically determining observation windows. On the other hand, the more popular tracking programs running on PCs do not track the sun, nor can they track two objects at once to determine the conjunction of conditions (ie, conditions D and E taken together). Moreover, simple programs preclude making the observer's location a moving platform, such as the satellite itself.

[8]*See* is used only figuratively here. A more precise statement would be that the satellite is on an unobstructed line of sight when the observer is in the satellite's footprint.

[9]The terminator is the border between sunlit and dark areas.

[10]M. Davidoff, *The Satellite Experimenter's Handbook*, (Newington: ARRL, 1984), p. 9-6.

[11]Because of increased atmospheric absorption along a line of sight approaching tangency or zero elevation, it is very difficult to see any satellite below about five degrees elevation. Furthermore, optimum viewing occurs when the satellite is seen in back-scattered light. That is, the satellite is often seen best when your back is to the sun and you face the satellite.

Bits

Kantronics PTT Watchdog

The Kantronics Watchdog circuit can be installed inside the Kantronics models KPC-1, KPC-2 and KPC-400 TNCs. The circuit monitors the PTT line of the TNC. If the PTT line has been active for approximately two minutes, the Watchdog is activated and the radio is unkeyed. This prevents a local-area network from being disabled by a hung up TNC. Once the Watchdog circuit has been activated, it's necessary to cycle the TNC power off and on again to restore normal operation.

The price of the Watchdog is $10. Shipping and handling charge in the US and Canada, $2.50; international, $7.50. For more information contact Kantronics, Inc, 1202 East 23rd St, Lawrence, KS 66046, tel 913-842-7745. *—Paul K. Pagel, N1FB*

Kantronics Morse Tutor PC

A Morse Tutor for IBM® PC and compatible computers is available from Kantronics. Morse Tutor provides practice, learning, quiz and general information features. The program also has alternate learning sequences and variable character speeds to simulate hand-sent CW.

Some of the program's features include: a speed range of 5 to 50 WPM, variable tone frequency of 500 to 2000 Hz, reading text files from disk and QSO simulation. The program sells for $19.95. Shipping in the US and Canada, $2.50; international, $7.50. For more information, contact Kantronics, Inc, 1202 East 23rd St, Lawrence, KS 66046, tel 913-842-7745. *—Paul K. Pagel, N1FB*

Algorithms and Methods for SITOR/AMTOR Systems

By Paul Newland, AD7I,
ARRL Technical Advisor
PO Box 205
Holmdel, NJ 07733

This paper provides an informal discussion of software-based methods and techniques that can be used, and are being used, on 8-bit microcomputers to implement the SITOR/AMTOR[1] protocol. This paper doesn't discuss the operation of FSK modulators or demodulators; that topic has been given excellent coverage by others.[2] Instead, this paper focuses on software algorithms—practical information about good ways to encode and decode AMTOR data. The difference between a good AMTOR code converter and a mediocre one is pretty obvious when the equipment is placed in the hands of a knowledgeable user. This paper discusses some tricks that programmers can use to ensure they create "good" AMTOR code converters.

Background

AMTOR basics have been given good coverage by others,[3] so I will only say a bit about them here. Readers unfamiliar with AMTOR should review those papers before continuing.

AMTOR is an error-reduction protocol that provides a reduction in user character error rate when compared to the Baudot RTTY systems commonly used by Amateur Radio operators. It's a low-speed system that provides the user with a maximum data rate of 66 WPM, selective calling via SELFEC (selective Mode B) and ARQ (Mode A) transmission formats, as well as FEC (collective Mode B) broadcast transmission to all stations. Because of the propagation phenomena found on the MF and lower HF bands, some people feel that AMTOR's "robustness" is superior to that of HDLC-based packet protocols (like AX.25) at these frequencies.[4] AMTOR characters are transmitted at a speed of 100 bauds over the radio channel, typically using 170-Hz-shift binary FSK signaling. In AMTOR, the two logic states are termed the B and Y states. The B state is represented by transmitting the higher frequency RF signal, while the Y state is represented by transmitting the lower-frequency RF signal.[5] Each B and Y element is transmitted for exactly 10 ms (±30 ppm). Each AMTOR character consists of seven elements, and each character has four B elements and three Y elements. This 4/3 ratio provides the error-checking mechanism that's used to determine whether or not a character has been received in error. Using a constant 4B/3Y ratio code for error detection may sound flaky, but because of the nature of errors that occur at MF/HF, it works well in practice.

There are two major AMTOR modes. The most common is the ARQ mode, in which the "sending" station transmits a block of three characters and the "receiving" station replies with a single ACK or NAK character in response to the block received. The other mode is FEC. This mode is used for sending information to more than one station at a time, or when the receiving station isn't able to transmit the ACK/NAK signal to the sending station. In an FEC transmission, each data character is transmitted twice, but not in immediate succession: Four other characters are sent before a given character is repeated. This four-character delay provides time diversity.

SELFEC (SELective FEC) is a submode of FEC; and is very similar to FEC. Unlike FEC, however, each SELFEC transmission contains an address that allows non-addressee stations to reject it.

Let's move on and begin to discuss some of the algorithms. Many of these algorithms have been designed into *Z-AMTOR*,[6] an AMTOR system that I completed in 1983 as a ham-radio project. Keep in mind that when I talk about "building" or "constructing" counters or registers, I am talking about using software, rather than hardware, to create those structures.

I have heard several names used to describe the AMTOR "box" that sits between a user's terminal and SSB radio. Terms such as *unit, decoder, system, code converter, modem,* and so on, have all been used. I happen to like *code converter* because code conversion is the major function I see the box performing; I'll try to stick to this term throughout the rest of this paper.

Bit Acquisition

Perhaps the most important aspect of any AMTOR code converter is the speed at which it can achieve synchronization to the received data. The AMTOR data rate is well known because of the ±30-ppm clock tolerance requirement placed on the transmitting code converter. If the receiving code converter could correctly "guess" the optimum time to sample the first data bit, we would only have a 10% bit clock error (or 1 ms lead/lag) after seeing 1666 additional bits fly by (assuming a cumulative 60-ppm clock difference between code converters). That's pretty good! This shows that once the correct clock phase has been determined for the receiving code converter, only very small additional phase adjustments are necessary to maintain synchronization.

An excellent algorithm for AMTOR synchronization is based on the use of multiple shift registers.[7] This algorithm uses 10 shift registers, each driven by one of 10 different clock phases, to acquire the signal. The code converter uses a clock interrupt interval of 1 ms (±30 ppm). All synchronous actions are referenced to this clock signal. Additionally, this signal drives a counter that I call the RX TIC counter. This counter is advanced once each millisecond (it's also accurate to ±30 ppm because it's derived from the same clock standard) and can be in one of 10 states (0 though 9). When this counter rolls over from 9 to 0, another counter, called the RX BIT clock counter, is incremented. The value of the RX TIC counter represents the 10 different phases of the RX BIT clock.

The microcomputer is programmed to create 10 shift registers, with each register containing 21 bits. At the next 1-ms system interrupt, the RX TIC counter is advanced to the next state and the output of the FSK demodulator is sampled. That sample (0 or 1) is moved into the shift register determined by the current state of the RX TIC counter. For example, if the

[1]Notes appear on page 12.

TIC counter has just advanced to state 3, the next bit sample is put into the third shift register.

Following the shift operation, the contents of the current shift register are compared to those in the last shift register. If the contents of the registers are the same, the "match" counter is advanced and no further action is taken. If the contents do not match, the value in the "match" counter is checked. If the count is less than 7, the match counter is set to zero and no further action is taken. If the count is 7 (or greater), and the current and last shift register's contents differ, we have reached a major decision point.

At this point, we know that the last seven (or eight or nine) shift registers have the exact same bit pattern (over 21 bits, or three AMTOR characters). Thus, the last 21 bits placed into these registers weren't affected by jitter (if the data bits were jittered, only a few registers would have the same bit pattern). We also know that the current shift register *doesn't* have that bit pattern, so we must be past the optimum sampling point. The next question is: "How far past the optimum sampling point *are* we?" If the last seven (or eight or nine) FSK demodulator samples (over 21 bits) all produced the same bit pattern, the best sample point is probably 3 or 4 ms back in time.

Once synchronization is established, a single shift register will get the FSK data bit samples when the RX TIC counter advances to the 0 state. Because of this relationship, and because we want the sampling point to occur 4 ms back in time, the software now forces the RX TIC counter to state 4. This effectively sets the next sample instant at 4 ms behind the previous reference point (plus one bit time), or exactly where it should be.

Character Acquisition

At this point, we may have established correct bit synchronization. But what about *character* synchronization? The next step is to look at the contents of any of the last seven shift registers (any of them will do because they all have the same bit pattern; we can't look at the current register because *its* bit pattern is different and of no value). If any of the three characters in the examined register don't have the correct 4B/3Y element ratio, correct character synchronization hasn't been achieved or errors have occurred—and the whole synchronization process is started over. If each of the three characters *does* exhibit the 4B/3Y ratio, there is an excellent chance that character and block synchronization have been achieved. If the three characters are the idle signals characteristic of the collective broadcast (FEC) mode (PS2/PS1/PS2), the software assumes it is listening to a FEC transmission, switches to the FEC receive mode and begins the decoding process. If the three characters match any of the ARQ selective call signals assigned to the station, subsequent blocks are checked to see whether or not they match the remaining call signal(s). The code converter should not restrict itself to receiving the 1st call signal as the first block. If the 2nd call signal is the first block found, the code converter should next look for the 1st call signal (or, for CCIR 625, call signals 2,3,1 or 3,1,2, and so on). When all call signals have been found sequentially and consecutively correct, but not necessarily in 1-2-3 order, the code converter should switch to the ARQ mode and begin to reply. If the three characters don't represent FEC idle signals, and they aren't the same as one of the station's call signals, the characters are not of interest and the whole synchronization process is started over again.

An important result of this synchronization method is that by the time the last bit of the 21-bit block is complete, not only have bit, character and block synchronization been achieved, but the code converter has also identified the mode *and the first block of data hasn't been lost in the process.* The first good block that provides complete synchronization information also provides usable characters for ARQ call-signal comparisons, monitor mode data, and so on. When no errors are present, monitor mode can synchronize on one block (450 ms), FEC mode can synchronize within 210 ms and ARQ mode can synchronize within the minimum number of call signals needed to identify fully the station being called (two or three blocks [900 ms or 1350 ms], respectively). It's tough to do it faster than that! A system that takes longer to synchronize than the times listed above probably has a less-than-optimum synchronization routine.

When bit synchronization, character synchronization and mode identification have taken place, only one shift register is used to acquire subsequent blocks of data. The data bits for this shift register are sampled when the RX TIC counter advances to state 0. The number of 10-ms RX BIT clock increments allowed before the end point of the next data block is considered is set to either 14 (FEC) or 45 (ARQ). Establishing the roll-over limit for the RX BIT clock is part of the mode-identification process.

How much computer power is necessary to do this type of synchronization processing? Well, for Z-AMTOR, a Z80A® microprocessor operating at a clock frequency of 4 MHz was programmed to do the synchronization and mode identification functions using less than 500_{10} bytes of object code. During the standby state, when the synchronization process is running full bore, about 70% of the processor's time is spent doing this task. Once synchronization has been established, the synchronization process is stopped and the requisite communications functions use only about 30% of the processor's time. Considering that the Z80A sells for under $2 in single-unit quantities nowadays, products that make use of fast synchronization algorithms should be inexpensive to manufacture.

Phase Tracking

Once synchronization and mode identification have taken place, and user characters are being passed between the transmit and receive code converters, some method of making small adjustments to the receive code converter's data clock is needed so that it can track the incoming data. A phase-error counter is used to do this. When initial synchronization is established the phase-error counter is set to zero.

After synchronization is established, one receive data bit is put into only one shift register once each 10-ms period. However, a routine still acquires a data bit from the FSK demodulator every millisecond and compares it to the value received 1 ms earlier to check for a data *transition*. When data bits are expected (in the ARQ mode, data bits are expected only 210 ms out of the 450 ms cycle time; during the other 240 ms data bits are *not* expected) and there is a transition, the phase-error counter is incremented if the RX TIC counter is in state 0-4 or decremented if the RX TIC counter is in state 6-9. When data bits aren't expected, the phase-error counter is not changed because the transitions detected during these periods are the result of noise and not valid data.

When the RX TIC counter advances to state 5, another routine checks the value of the phase-error counter. If the phase-error count is between −63 and +63, nothing happens. If the phase-error count is more positive than +63, a negative phase adjustment is needed. This is done by setting the RX TIC counter to 4, which moves the sampling point closer to the center of the received bit. If the phase-error count is more negative than −63, a positive phase adjustment is needed. This is done by setting the RX TIC counter to 6, again moving the sampling point closer to the center of the received bit. Following any phase adjustment, the phase-error counter is set to zero to restart the phase-error accumulation process. If small amounts of noise cause the data transitions to jitter, the phase-error counter will sometimes be slightly positive or negative. The jitter will average out, however, and only the difference in clock speeds will cause the receiving code converter's RX TIC counter to adjust its count (phase) to that of the data transmitter. This operation is similar to that of a phase-locked loop

(PLL). The overflow value (64 in this example) is analogous to the bandwidth of the PLL low-pass filter. A low overflow value corresponds to a low-Q or wide filter bandwidth; a high overflow value corresponds to a high-Q or narrow filter bandwidth.

Telegraphic Distortion Test

One method of checking the quality of the incoming data is to observe how close, in the time domain, the data transitions from the FSK demodulator come to the optimum sampling point. With a bit time of 10 ms, we would hope that data transitions always occur 5 ms away from a sampling point. Atmospheric noise, interference and multipath fading can cause the data transitions to move away from this desired time, however—and any movement away from the desired time is movement closer to the sampling point. The closer the transitions come to the sampling point, the greater the likelihood that errors will occur. We hope that such errors will be detected, but we can't assume that they will *always* be detected.

An extra level of error protection can be had by rejecting any character during which a data transition occurs within *X* ms of the sampling point, even if that character passes the 4B/3Y test. (I use 3 ms for my software.)

This technique works well on ARQ: Its result is that when signals are good, there is no change in throughput or error rate. Under fair-signal conditions, the throughput slows slightly, but the error rate remains extremely small. When signals move from fair to poor, however, the telegraphic distortion test ensures that the error rate remains low. It's important to keep in mind that during horrible propagation conditions—a degenerate case—the test minimizes error rate by bringing throughput to a standstill. (If characters aren't printed, errors can't be printed!) The point to keep in mind is that the telegraphic distortion test further minimizes the error rate of AMTOR systems beyond that of systems that rely only on the B/Y-ratio test.

The telegraphic distortion test can also be used in FEC modes, but with an undesirable result: The test forces the code converter to stand by more often than I want. (When using FEC, my goal is not to achieve perfect copy. Instead, my goal is to get the *gist* of the copy. Printing a few errors under poor transmission conditions is a reasonable tradeoff compared to getting nothing at all because the code converter has reverted to standby. Because of its "perfect copy or no copy" trait, the telegraphic distortion test is not used as part of my code-converter software for reception of FEC signals.)

FEC Error-Out Criterion

When errors are received during reception of an FEC transmission, some criterion must be applied to determine when the code converter should revert to standby. I considered an error rate of 25%, averaged over 64 characters, to be the point at which the code converter should quit trying to make sense of the incoming data. Here's a description of how I implemented this function.

The error threshold is measured by having an error counter that is incremented four times whenever an uncorrectable error is received. When a correct (or correctable) data character is received, the counter is decremented by one (but never to a value less than zero). When the error counter reaches 64 (or more), the code converter decides that it has received "too many errors" and reverts to standby. This test is a good one; it works well and achieves just about the right balance between "hanging in there" during intermittent interference (or noise) and going to standby quickly when reception degrades to terrible (or signals just disappear).

Monitor Modes

The SITOR specification assumes that a station's code converter will be able to print all FEC traffic, but will *not* be able to print SELFEC or ARQ traffic that isn't addressed to that station. SITOR users consider ARQ and SELFEC to be private communication modes because other SITOR stations can't intercept these transmissions. Such "private" modes are inconsistent with Amateur Radio operations, given the need and desire for self-policing in the Amateur Radio services. This section discusses methods that code converters can use to monitor ARQ, SELFEC and FEC transmissions.

When AMTOR was first developed, a monitor mode was incorporated so that hams could monitor the AMTOR transmissions of other hams. All major AMTOR code converters in the marketplace can monitor FEC and ARQ transmissions; a lesser number can also monitor SELFEC transmissions. Most AMTOR systems are capable of monitoring FEC and SELFEC transmissions from the standby state without requiring operator intervention. When the code converter receives transmissions in either the FEC or SELFEC modes, it prints the message. Such is not the case for ARQ transmissions. Most AMTOR code converters provide a special LISTEN or MONITOR mode that can only be used to monitor ARQ communications.[8] If an FEC message is received while the code converter is in the ARQ monitor mode, gibberish is printed. This is tolerable, but less than ideal. A better operation would be to have a monitor mode in which ARQ, FEC or SELFEC will be printed without requiring the operator to change modes. Such operation is more desirable than what is currently available today in most AMTOR code converters.

Consider a "do-it-all" monitor mode in which FEC and SELFEC messages are printed in addition to ARQ messages—all without regard to addressee, and without operator assistance in determining the mode in use. Let's examine how the synchronization and mode identification process would operate for this new do-it-all monitor mode.

First, look again at the "fast" synchronization process. When seven (or more) shift registers all have the same bit pattern, a check is made to see whether or not each of the three characters has a 4B/3Y ratio. If the answer is *yes*, the characters are checked to see if they match the FEC idle signals (PS2/PS1/PS2). If this also is true, the FEC decoding process begins. If there is no FEC idle-signal match, the characters might be part of an ARQ transmission.

The presence of an ARQ transmission is confirmed by looking at the radio channel for an additional 210-ms block (that is, for another 21 bit times) to see if it *also* contains valid AMTOR characters. If the additional block *does not* contain valid characters, you are probably looking at the "dead time" between ARQ data bursts and are receiving an ARQ transmission. If the additional data block *does* contain valid AMTOR characters, the transmission is probably FEC, but you haven't found the idle signals (PS2/PS1/PS2) yet.

On the other hand, if the characters don't have the 4B/3Y ratio, it's time to look for a 3B/4Y ratio. This would suggest that the data bits are inverted and, thus, probably represent SELFEC characters. If the 3B/4Y (inverted) test is true, the software waits for the SELFEC idle signal (inverted $\beta/\beta/\beta$). Once this has been found, you *know* you are looking at SELFEC. Now, the problem is to determine which characters are in the DX and RX positions. Probably the easiest thing to do here is to have two different routines that each assume the opposite choice. While the code converter is receiving idle signals, you don't know anything about DX/RX associations (that's because SELFEC, unlike FEC, uses the same idle symbol in both the DX and RX positions). However, once user data begins to move over the channel, one routine will see that the DX/RX characters *do* match each other, while the other routine will see that they differ. This assumes, of course, that the first user data following the idle signals is not something repetitive like a consecutive group of spaces or dashes. To ensure that this "correlation" works during such worst case conditions, it might be best to have a counter that one routine *increments* when it finds that RX/DX characters match and that the alternate routine *decrements* when it finds a DX/RX match. When the counter reaches either +10 or −10, you could consider the relation between DX and RX to have been found. When the same character is being received over and over again, the counter will hover around zero until a mix of characters is received. Only then will the DX/RX relationship become obvious, allowing the subsequent data to be printed.

FEC Transmission

Next, we'll discuss a significant question: How easy (or difficult) should it be to achieve synchronization with an FEC transmission? CCIR 476 is nonspecific on this point, and this lack of specificity has allowed some manufacturers unwittingly to make code converters that are difficult to synchronize with during FEC transmissions. This section outlines some simple steps that designers can take to avoid this problem. There are two major elements to the synchronization problem, and both are caused by a lack of consecutive idle signals.

The first element deals with effective transmission speed. CCIR 476/625 specifies that one user character, in FEC mode, will take 140 ms to transmit (that is, two AMTOR symbols at seven elements each and 10 ms per element will be equivalent to one user character). That's 7.14 user characters per second, or 71.4 WPM. However, the protocol assumes that a 66-WPM telex terminal is used to send characters to the code converter. Even data generated by a tape reader leaves such a terminal at a maximum rate of 66 WPM. The difference between these two character rates (71.4 and 66 WPM) cause the code converter to insert idle characters into the data stream. These idle signals may allow a receiving station that "errors-out" to resynchronize with the sending station.

Code converters are expected to synchronize only on the FEC idle signals. If sufficient number of consecutive idle signals are not present in an FEC transmission, receiving stations will be unable to synchronize with it.[9] If a personal computer sends data to the code converter at 100 WPM, it will fill the code converter's transmit data buffer faster than the data can be transmitted over the radio channel. If the code converter has not been designed with care, it will most likely transmit that data at the FEC maximum long-term rate of 71.4 WPM—a rate achievable only if no idle signals are transmitted. (After all, as long as the *transmit data buffer isn't empty, why transmit idle signals?*) But without the liberal use of idle signals throughout an FEC transmission, receiving stations cannot synchronize to that transmission if they error-out or tune in after the transmission has started. In fact, several *consecutive* idle signals must be transmitted to ensure that the code converter has a good chance of synchronizing to the signal. Six pairs is a suggested minimum number of consecutive idle signals to be transmitted for synchronization; each pair consists of one idle symbol in the DX position and one in the RX position.

Two simple approaches can be used by a designer to ensure ease of synchronization with a code converter's FEC transmissions. The simpler and less desirable method to preface every transmitted carriage return/line feed (CR/LF) with six idle-signal pairs. This inserts plenty of idle signals into the FEC transmission and ensures that, for lines of 80 characters or less,[10] the effective character rate will not exceed the maximum speed of a standard terminal (66 WPM). Code-converter designers must also assume that the long-term data rate of the receiving terminal(s) cannot exceed 66 WPM.

The second approach: Never allow the transmission of *just one or two* idle signals when an idle signal needs to be transmitted. (So few consecutive idle signals are useless for synchronization, especially on systems that don't use a "fast" method of synchronization.) Instead, the code converter should transmit *a minimum of six consecutive idle signals* when an idle signal is needed. This ensures, for example, that the code converter doesn't transmit the following in response to an operator's slow typing:

L idle A idle Z idle Y idle space idle D idle O idle G

Code converters would be unable to synchronize with the single idle signals in this example. A code converter using the "six pair" idle-signal method, however, would instead produce

L idle idle idle idle idle idle AZY space D idle idle idle idle idle idle OG

—a transmission with which *all* AMTOR code converters should be able to synchronize.

If a designer wishes to keep the effective data rate closer to the maximum speed of 66 WPM regardless of line length, more complex techniques are required that don't assume a universal line length of 80 characters. One such method that works well is as follows: Use a counter that increments every time a nonidle signal is transmitted. When transmission of CR/LF characters is called for, the counter is first checked to see if its value is greater than 56_{10}. If so, 56_{10} is subtracted from the counter, six idle signals are transmitted and the CR/LF characters are transmitted-in that order. Additionally, if the transmit data buffer empties at any time and an idle signal is needed, six pairs of idles are transmitted and 56_{10} is subtracted from the counter. If the result of this subtraction leaves the counter negative, the counter is forced to zero. This method keeps the maximum long-term throughput near 66 WPM regardless of the number of characters in a line and ensures idle signals will always be useful to the synchronization process. *Every* CR/LF will not be preceded by idle signals, but when the terminal demands maximum throughput from the code converter by sending data to the converter at top speed, idle signals will occur *only* where they will do the most good: just before a CR/LF.

Conclusion

This paper has discussed some techniques and methods that should be of interest to those implementing AMTOR and/or SITOR protocols. Because the AMTOR data rate is slow (100 bauds), a common 8-bit microprocessor can do a significant amount of signal processing of logic-level data from the FSK demodulator without requiring special hardware.

I am always interested in discussing topics involving low-speed data communications over MF/HF radio systems with other Amateur Radio enthusiasts. If you are interested in developing similar systems, have questions about something I touched on here or missed, or have some suggestions about how to do it better, I would be pleased to discuss them with you. Feel free to contact me at the address listed at the beginning of this paper.

Notes

1The term *SITOR/AMTOR* refer to communications systems based on CCIR Recommendations 476 and 625. I will use the term AMTOR to refer to both AMTOR and SITOR systems. I consider AMTOR to be a superset of SITOR because AMTOR units can monitor ARQ communications but SITOR units cannot. A full description of CCIR Rec 476 (the AMTOR protocol) is contained in the proceedings of the Third ARRL Amateur Radio Computer Networking Conference (now published as part of *ARRL Amateur Radio Computer Networking Conferences 1-4* [Newington: ARRL, 1985]). A paper that complements the protocol specification (Paul Newland, "A Commentary on CCIR 476-3," *unpublished)* is available from the author.

2G. W. "Bill" Henry, "RTTY Demodulators," *CQ*, Nov 1983, pp 20-24; reprint available from Hal Communications, PO Box 365, Urbana, IL 61801.

3A discussion of AMTOR is given in *The 1988 ARRL Handbook* (chapter 19) and by Martinez the Jun/Jul 1980 issue of *Radio Communications* (RSGB).

4Paul Blankmann, "Can We Compare AMTOR with HF Packet?," *RTTY Journal*, Vol 31, No. 1, Jan 1988, p 18.

5Note that the use of LSB or USB or the particular set of audio modem tones is a "don't care," provided that the RF frequency shift is 170 Hz and that the higher radio frequency corresponds to the B signal.

6Paul Newland, "Z-AMTOR: An Advanced AMTOR Code Converter," *QST*, Feb 1984, pp 25-34.

7The concept of multiple shift registers was suggested to me by Peter Martinez, G3PLX. Peter developed the first AMTOR code converter for use by Amateur Radio operators. Based on the Motorola 6800 microprocessor, it was described in J. P. Martinez, "Amtor, an improved radioteleprinter system, using a microprocessor," *Radio Communications*, Aug 1979, pp 714-719.

8The INFOTECH M-44 is a notable exception. It decodes both ARQ and FEC from the monitor mode.

9Of course, with exceptional programming like that described in Monitor Modes, a code converter could be made that would be capable of synchronizing with a FEC transmission that didn't contain idle signals. Such capability is beyond the function of a "normal" code converter in the standby state, however.

10The recommended maximum number of characters on a line is 69 unless the operator knows for certain that the receiving station(s) can handle longer lines.

>50

Focus on technology above 50 MHz

By Bill Olson, W3HQT
Box 2310, RR 1
Troy, ME 04987

RF Hybrid Modules: Building with Bricks

RF hybrid modules are showing up more and more frequently in the literature these days. Commonly referred to as "bricks," these modules are small, rectangular flange-mounted devices. They are also referred to as RF power modules, mobile modules, hybrid ICs, or sometimes by the more technical terms, *thick-* or *thin-film hybrids.* The *hybrid* part of the name states precisely what these modules are: that is, a hybrid circuit that uses surface-mount circuit-board techniques *and* semiconductor assembly techniques. Basically, a hybrid module consists of a copper or copper-alloy flange (typically approximately 2 × 1 inch) onto which is soldered a ceramic circuit board or *substrate* containing densely packed circuits and components for use in relatively narrow-band amplifying applications. The device is protected from dust and fingers by a plastic lid that either snaps on or is glued in place. Hybrid modules are usually 50-ohm-input/output devices and require very few external components. Just apply drive and dc, attach the antenna and you're on the air...well, almost.

Why Hybrid Modules?

RF hybrid modules have been around for over 20 years, and in fact were the original ICs. Used in military and commercial equipment where small size and uniformity of operation are important, RF hybrids have been used as IF amplifiers and in other low-power applications for years. The first mobile power-hybrid modules showed up in the late '60s (à la RCA) and became more and more prevalent as the years went on, as the mobile-radio industry started to slow down and consequently strove to reduce the costs and the number of components in their radios. In addition, the tendency toward more power from smaller packages forced many designers to go the hybrid route. More recently, hybrid modules have shown up in commercially manufactured Amateur Radio equipment, for both FM and SSB, from 50 through 1300 MHz.

What's Inside

Popping the lid on an RF hybrid module, we see what looks a lot like an RF power transistor; that is, there are silicon chips mounted on a ceramic insulator. The chips are bonded to gold-metallized traces that run along the top of the substrate. There are also chip capacitors, RF chokes and other components like those seen in more conventional printed circuits. The substrates are either aluminum- or beryllium-based for low- or high-power applications, respectively.

The interconnections are formed using either thick- or thin-film techniques. Although the end result is pretty much the same (gold traces on top of a ceramic board), the thin/thick terminology refers to how the traces are applied. Basically, thick film is an additive process where the conductive material is silk-screened onto the substrate and then fired at a high temperature. The thin-film process is subtractive; that is, the whole substrate is plated with gold and the material is etched away where it is not needed—as in a normal PC-board process.

Film conductors can be implemented in either process by normal microstrip techniques. Film resistors can be manufactured by deposition of resistive material. More commonly, miniature discrete components (chip resistors and capacitors) are used. Transistor chips are eutectically mounted to the substrate, just as in RF power transistors, and interconnections are made by wire bonding. A protective coating is usually applied to the semiconductor chip after it is wired, to protect the chip from contamination.

Applications

Hybrid modules are usually two- or three-stage amplifiers with appropriate matching and biasing circuitry. They were originally available only for class-C operation, because their major use was in the mobile FM communications industry. More recently, class-AB linear modules have been developed for amateur gear and other AM applications. The input level of most such bricks is in the 100- to 250-mW range, and outputs are up to 50 or 60 W per module at VHF, and up to 20 W or so at UHF. Some driver modules and high-gain devices only require 10 mW of drive. Typical RF hybrid pin-outs are shown in Fig 1. Pin-outs vary from manufacturer to manufacturer, but the end pins are always the input and output, and the dc and control voltages are applied to the middle pins. The mounting flange is at RF and dc ground, though some models also have ground pins.

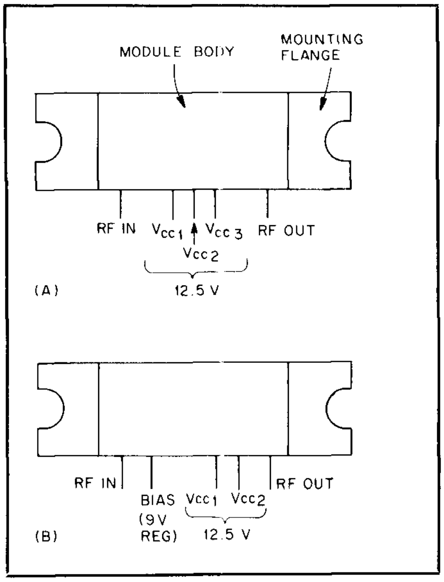


Fig 1—At A, a diagram of a typical three-stage class-C hybrid RF power amplifier module is shown. This module has a collector-supply line for each stage brought out of the case. $V_{cc\,1}$ can be varied as a gain control for the amplifier module, or V_{cc}s 1, 2 and 3 can be tied together. At B, a typical two-stage class-AB hybrid amplifier is shown. This module has two collector-supply pins and a separate bias pin in addition to RF input and output pins.

Using Hybrid Modules

Obviously, RF hybrid modules were designed to be easy to use, and they are! The biggest problems are keeping the input and output transitions low in inductance and at 50 Ω, and providing good RF bypassing and dc decoupling on the supply leads. The class-AB linear modules can be turned off during receive

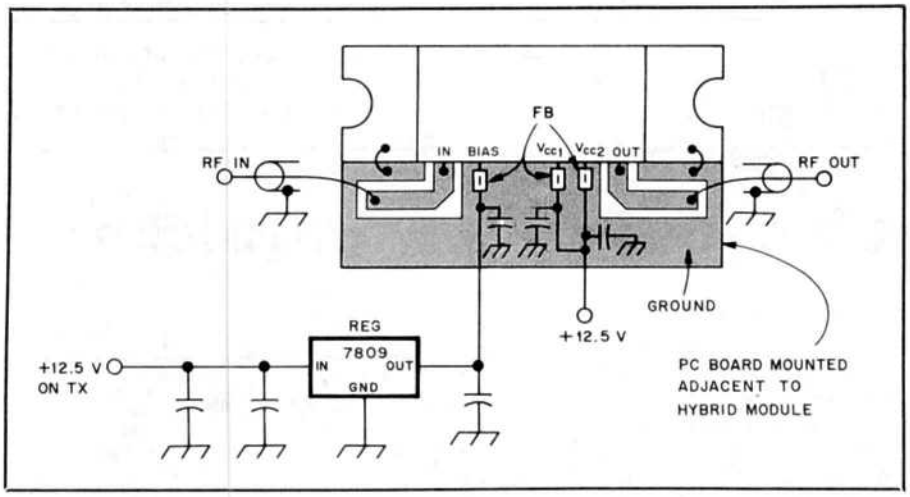


Fig 2—Typical necessary external wiring for a two-stage class-AB hybrid power amplifier.

by removing the bias voltage, so the bias lead is usually brought out separately from the supply lead.

See Fig 2 for typical installation information. Interconnection to the outside world is most often accomplished by mounting a circuit board flush to the edge of the module, with the pins sitting right on top of the board (near zero lead length). Table 1 shows typical performance numbers for some commonly available modules. Note that most of these are spec'd very conservatively. A 10-W-rated module usually delivers better than 20 W.

Table 1 contains only a partial listing. Some modules listed are no longer manufactured, but many are still available through distributors. ICOM modules are manufactured by Mitsubishi and NEC, and are available through ICOM America. Some Toshiba and Mitsubishi modules are available through RF Parts, 1320 Grand Ave, San Marcos, CA 92069. NEC modules are available through California Eastern Labs (CEL).

Table 1

Hybrid Module Specs, Manufacturers and Models

Manufacturer	*Model*	*P_{out} (W)*	*P_{in} (W)*	*P_{out} (W)*	*Freq (MHz)*	*Class*
Mitsubishi	M57735	10	0.1	22	50	AB
Mitsubishi	M57713	10	0.1	20	144	AB
Mitsubishi	M57727	25	0.3	40	144	AB
Toshiba	SAV7		0.2	28	144	C
Toshiba	SAV17		0.4	60	144	C
Toshiba	SAV15		0.2	32	220	C
Toshiba	SAU4	10	0.2	20	432	AB
ICOM	SC1027	10	0.2	20	432	AB
Mitsubishi	M57716	10	0.2	20	432	AB
Motorola	MHW709-1	7.5	0.1	12	432	C
Motorola	MHW710-1	13	0.1	15	432	C
Motorola	MHW720-1	20	0.1	25	432	C
TRW	MX20-1	20	0.1	25	432	C
Toshiba	SAU15	0.15	0.01	0.2	902	AB
NEC	MC5809	0.15	0.01	0.2	902	AB
Toshiba	SAU17		0.02	8	902	C
NEC	MC5842	7	0.1	9	902	C
NEC	MC5843	13	0.2	18	902	C
Motorola	MHW806-3	6	0.3	7	902	C
Motorola	MHW820-3	20	0.4	25	902	C
NEC	MC5874	1	0.01	2	1296	AB
ICOM	SC1043	1	0.01	2	1296	AB
Mitsubishi	M57762	10	0.5	20	1296	AB
ICOM	SC1040	10	0.5	20	1296	AB

Mounting

The overall efficiency of most hybrid modules is between 25 and 50%, so they must dissipate quite a bit of heat. For this reason, careful mounting is important, especially for the higher-power devices. Make sure the heat sink and flange surfaces are clean and flat, and coat the module flange with thermally conductive compound. Tighten the mounting screws snugly and make sure the device leads won't be torn off when you tighten further. Alternately tighten each mounting screw a little at a time until the brick is seated. Solder the pins to the circuit board last.

Additional Thoughts

One of these modules is an ideal (and simple) building-block candidate for combining to get higher power-output levels. How 'bout this for a neat idea: Take one MC5874, use it to drive a pair of M57762s combined with Sage Wireline™, and drive the whole setup with a few milliwatts. You'll get over 40 W output anywhere in the 1240- to 1300-MHz band! Just be sure to put this baby on a *large* heatsink—such an amplifier dissipates over a hundred watts at full output.

Summary

Although they're still a little more costly compared to discrete components that will do the same job, RF hybrid modules are finding their place in modern amateur gear. For a simple medium-power amplifier with a lot of gain in a small package, hybrids can't be beat. Try a brick in your next VHF or UHF project!

Bits

Yaesu USA Consolidates Facilities

Yaesu USA has announced the consolidation of their repair facilities at corporate headquarters in Cerritos, CA. This move closes the Hamilton, Ohio location.

Owners of Yaesu radios can request service from Yaesu USA, 17210 Edwards Rd, Cerritos, CA 90701. For for information, contact Yaesu USA at 213-404-2700. —*Paul K. Pagel, N1FB*

VHF+ Technology

By Geoff Krauss, WA2GFP
16 Riviera Drive
Latham, NY 12110

Odds and Ends

Several readers have asked for help in obtaining information and manuals for the following VHF+ equipment: Alfred type 504 and 508 TWTAs and type 240 high-voltage power supply. If you can supply any info, please let me know.

Speaking of TWTs and TWTAs, some of the W2SZ/1 group recently tested almost 20 surplus units in the 2 to 4, 4 to 8 and 8 to 12.4-GHz bands. All except one worked very nicely, and should show up on the air (later or sooner). The one loser (apparently because of a gassy envelope), was a 25-W, 4 to 8-GHz tube. Is such success normal for untested tubes acquired at various flea markets and such? Possibly, if you make sure to test for heater continuity before buying. How do you know which are the heater leads? You usually don't, but you should be able to check through the relatively small number of combinations of lead pairs. (The maximum number of combinations is equal to

$$\frac{L \times (L + 1)}{2}$$

where L is the number of leads). There is usually only one pair of leads between which there is a low resistance! A typical TWT may have five leads (heater, heater/cathode, anode, helix and collector), so that there are only 15 possible combinations of two different leads; it shouldn't take more than a minute to check out. (Now you know why many VHF+ers carry pocket VOMs to hamfests!)

I have received several responses to my comments about VHF (2-meter) SSB hand-held transceivers, including one photo of a young lady draped with 6-meter, 2-meter and 220-MHz SSB transceivers. Yes, I agree that one or two companies do make such units, but in nowhere near the number (or general availability) of FM rigs manufactured for the same bands. If you look at technical specs, prices, and so on, I believe my original comments still pertain.

220-MHz "State of the Art"

The technology in use on the 220-MHz band is not far behind that on 2 meters, and the amount of commercial equipment now available (thanks, in part, to Novice enhancement) should be sufficient for use by all but the leading-edge experimenter. High-gain antennas are almost always multiple-wavelength Yagis of the NBS/DL6WU type, allowing gains and patterns comparable to those achievable on 2 meters, but at only ⅔ the physical size. Arrays suitable for EME (four or eight long-boom Yagis), can be relatively easily handled by most towers and rotators. Low-gain omnidirectional antennas, intended for the rapidly growing 220-MHz FM trade, abound.

Some form of commercially made 220-MHz FM transceiver has been available for a number of years, although the selection and choice of features have only become respectable since Novice enhancement assured the existence of sufficient sales base in the US. That there is no 220-MHz amateur allocation in Japan [in fact, in most of the world—Ed.] has long meant insufficient potential for the large-scale market apparently needed to fuel development by the Japanese of a wide variety of 220-MHz equipment. This has been so even though the 144- and 220-MHz bands are close enough to each other to allow many designs to work well on both bands, once the obvious changes (frequency-determining elements and networks) are made. This situation is changing, however, and 220-MHz FM units are now available with every feature found on at 2-meter rigs, and at comparable prices.

Non-FM 220-MHz equipment, including receiving converters and CW transmitters, has been commercially available for many years, although the selection of such rigs has not been large. Until a few years ago, really good equipment had to be homemade. Much more commercial equipment is now available, including several forms of SSB transmitting and receiving converters, and even multimode transceivers. Almost all of the latter use some form of phase-locked loop for frequency determination. The phase-noise problem is apparent in many of these units. (If you do not understand the causes and effects of phase noise, read the recent two-part *QST* article[1] on the subject. It is by far the best non-mathematical explanation of the phase-noise problem I have read.)

The best 220-MHz receivers and receive converters have noise figures (NFs) in the 0.2- to 0.4-dB region, but must have sufficient selectivity to suppress any strong channel-13 TV signals to make full use of NFs this low. A strong signal just below the weak-signal sub-band (220 to 222.1 MHz) can create intermodulation products or block the front end of your receiver, unless proper filtering is used. Providing sufficient filtering is not difficult, but the filter impedance outside the passband is often reactive enough to force many low-noise preamplifiers into marginal stability, if not into oscillation. This challenges the state of the art with providing very low NFs while providing sufficient band-pass filtering. The ideal setup is a low-loss cavity band-pass filter (BPF) ahead of a GaAsFET preamp, feeding a multiple-resonator BPF. (This combination can be extremely unstable, however, and can go into oscillation easily.)

Transmitters for 220 MHz (separate transverters or part of transceivers for CW and SSB and/or FM operation), are available with all of the features found in HF units, although output power levels are generally lower (typically in the 5- to 25-W range). The third-order intermodulation distortion (IMD) levels of 220-MHz SSB transmitters are likely to be high (anything greater than −30 dBc [decibels relative to the carrier] is unacceptable by today's engineering standards).

Although I don't know of any commercially made high-power (300- to 1500-W) 220-MHz amplifiers, many proven designs for ceramic-tube units (4CX250 family, 3CX800, 8874 and 8877) have been published in *QST* and in the *ARRL Handbook*.[2] Because these are often 2-meter units with shortened grid and plate tuning lines, modification of many other designs (including government surplus units) is not too difficult for the average VHF+er. There are a fair number of solid-state power amplifiers (often called SSPAs or "bricks") available, most with built-in RF-sensed TR switching. Some also have built-in receive preamplifiers (many of these preamps have measured NFs in the 1- to 3-dB region, however, and may not significantly improve many modern

[1]Notes appear on page 17.

220-MHz receiving systems).

Intermodulation Distortion

The biggest problem with most solid-state power amps, including those in SSB transceivers for VHF, is (as previously mentioned) poor IMD performance. For example, one commercial multimode transceiver has a measured third-order IMD suppression (IMD_3) of only 23 dB at 30 W PEP output. The same radio produces a more acceptable level (IMD_3 = −33 dB), at about 5 W PEP output. Careful design and construction are necessary to achieve a useful IMD_3 output level (at least −30 dB) in a VHF SSPA. Why is this of growing concern?

IMD occurs in *all* amplifiers, small- and large-signal. As seen in Fig 1, the input signal is a two-tone signal with components at frequencies f1 and f2. The two tones, of equal amplitude at −6 dBc, are applied to the circuit being tested and the output spectrum is observed (typically with a spectrum analyzer). The amplitudes of the amplified f1 and f2 signals should still be equal at −6 dBc PEP. Any active circuit can act non-linearly, and generate distortion products in addition to the desired output signal. The composite output of such a circuit consists not only of the desired signals, but also the sum and difference products of the input signals.

Even if the two-tone input signal is perfectly free of undesired components, passage through an active circuit can cause the frequency spectrum of the output to look like that of Fig 1: The two desired output signals are surrounded by unwanted signals of the form (k × f2 + n × f1), where n is negative below the f1 signal, and k is negative above the f2 signal. The sum of n and k is an odd number, and is known as the *order* of the unwanted distortion product. Note that even-order products are not shown, as they occur either at about zero frequency, or at about twice the center frequency (2 × f0).

The largest of the unwanted distortion signals are the third-order products (at 2 × f1 − f2 and 2 × f2 − f1) which are at a level (IMD_3) below the PEP level of the desired signal. The larger the difference (IMD_3), the less the amplitude of the unwanted signal and the smaller the ill effects that the spurious signal creates. Higher-order products (fifth, seventh, and so on) have lesser levels and, being even farther separated from the frequencies of interest than the third-order products, are usually less of a problem. Amplifier linearity is generally rated in terms of the IMD_3 level.

The reason for high IMD products, and one possible cure, can be seen in the P_{in} versus P_{out} curves of Fig 2, for a 220-MHz transistor amplifier with 13 dB of linear gain. The basic linear amplifier curve has a slope m = 1, meaning that any change in input power results in a proportional change in output power. The amplifier is linear until an output value of P_b (rated output) is reached. At this point, the amplifier has entered the saturation region, and its gain falls off, or *compresses.* The degree to which an amplifier is saturated is usually characterized by the amount of gain reduction. A −1-dB-saturation power output level (P_{-1}) is reached when the gain is compressed by 1 dB, a −2-dB level (P_{-2}) when the gain is compressed by 2 dB, and so on.

The level of the third-order products in the output of this amplifier is shown by the lower curve of Fig 2. This curve (slope m = 3) shows that every change in input signal yields a differential output change of 3 times. Note that this characteristic curve also shows a saturation region.

In one commercial amateur transmitter, IMD_3 products of −22.5 dB are produced when the final amplifier is driven deeply into saturation (P_{out} = 60 W PEP). This is pretty poor. When the drive is reduced (to produce the rated

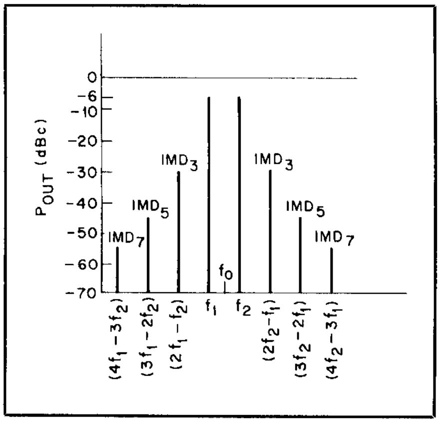


Fig 1—The levels of third, fifth and seventh-order IMD products are related to amplifier linearity; the frequencies of the IMD products are related to input-signal frequencies.

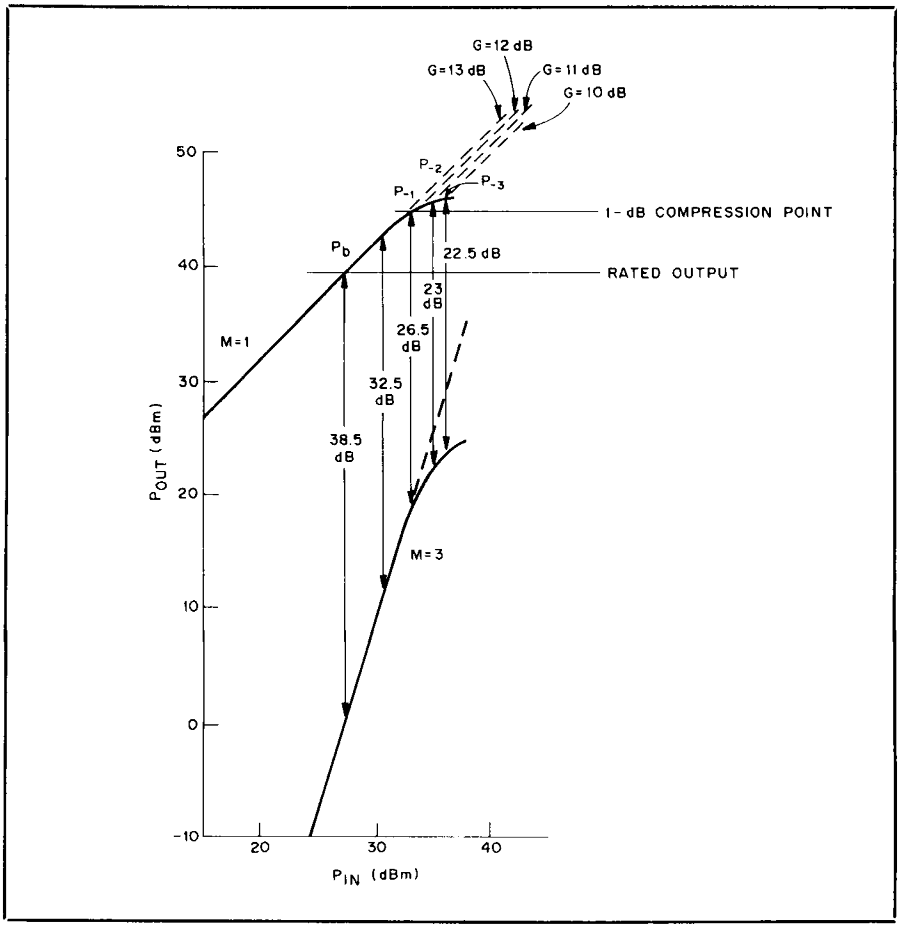


Fig 2—Typical amplifier gain curves. The upper curve shows a linear gain of 13 dB until P_b is reached. The lower curve represents the level of third-order IMD products in the same amplifier. IMD_3 dynamic range decreases from 38.5 dB at P_b to 22.5 dB at the 3-dB compression point (P_{-3}).

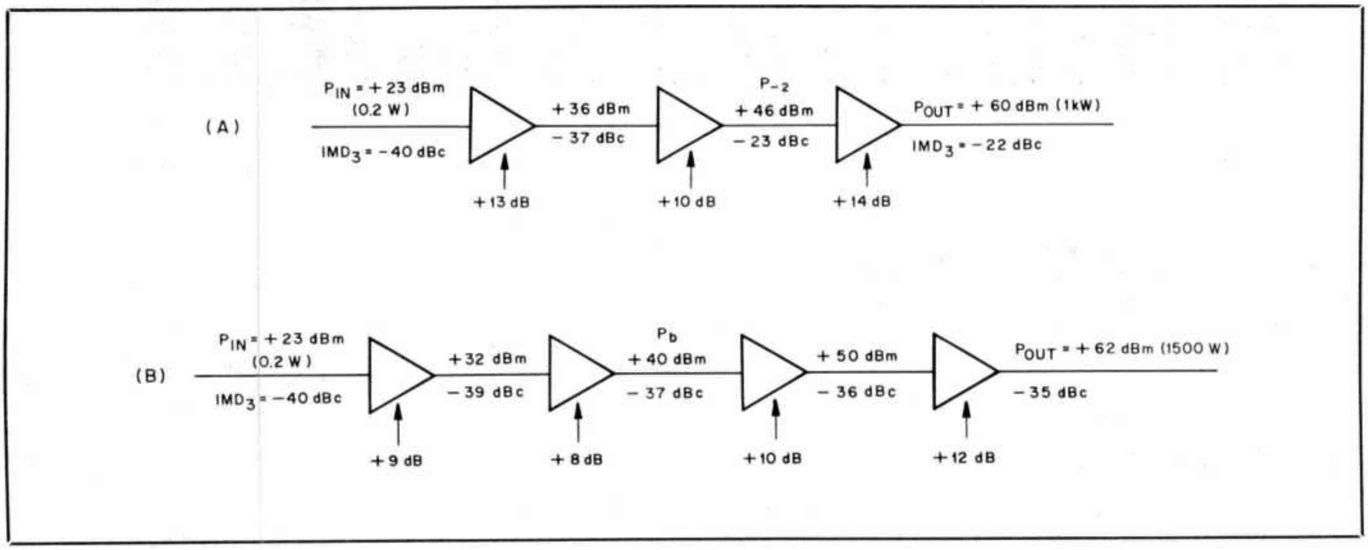


Fig 3—The three-stage amplifier at A boosts a 23-dBm signal to 60 dBm, but the resultant IMD_3 products are unacceptably high at −22 dBc. Adding another stage to the chain (B) assures that no stage is pushed as far into saturation as in the three-stage amplifier at A. Result: The same 23-dBm input signal is amplified to 62 dBm, but third-order IMD products have been reduced by 13 dB to only −35 dBc.

output of 40 W), IMD_3 products are reduced to −26.5 dB. A further reduction to P_{out} of 10 W PEP reduces IMD_3 to an acceptable level (−32.5 dB).

The secret of minimizing IMD_3 is to ignore the advertising hype that says how much power output you can get by pushing an amplifier to the limit, and instead use the amplifier well below saturation! This may require inclusion of an additional stage to achieve about the same clean output power as that obtainable from the saturated amplifier, but the result will be dramatically reduced IMD and a cleaner signal. See Figs 3A (before) and 3B (after) to see how much of an improvement such good engineering made in one 220-MHz transmitter chain.

Notes

[1] J. Grebenkemper, "Phase Noise and its Effects on Amateur Communications," part 1, *QST*, Mar 1988, pp 14-20; part 2, *QST*, Apr 1988, pp 22-25; Feedback, *QST*, May 1988, p. 44.

[2] M. Wilson, ed, *The 1988 ARRL Handbook* (Newington: ARRL, 1987), chapter 31.

Bits

SIQ Repeater Controller

A-Tech Electronics has announced the availability of the SIQ repeater controller. Using the power of a microcomputer, the SIQ-2 provides all the basic repeater functions as well as features such as voice and Morse ID, autopatch, reverse autopatch, audio mixing and linking. DTMF tones are used to control the many features. Courtesy tones, squelch-tail length, CW ID, sleep/wakeup mode, alarms and other control commands are all remotely programmable. Sixteen I/O lines are provided to control any number of devices. An optional phone-patch board with many advanced software features is also available. Up to five area codes can be programmed into the controller to aid in long-distance access.

The SIQ controller is contained in an RF-proof, steel rack-mount box; all 16 I/O lines are RF-proofed with ferrite beads. The accompanying manual provides all the information you will require to connect your radios; feature-programming and user commands are all explained in detail. A schematic diagram and a source-code listing are part of the package, allowing you to make custom modifications.

The SIQ repeater controller is available from A-Tech Electronics, 1033 Hollywood Way, Burbank, CA 91505, tel 818-845-9203; FAX 213-969-0183. Price: $349.95; with phone patch, $449.95 —*Paul K. Pagel, N1FB*

NEC Silicon MMIC Prescalers

California Eastern Laboratories offers a new family of silicon MMIC prescalers from NEC. By directly synthesizing frequencies to 2.5 GHz, these prescalers simplify design, minimize component count and reduce board space.

Specifications for the devices are given in Table 1. The UPB584 and UPB585 are divide-by-two and divide-by-four prescalers. The UPB587 is a selectable divide by 2, 4, or 8 prescaler operating to 1 GHz with low power consumption. Both the UPB584 and UPB585 require a +5 V power supply; the UPB587 needs only 2.2 to 3.2 V. All devices are available in ceramic and plastic packages.

These devices are ideal for use in MW, VHF and UHF equipment, including MW radios and satellite communications systems. For further information, contact Richard Chou, Product Marketing Manager, California Eastern Laboratories, 3260 Jay St, Santa Clara, CA 95054, tel 408-988-3500; FAX 408-988-0279. —*Paul K. Pagel, N1FB*

Table 1

Performance Features

Division Ratios	*Frequency Range (GHz)*	*Output Level (dBm)*	*Supply Current (mA)*
UPB584B/G — 2	0.5 to 2.5	−4	18
UPB585B/G — 4	0.5 to 2.5	−4	26
UPB587B/G — 2, 4, 8	0.1 to 1.0	(0.3 V P-P into 200 ohms)	5.5