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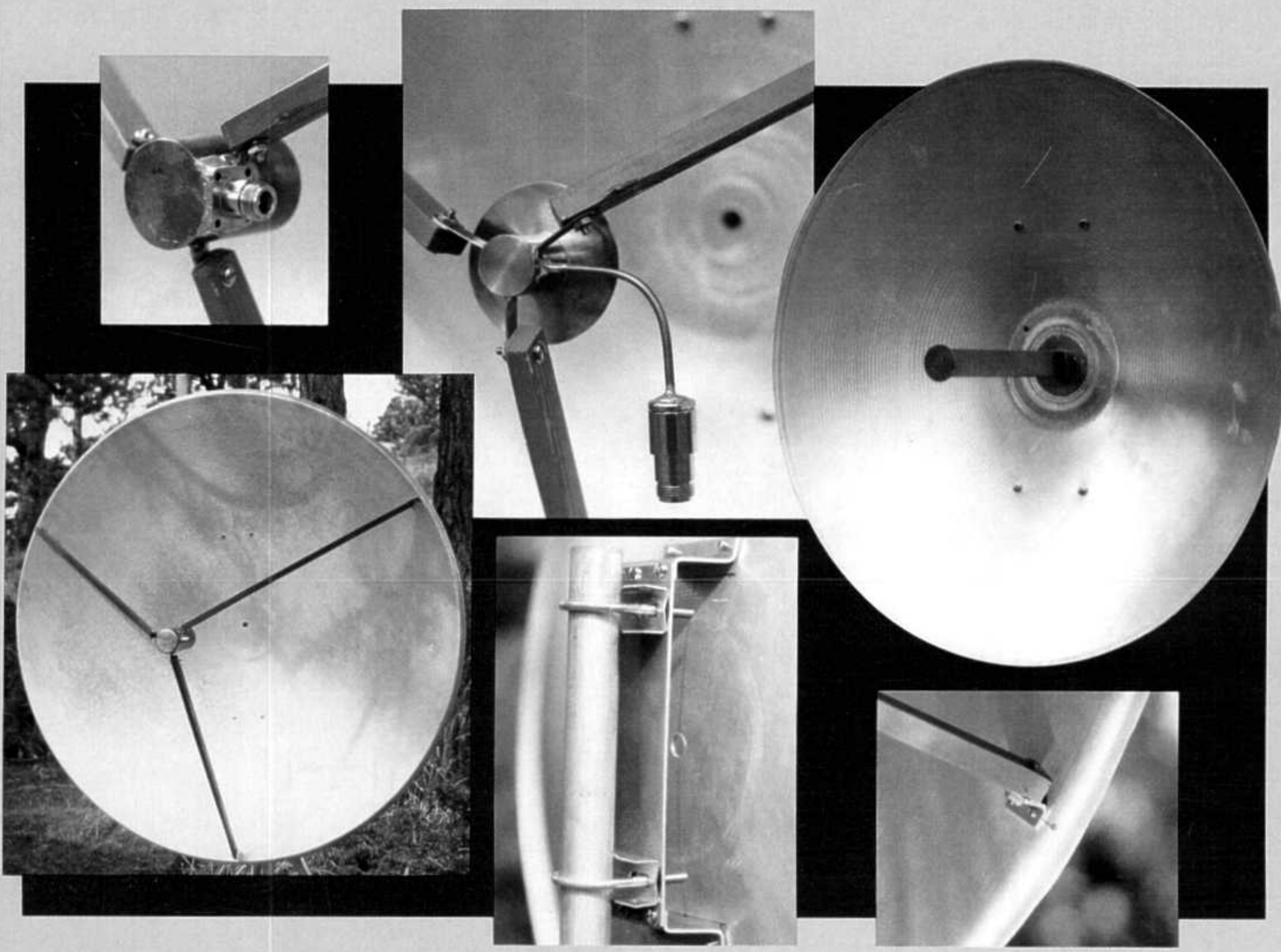

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COLUMNS

ABOUT THE COVER

The cover montage illustrates what a lot of enthusiasm and a little elbow grease can accomplish. WØPW spends a fair amount of time constructing dish antennas for his microwave activities. Clockwise from the top left-hand corner is a 5.7-GHz feed horn, a 10.3-GHz feed horn, a 19-inch dish for the 10.3-GHz band, a close-up view of the spar mounting method used, the mounting method used on the 32-inch dish and a 48-inch dish for the 3.45-GHz band.

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.

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

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

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Purposes of *QEX:*

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

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

Both theoretical and practical technical articles are welcomed. Manuscripts should be typed and double spaced. Please use the standard ARRL abbreviations found in 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*.

Empirically Speaking. . .

Amateur Satellites on the Horizon

If you want to graduate from high school biology, sooner or later you have to dissect that frog. Sooner or later you have to launch satellites if you're called Radio Amateur Satellite Corporation (AMSAT). That's a simple concept. Now comes the hard part. If you're a 99% voluntary organization, where do you get the money, technical and managerial talent, launch opportunities, and lots of good luck? Launch good satellites and hams will be beating down the doors to get in. Aha! Another chicken-and-egg loop.

Last time AMSAT lit the candle, AMSAT-OSCAR 10 was born. Unfortunately, some antennas received a few unwelcome lumps aborning. So, AO-10 wasn't able to be all that it could be, and people didn't flock. But some people operated through AO-10, joined AMSAT and supported the Amateur-Satellite program. It was clear that AO-10 couldn't sustain the program for long and that some new satellites were needed.

Phase 3C has moved from the drawing boards to flight hardware to launch integration. Dick Daniels, W4PUJ, recently returned from a visit with AMSAT-DL in Germany and reports that the propulsion system on Phase 3C and the shake and vibration test all went very well. The spacecraft is in very good shape. Congratulations to the engineering and test teams! The launch is reserved, but the date keeps slipping, unfortunately. The latest word is maybe late March or April 1988.

At the AMSAT Board Meeting in early November, an initiative was taken to build and launch an amateur PACSAT (packet satellite) on an expedited basis. AMSAT's original PACSAT project branched off into a joint project of Volunteers in Technical Assistance (VITA) and the University of Surrey (UoS), and recently obtained government and private financing. For the past two years, AMSAT wanted to get back on the main track of building a PACSAT for amateurs. But things didn't come together until November. An engineering axiom is: Put off designing something as long as possible because it'll be easier then. PACSAT was no exception. Obviously, lessons were learned in the design of the UoSAT-OSCAR 11, Fuji-OSCAR 12 and VITA PACSAT spacecraft. Moreover, the ground-station equipment (eg, modems) needed to access UO-11 and FO-12 are assets that have been developed and deployed. The amateur packet radio has grown to the point that PACSAT teleports would have a ground network for regional pickup and delivery. The thinking for the first PACSAT bird centers around use of existing modems designed for FO-12. Speeds higher than 1200 Bd are planned further down the learning curve.

Then there's Phase 4—the geosynchronous satellite program. It's going to be tough keeping that ambitious plan on schedule as some of its key players have PACSAT adrenal fluids surging through their veins. The main resources caught in the PACSAT/Phase 4 stretch are engineers, managers and finances. If you have talents in these areas, AMSAT would like to hear about them.

From a packet-radio viewpoint, having both low-earth-orbit (LEO) PACSATs and geostationary Phase 4 satellites seems like the best of both worlds. The synchronous birds permit real-time relay between points within one third of the earth. LEO PACSATs don't give much real-time geographical coverage, but it quickly gets around to the other side of the earth for delivery of messages on a store-and-forward basis. What's more, PACSAT's low orbit means that transmitter-power and antenna requirements on the ground are modest. Of course, there's the possibility of linking Phase 4 satellites. But that depends on having more than one up there. At $3 million a pop. . . Now that's ambitious.—W4RI

Antenna Ideas For 3.5, 5.8 and 10.4 GHz

By Donald L. Hilliard, WØPW
PO Box 563
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Since manufacturers began producing commercial equipment for the 10-GHz amateur band, interest in that microwave band has soared. Many of these new SSB/CW units typically have output power levels between 150 and 200 mW. When this power is fed into a 30-dB gain antenna, an ERP of 150 to 200 W is realized. A gain of 40 dB produces an ERP of 1500 to 2000 W. Of course, an antenna with 40 dB of gain has a very small beamwidth. A dish with a 60-inch diameter typically produces close to 40 dB of gain at 10.3 GHz (assuming approximately 55% efficiency). A dish diameter of 32 inches produces a gain of approximately 35 dB at 10.3 GHz, and approximately 31 dB at 5.7 GHz. Even at 3456 MHz, a 32-inch reflector can provide 27 dBi gain. Although these are modest gains, the resulting beamwidth is perhaps a little easier for most amateurs to work with.

A company in Michigan distributes reflector antennas that are quite useful for amateur work.[1] Some of their products are shown in Table 1. Their solid-surface dish antennas are made from spun aluminum.

The reflector discussed here is a 32-inch diameter unit. These feed horns, however, can be used to feed any of the other size reflectors as well.

Feed Horns

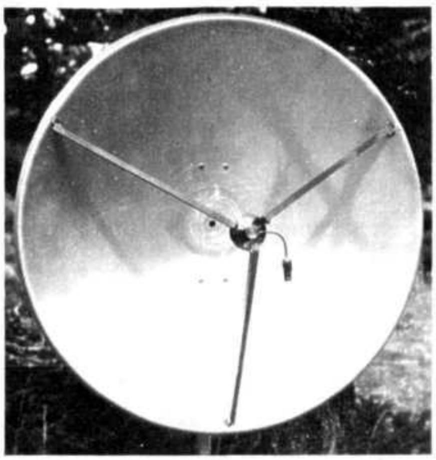
Cylindrical waveguide feed horns are very simple and inexpensive to make. They perform reasonably well when used with the 32-inch (or larger) dish. Figs 1 and 2 show different views of how the feed horn can be mounted. Small L brackets at the edge of the dish hold the spars in place. By adjusting the mounting tab positions on the feed horns, one set of spars will work with all three described feed horns, placing the focal point at the proper place.

The 10-GHz horn uses a choke ring. The choke ring can also be added to the 3- and 5-GHz horns. The use of these chokes is discussed in an article by Foote,[2] and is recommended reading for those planning to add choke rings to the 3- and 5-GHz units.

[1]Notes appear on page 5.

Table 1
Available Reflector Antennas

Antenna Diameter (in inches)	*Price*	*Shipping Information*
19	$ 19.95	UPS shippable
24	28.00	UPS shippable
32	38.00	UPS shippable
48	68.00	Shipping weight: 9 lbs
60	118.00	Shipping weight: 14 lbs
72	156.00	Shipping weight: 25 lbs



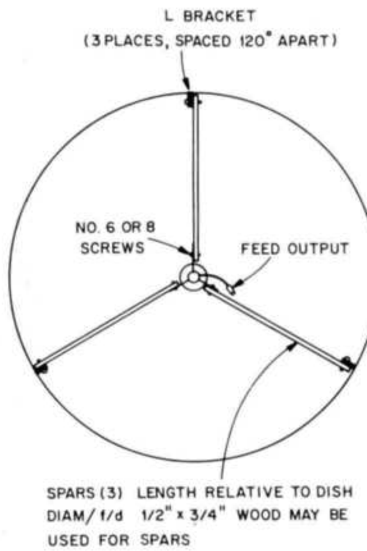


Fig 1—Front view of the 32-inch reflector.

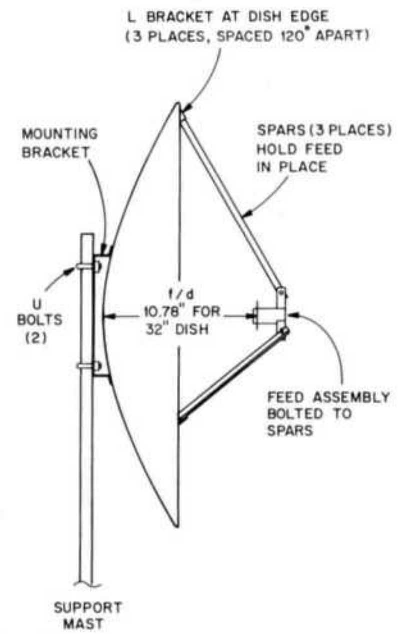
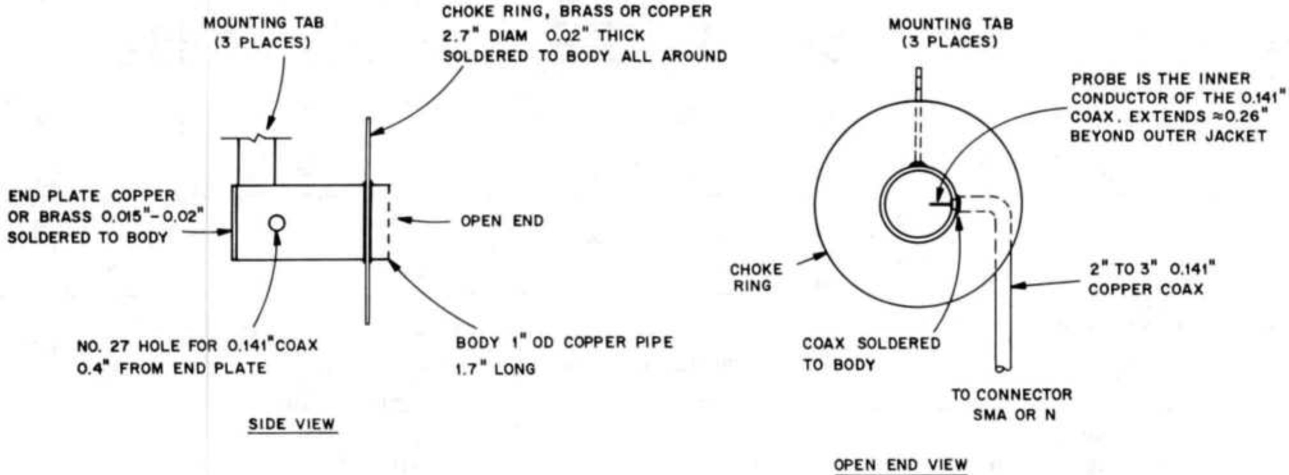
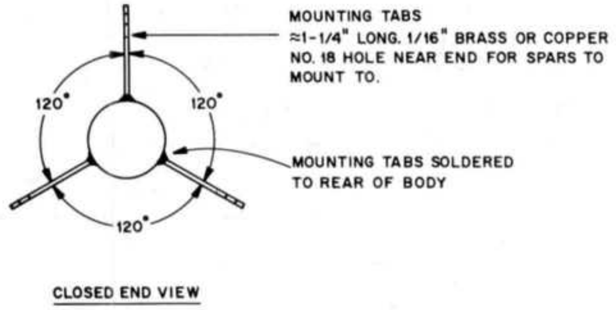


Fig 2—Side view of the 32-inch reflector, and details of the dish-to-mast mounting.

Fig 3 gives a description of the construction of the 10-GHz horn. In an attempt to minimize connectors, a short length of 0.141-inch copper coax is soldered in place with the inner conductor being used as a probe.

Fig 4 details the 5.7-GHz feed horn. This uses a standard 1 ½-inch copper pipe coupling available at most plumbing supply houses.





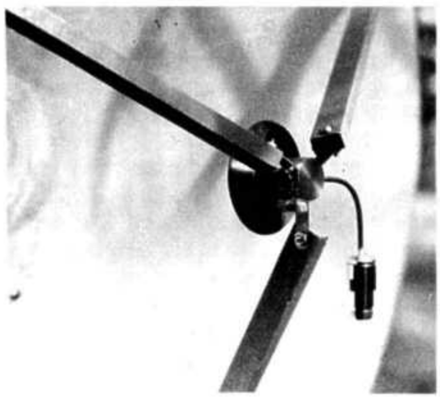
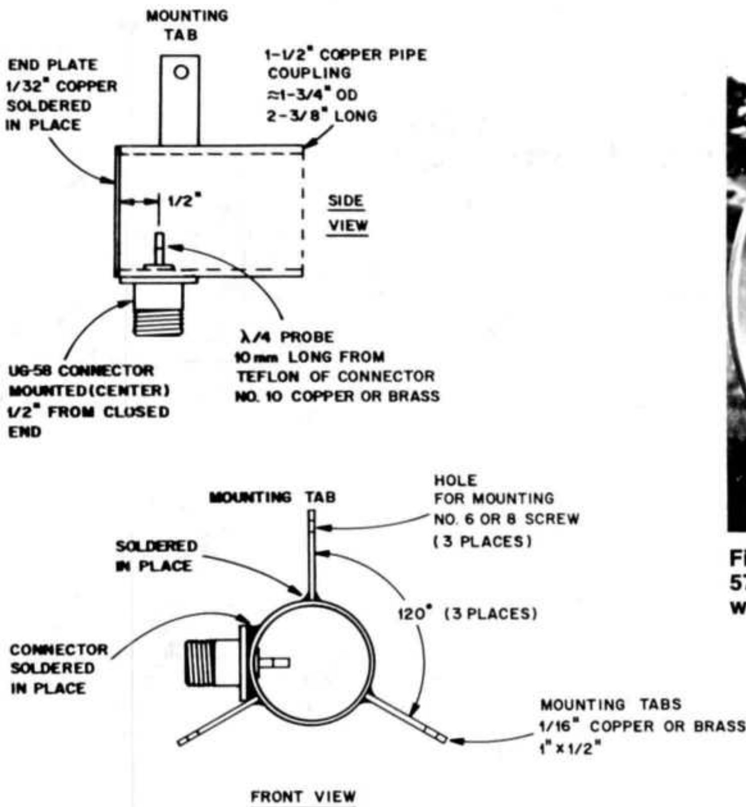


Fig 3—Construction details for the 10.3-GHz feed horn.



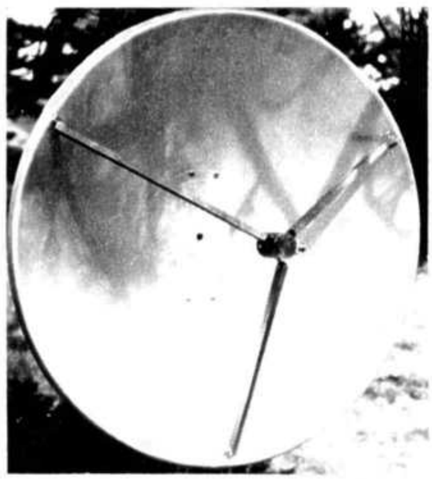


Fig 4—Constructon details for the 5760-MHz dish feed and the circular waveguide.

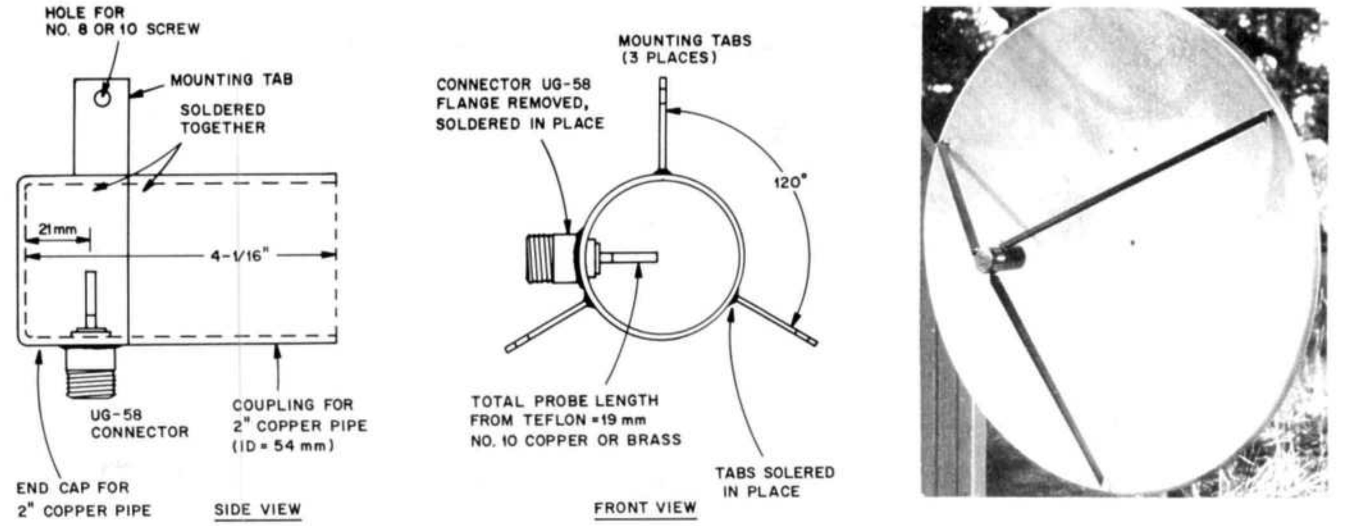


Fig 5—Construction details for the 3456-MHz dish feed and the circular waveguide.

Fig 5 shows the 3.4-GHz feed horn. Again, standard size copper plumbing pieces are used. On this unit I chose to remove the square mounting flange on the UG58 N connector. The other construction phases are similar to the 5.7-GHz unit.

Figs 3, 4, and 5 give adequate information for constructing the feed horns. These horns have all been used on a 32-inch dish on "grid expeditions," and all have performed well.

Notes

[1]Reflector antennas are available from The Antenna Center, 505 Oak St, Calumet, MI 49913, tel 906-337-5062.

[2]Norman Foote, "Second-Generation Cylindrical Feedhorns," *Ham Radio*, May 1982, p 31.

BOOK REVIEW

Log Periodic Antenna Design Handbook

Editor Carl E. Smith. Published by Smith Electronics, Inc, 8200 Snowville Rd, Cleveland, OH 44141. Second printing, 1979. Soft-bound volume 8½ × 11 inches, 478 pages, $29.50 plus $2.50 shipping and handling.

"Design your own log periodic antenna without referencing other work." Upon reading this ad, I was skeptical, but as a professional engineer interested in the design of antennas, I had to have a copy. When my book arrived, I found the claims about its completeness to be true. Original funding for the book in the 1960s was from the US Navy and the General Electric Co. Their intent was to produce the ultimate design manual on log periodic antennas.

The book is broken down into eight chapters that detail the basics of log-periodic design, design of *arrays* of log periodics, transmission lines and wide-band matching systems, and factors affecting vertical take-off angle. A ninth chapter lists the references, and five appendices are included.

To say the book is liberally illustrated is an understatement. I counted over 200 radiation patterns, excluding photographs, line drawings, and data tables. Radiation patterns are given for both theoretical and measured cases. Graphs show hard-to-locate information, such as front-to-back ratio over wide frequency ranges. I could not think of a question to which there wasn't information in this book. There is one major drawback, however. Because this book was published 15 years ago, information is lacking on the developments made since that time.

Although the book was written for professional engineers and advanced technicians, it has a lucid text that clearly explains all matters discussed from a relatively basic level. There is much technical data and many formulas, but hams with a solid technical interest in log periodics should be able to follow the text.

If your interest is antennas, or you are trying to design a five-band antenna to cover the "old" and WARC bands, this book is worthy of consideration. In these days of high book prices, the *Log Periodic Antenna Design Handbook* is a bargain.—*Domenic Mallozzi, N1DM, 26 Carey Ave, Apt 8, Watertown, MA 02172*

Bits

Feedback

The December 1987 issue of *QEX*, p 13, mentions that an improved satellite tracking program (Quiktrak 3.1) is available from Robert McGwier, N4HY. Bob's new address is IDA CRD Thanet Rd, Princeton, NJ 08540.—*Maureen Thompson, KA1DYZ*

Telecommunications Freedom—Technology on the Move

This is the theme of the 1988 IEEE Vehicular Technology Conference being held in Philadelphia, PA on June 15-17. Papers were sought late last year that include the following topics:

- Mobile data and communications systems
- Frequency planning and usage
- Automotive electronic systems and vehicle onboard computer systems
- Antennas and Propagation
- Base station equipment design

For information on the 1988 IEEE Vehicular Technology Conference, contact Jesse E. Russell, Technical Chairman, AT&T Bell Laboratories, Whippany Rd, Whippany, NJ 07981, tel 201-386-3000.

New Directions in Amateur HF Data Transmission Systems—Part 2†

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The benefits of using diversity reception have been known since the early days of radio. In spite of this, it has found little application in Amateur Radio communications. This month we will summarize diversity techniques briefly and focus on their application to packet-type digital data communications.[12] Then, we will discuss other signal-processing techniques that can be applied to HF data systems, and, finally, we return to the question of how to design a data-link protocol that is well-suited to the HF channel.

The Different Faces of Diversity Reception

Diversity reception can be defined as the processing of alternate versions of the same transmitted information in order to demodulate it more completely. The alternate versions may be generated at the transmit end by transmitting redundant information (in which case the technique bears more than a passing resemblance to error-correction coding!), or they may be generated solely at the receive end by sampling the received signal in two (or more) different ways. The first category includes frequency and time diversity, and the second includes space and polarization diversity. The key to success of the technique is that the different versions of the signal have encountered quite different perturbations during their travels through the ionosphere, or, in mathematical parlance, they must be highly uncorrelated.

A straightforward application of the diversity principle that is widely used in commercial HF links is *frequency diversity*. In this application, the same data is transmitted simultaneously on two or more frequencies. The most common implementation is *dual diversity*. Two subcarriers carry the same data; more than two produces a state of rapidly diminishing returns. The separation required between the subcarrier signals to yield little or no correlation varies considerably with channel conditions. It may be tens of kilohertz under extremely good, stable conditions, or as little as 100 Hz during unstable conditions. The minimum separation for uncorrelated signals depends upon the multipath spread, and it should be at least one-half its reciprocal. For example, when the spread is 1 ms, the separation should be at least 500 Hz. In most cases, the separation used is on the order of 1 kHz. These implementations are known as *in-band frequency diversity* because the data subcarriers are contained within the bandwidth of a single voice channel. Larger separations provide better performance, but the technical and regulatory problems become more formidable. Even relatively small separations can give worthwhile performance gains. One study of in-band frequency diversity yielded an average improvement in bit error rate of about one order of magnitude over single-channel operation.[13] Such an improvement could result in a dramatic increase in system throughput. In this case, the data rate was 75 bit/s and the subcarrier frequency separation was 1360 Hz.

Returning for a moment to the parallel 300-bit/s modem proposed in part 1, dual frequency diversity could be added by using three more FSK subcarriers.[14] The fourth subcarrier would carry the same data as the first, and so on. The simplest subcarrier frequency assignment would use the next three standard center frequencies, maintaining the 170-Hz spacing. This gives a separation of 510 Hz between subcarriers carrying the same data. This separation is considerably less than ideal; nevertheless, diversity gain would be available for much of the time, and in particular, when the multipath fading is severe.

Other schemes are possible. The two groups of subcarriers could be spaced farther apart to create a "hole" between them. This hole could then be occupied by other signals, but special IF filtering would be needed in the receiver to remove the unwanted signals between the channels. Without the special filtering, these signals could reach the AGC detector and desensitize the receiver.

The next major category of diversity operation is *time diversity*. Here again, the same data is repeatedly transmitted, but a time separation between the transmissions (typically at least one to two seconds) is chosen such that the perturbations undergone by the signal are largely uncorrelated from one transmission to the next. There are many practical problems involved in implementing such a scheme. In any case, it can be argued that a system employing an ARQ (*A*utomatic *R*epeat-reQuest) protocol already has time diversity built into it, and the interval between repetitions of a data block is almost guaranteed to have uncorrelated conditions. Furthermore, the ARQ system tends to adapt to channel conditions, since the rate of repeats is inversely related to the severity of the disturbances. When the channel is good, repeats are few, and thus it does not suffer the penalty imposed by the fixed amount of redundancy in a simple time diversity scheme.

The next form of diversity reception is *space diversity*. It has some intriguing possibilities that involve the simultaneous reception and subsequent demodulation of signals from two or more physically separated antennas. Once again, the aim is to derive uncorrelated versions of the signal. In this case, we want to demodulate signals that have followed slightly different paths through the ionosphere, and hence have undergone different perturbations. This technique has been widely used in commercial HF applications for many years. Amateurs, however, have largely ignored space diversity schemes, presumably because of the physical constraints imposed by their installations.

Space diversity does *not* involve adding redundant information to the transmitted signal. Only the receiving setup is different. The technique could be applied immediately to existing data transmission techniques, as well as future ones, without overcoming regulatory hurdles.

Now for the bad news. In addition to two antennas, you will need two receivers and two demodulators. (The use of dual diversity is assumed hereafter.) Other than having antennas with reasonably similar gain properties, the primary requirement is that they be spaced far enough apart to yield worthwhile diversity gain. Opinions vary on spacing requirements between the antennas, and actual measured data are scarce. Most references state that the spacing should be 9 or 10 λ; another source says the minimum useful spacing is 4 λ.[15] *The 1987 ARRL Handbook* gives a value of only 3/8 λ as providing useful gain.[16] A value of 3/8 λ is hard to believe, although Nagle claims that good results have been obtained with a spacing of around 1 λ. In addition to

[1]Notes appear on page 10.

†Figs 1-4 and notes 1-12 appear in Part 1, Dec 1987 *QEX*, p 3.

reducing the potential diversity gain, close spacing may cause problems with antenna matching (mutual coupling effects).

You cannot have too much spacing between antennas; try for the maximum that is practical. To get around the constraints of small city lots and the need to own two sets of receiving equipment, you could make arrangements with a neighboring ham to use his station as a remote receiving site. Bring the received audio back to your QTH using a telephone hook-up or low-power UHF link. The major stumbling block here is the need for some type of remote control of receiver tuning, but receivers with this capability are becoming increasingly common. Strictly speaking, the two receivers should also be matched in gain, which generally means tying their AGC lines together. This is not an absolute necessity, however, especially if an "intelligent" diversity combining scheme is used (more about this later).

The requirements for space diversity receiving systems are a bit daunting. There is another solution, however, capable of providing equally good results, and which simplifies antenna requirements. The technique is known as *polarization diversity*. The two spaced antennas that were used for space diversity are replaced with two antennas having little or no spacing, but with opposite polarization. For example, you may think of a horizontal dipole and a ground-plane vertical antenna. Many amateurs already possess two such antennas, but a horizontal and a vertical antenna is probably *not* the best way to go if a new installation is being considered.

To achieve optimum polarization diversity performance, the two antennas should be reasonably well matched in terms of their gain and directional properties. Each should deliver roughly the same signal and noise levels. Matching these characteristics is difficult because of the fundamental differences in antenna patterns, susceptibility to local noise pickup, and the different behavior of the horizontal and vertical ground reflection coefficients. The preferred arrangement is to have two identical antennas installed at right angles to each other, and at 45° angles to the ground. One such arrangement consists of a pair of sloping dipoles in an "X" configuration, with their feed points coinciding at the center of the "X" (fed by two separate feed lines). For more gain on the higher HF bands, this arrangement extends naturally into the "cross Yagi," with two sets of orthogonal elements on the same boom, similar to that used in the VHF/UHF bands for circular polarization. Another possible arrangement is to have a pair of dipoles or slopers extending down from a single support in a 90° "inverted vee" configuration. The field is ripe for experimentation!

The efficacy of polarization diversity was demonstrated some thirty years ago.[17] At that time, it was shown to be essentially equivalent in performance to space diversity in a series of tests performed in the 6- to 18-MHz range, with wide antenna spacing (at least 300 meters). This form of diversity even outperformed space diversity on some transatlantic links. Given these impressive results, it is surprising how little the technique is used today.

Combining the Diversity Signals

Once a pair of signals is received, they must be combined to produce a single output data stream. To begin with, each signal should be separately demodulated up to, but not including, the point at which a hard decision is made (which data symbol is transmitted). The corresponding signal, known as an *eye pattern*, is observed in modem testing. (A signal whose timebase is synchronized to the symbol timing of the received data signal appears on an oscilloscope in the shape of an eye.) The eye signals from the separate diversity paths can be combined by one of three basic techniques: linear, selection, or maximal-ratio combining.

Each combining technique has its own set of theoretical characteristics, but performance on HF channels does not always subscribe to the theories! *Linear combining* is the easiest to implement. The signals are added together (typically with an op-amp summing circuit) before being channeled to the comparator or other circuit that produces the binary output data. This scheme works surprisingly well, but it is not recommended for situations where a diversity channel may produce a high-noise output when the signal fades in that channel. This situation prevails in FSK demodulators that use hard limiters, or in separate-receiver systems in which the receivers have independent AGC circuits.

With *selection combining*, only one of the channels is connected to the output decision circuit at any given time. Signal strength is continuously monitored in each diversity path, and the receiving station rapidly switches to the strongest signal. In practice, some hysteresis is built into the selection circuit to prevent excessive "hunting" between the channels. Selection is clearly suboptimal—potentially useful contributions to the decision process from unused channel(s) are thrown away.

The third technique is *maximal-ratio combining*. In a sense it combines the best features of the first two. The signals are summed as in linear combining, but before summation the amplitudes of the signals are adjusted by multiplying them by a weighting factor that is proportional to the signal power in the corresponding channel. This approach makes the best possible use of all of the received signal information, but its theoretical advantages may not always materialize in real-world use, and the complexity of the circuitry is considerable compared to the other methods. The design of a maximal-ratio combiner, nevertheless, is straightforward. Through experience I've found that it generally outperforms the other methods by a small margin on the HF bands.

There has been a recent trend towards building more "intelligent" diversity combining systems. The circuits of most combiners that measure signal power (to provide the basis for selection or maximal-ratio combining) are usually "dumb." They cannot distinguish the desired signal from noise and interference because their function is to measure the total energy within a certain passband. This causes errors in selection or weighting to occur which can seriously degrade the performance of the diversity system. To overcome this problem, the circuitry that assesses the separate channels must be made sensitive to certain known attributes of the desired signal. For example, a 100-bit/s eye-pattern signal can be fed to a circuit that generates a fixed-length pulse for each zero-crossing of the signal. If the data signal is strong, the pulses will occur at 10 ms intervals, or integral multiples of 10 ms. The frequency spectrum of the pulse train will tend to have its energy concentrated around 100 Hz and its harmonics. If the signal is dominated by noise and interference, the pulses are more randomly distributed in time, and the spectrum does not exhibit the same concentration of energy. A circuit consisting of two narrow bandpass filters centered on 100 Hz, followed by rectifers, low-pass smoothing filters, and a comparator can be used to distinguish between the two conditions. The output of such a circuit makes a more reliable signal quality assessor than a simple energy detector. Gartell and Cawsey offer additional details on building intelligence into diversity systems.[18]

An example of an intelligent diversity combination scheme is outlined in Fig 5. This is akin to the maximal-ratio combiner; the eye-pattern signals from two diverse branches are weighted according to quality before being summed. If the system is asynchronous, as in Fig 5, the resulting signal is hard-limited. For synchronous applications such as packet radio, it is sampled by a clock derived from the data. Analog implementation of a circuit like this, because it involves multipliers and several filters, can get a bit messy. It is an ideal candidate, however, for digital-signal processor implementation.

Soft-Decision Decoding and Memory ARQ

Most demodulators form a "hard" decision by extracting an analog data signal and comparing it to a threshold, thereby converting it to either a "1" or a "0" (assuming binary signaling). In doing so, we throw away potentially useful information! Suppose we sample and

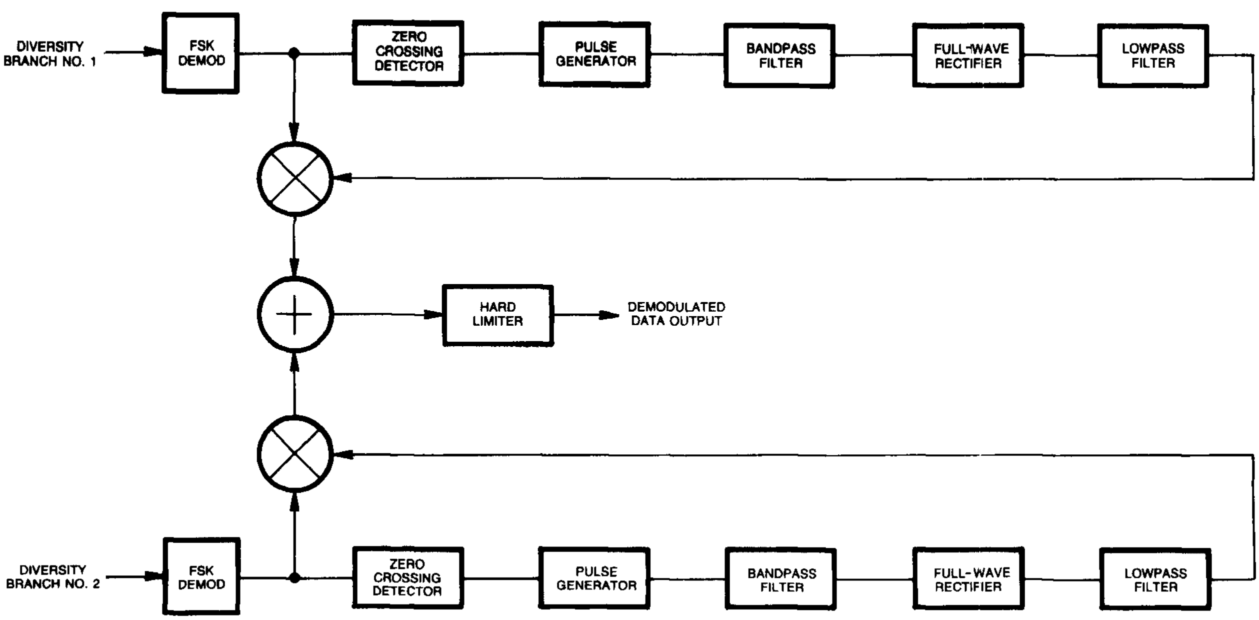

Fig 5—An intelligent diversity combiner design.

digitize the signal at each decision instant (the center of the eye) such that it is represented by a four-bit number. A very strong "1" near the maximum value would be represented as +8, a weak "1" just above the hard decision threshold would be +1, a weak "0" would be −1, and so on down to −8 for a strong "0." This scale gives us an idea of the quality of each received bit, in terms of its distance from the threshold.

Now suppose we have an ARQ system such as AX.25. A packet arrives, and we perform a cyclical-redundancy check (CRC) to find that it contains errors. The packet is discarded, and a new packet is retransmitted. Again our CRC detects errors. We discard the second packet, and are no further ahead in retrieving useful data. Had the bits in the first packet been digitized as outlined, and stored in memory, we could try the following strategy: Digitize the bits in the second packet, and then create a hard decision version in order to perform the CRC. When the test indicates errors are present, retrieve the stored soft-decision values from the first transmission and add them to the corresponding values from the second transmission. Next, a hard-decision version is created from the combined values. Our last step is to perform the CRC again. There is a reasonably good chance that the soft-decision processing has corrected the errors, in spite of the fact that neither transmission was error-free. If errors still prevail, the combined soft-decision values can be retained in memory, to be merged with the values from the next retransmission.

How does it work? Suppose the first transmission contains one bit error; a transmitted "1" is clobbered by a noise pulse to become a "0," as seen at the demodulator output. On a good channel, the soft-decision value for that bit would have been +8; instead it has become a negative value. The amplitude probability distribution of the signal plus noise, however, is such that the negative value is more likely to be small (near the threshold) than it is to be near the −8 value that corresponds to a transmitted "0" on a good channel. For the sake of argument, let's say that the value is −3. Now the second transmission arrives. Unless the error rate is extremely high, it is unlikely that the same bit is in error again. Let's suppose that our packet arrived in reasonably good shape, with a soft-decision value of +5. We add up the values, bit by bit, and for this particular bit we have a sum of +2. The +2 is correctly decoded as a "1." If other errors are present in the second packet, we hope that they are correctly decoded when added to the corresponding values from the first transmission. If not, the process is continued. Instead of throwing away information, we are time-averaging the soft-decision values of each bit. Since the error patterns are uncorrelated from one packet transmission to the next, the correct hard-decision values of all of the bits eventually emerge, and this condition is detected by the CRC.

There are a couple of problems with the technique outlined. There is a danger of accepting "pseudo-packets." These packets are mainly, or entirely, generated by random noise. Using these in the averaging process hinders, rather than helps, the demodulation process. The solution is to place an acceptability criterion on a received "packet": A certain percentage of the bits in the packet must have soft-decision values over a given threshold, or else the packet is discarded. A more serious problem is that in most protocols, we do not have prior knowledge of which packet in a sequence will be received next. We have no basis for identifying and merging multiple copies of the same packet. A new protocol design could accommodate this requirement by including, at the beginning of each transmission, a separate packet that gives the sequence numbers of the information packets that follow. As long as this initial packet comes through intact, the remaining packets can be identified and used for soft-decision processing. If the initial packet is lost, then only the error-free packets that follow can be used.

The technique just described belongs to a class of systems known as *memory ARQ*. Information on received packets containing errors is gathered in the receiver's memory until they can be successfully decoded. Further analysis of memory ARQ systems can be found in Benelli's work.[19]

There are other ways to make use of soft-decision schemes. One possibility is to use the information to correct bit errors in individual packets when the number of errors is small (one or two). The algorithm might proceed as follows: A packet is received, and a CRC on the hard-decision version indicates errors. A look at the soft-decision values indicates all but a few are large (ie, probable good bits). If many errors exist, discard the packet; otherwise, proceed by finding the bit with the smallest soft-decision value (if two values are the same, choose one at random). Toggle the hard-decision value to change this bit to the opposite state, and retry the CRC with only this bit altered. If no errors are indicated, accept this as the correct packet. If errors remain, locate another candidate bit and repeat the procedure (with the first bit restored to its original hard-decision value). If the CRC again indicates errors, try the remaining combination with both bits toggled. Discard the packet if the CRC continues to indicate errors. The procedure can be carried further, but it becomes time-consuming, and there is a danger of significantly increasing the undetected block error rate if the technique is overused.

Soft-decision techniques can also be used to enhance the performance of frequency diversity systems. Take, for example, the six-channel dual-diversity 300-bit/s FSK system we mentioned earlier. This modem transmits six data bits every 10 ms. Three of the bits are information bits, and the other three are redundant copies of the information bits. This can be thought of as a six-bit code word, with three information bits and three parity bits. Because the parity bits are the same as the information bits, this is known as a *repeat code*. Since a particular parity bit only provides a check on a single information bit, repeat codes are not very powerful. Better codes, having the same degree of redundancy, but more capability to correct errors, are available. A simple look-up table can generate the six-bit code word, and the diversity combiner can be replaced by a *maximum-likelihood decoder*. This decoder uses soft-decision techniques to compare incoming code words with the eight possible valid transmitted code words, and selects the best match. The potential coding gain increases with the number of parallel channels. I have published some information on the technique, and can supply further details.[20]

Hybrid ARQ

Although error-correction coding has its drawbacks, there is a method by which it can be neatly integrated into an ARQ system without incurring the penalty of high redundancy usually associated with its use. The technique is known as *hybrid ARQ*.[21] It works like this: The first transmission of a packet takes place as usual. Let's say it is received with errors and is therefore not acknowledged. The transmit end would then normally retransmit an identical packet. As already explained, sending the same information twice is regarded as repeat coding. As codes go, it is a feeble one because it has no inherent error correction capability (assuming hard decisions) in spite of the very high (50%) redundancy. More powerful codes are available that have the same redundancy, so why not use them? If a retransmission is called for, why not encode the information in the packet with one of the other codes? This time let's send only the parity bits. The receiver combines this packet with the one stored from the previous transmission to form the complete code word. Unlike the first case of a simple data repeat, there is now a good chance of correcting the errors and recovering the transmitted information, even if errors occurred during both transmissions.

This sounds great, but some thought about the technique reveals a potential flaw. Suppose the first transmission is loaded with errors, whereas the retransmission comes through error-free. By combining the two, we have an incorrect code word, one that is beyond the error-correction capability of the code. The result is no throughput, although the standard ARQ system would deliver the data by virtue of the error-free retransmission of the information. Fortunately, a class of codes known as *invertible codes* is able to rescue us from this situation. With an invertible code, the information bits can be uniquely determined from knowledge of the parity bits alone. Therefore, if the packet containing the parity bits is error-free, we can disregard the previous transmission and simply obtain the information bits by an "inversion" process. If continued retransmissions are necessary, the hybrid ARQ system normally alternates between the information bits and the parity bits. The retransmissions are successfully terminated upon reception of any single error-free packet, or by successful decoding of two successive packets containing errors. The result is higher throughput than in the pure ARQ system.

Although the hybrid ARQ technique allows the use of error-correction coding with no increase in redundancy, it does not eliminate the need for a lot of number-crunching! The decoding algorithms for these codes are much more involved than the CRC calculation that is generally used for error detection. The practicality of the technique is dependent on whether software can be written to perform the algorithm sufficiently quickly, while at the same time carrying out the other data link protocol functions. Dedicated chips for error correction are surfacing on the market, but the codes implemented may not be suitable for HF applications.

HF Protocol Design Revisited

We've completed our evaluation of some of the techniques available for improving modems and receiving systems. Now, we must revisit the issue of protocol design. At this point, it is worth restating some of the most desirable attributes of a protocol for HF data transmission:

1) *Low overhead*. Every effort should be made to minimize the overhead in order to maximize the throughput. Overhead includes any non-information bits that must be transmitted, such as those used for synchronization, control, error detection, and so on. It also includes the time needed to turn around the link for acknowledgements (length of acknowledgement packets, transmitter turn-on time, and receiver AGC recovery time).

2) *Very low undetected error rate*. Undetected errors should be so rare as to be insignificant.

3) *Selective acknowledge capability*. For best efficiency, a selective-repeat retransmission protocol should be used, and it should allow the receiver to immediately acknowledge (and buffer for delivery, if necessary) any correctly decoded packet, even if it arrives out of sequence.

4) *Allowance for advanced signal processing*. The protocol should be designed so as to allow the use of hybrid and memory ARQ techniques for enhanced performance.

As we have discussed in part 1, the overhead in AX.25 is substantial, primarily because of the lengthy address fields in each frame that carry the call sign information. There is also some overhead caused by "bit stuffing," bits added to the data in order to avoid false flag sequences. This overhead can be minimized by using a long packet length, but these have a lower probability of getting through the channel without errors (no net improvement in throughput). The overhead caused by link turnaround time can be minimized by using maximum-length transmissions (7 frames). Unfortunately, the lack of a selective-repeat capability in the protocol tends to cancel the potential gain in throughput (see the next section). In other words, the overhead in AX.25 could be better.

Low undetected error rate is one of the strong points of AX.25. A more serious limitation of AX.25 is that it has no selective acknowledge (or reject) capability whatsoever. AX.25 uses the ARQ technique known as *Go-Back-N*. This means that the receiving station can only acknowledge a packet if all preceding packets have been received correctly. It does not acknowledge particular packets; it can only assert that *all* packets up to a given sequence number have been received. A packet received out of sequence is discarded, and the sender must continue to needlessly retransmit that packet until it, and all previous packets, have been acknowledged. This is a relatively simple strategy to implement, and it works well on most channels. Any protocol, however, that wastes a significant amount of the limited capacity of the HF channels obviously leaves something to be desired.

Like most data-link protocols in use today, AX.25 is bit-oriented. The data field in a transmitted frame is a variable-length sequence of bits whose beginning and end are delimited by the flag pattern 01111110. Additional 0 bits are inserted into the data in order to avoid the appearance of this pattern in the data field. The great attraction of bit-oriented protocols lies in their flexibility; virtually any type of data can be handled with ease, without the need for conversion to a fixed character length and block length. For this flexibility, however, the tradeoff is in terms of performance on high error-rate channels. A single bit error in the flag sequence causes loss of the associated frame, even if the data itself is error-free. In many cases, the flag is associated with two frames (ie, it denotes the end of one frame and the beginning of another). In this case, both frames are lost. Similarly, a single bit error within a frame can cause the appearance of a false flag sequence, again resulting in a lost frame. In the latter case, it can be argued that the frame would be lost anyway; however, not knowing with any confidence when the frame really ended prevents us from making use of memory ARQ and soft-decision techniques to recover useful information from the corrupted frame. What it boils down to is this: In exchange for the convenience that data transparency and variable-length fields provide, we have limited our ability to apply various coding and signal processing techniques designed to get the most out of the HF channels. This seems like a high price to pay to avoid doing some simple buffering and data format conversion, especially when the vast majority of the data transmitted is 8-bit ASCII or binary code.

Now consider a hypothetical protocol that uses a selective-repeat ARQ strategy. Suppose that each transmission consists of eight frames, and each frame has a fixed length containing perhaps 40 bytes of information and five or six bytes of overhead. At 300 bit/s, the length of the transmission is about 10 seconds, and typical turnaround times would have a very small effect on throughput. The receiving station would reply with a selective acknowledge of the eight frames, possibly piggybacked with other data flowing in the reverse direction. The acknowledge could be an eight-bit field, each bit being set to 0 or 1, depending on whether or not the corresponding frame was received correctly. Out-of-sequence frames would be buffered at the receive end for later delivery to the connected device (memory is cheap!). For example, suppose frames with sequence numbers 1 through 8 are transmitted, and the receiver successfully decodes only 2, 3, and 6. It then sends 01100100 in the acknowledge field. Upon receiving this, the transmit end sends frames 1, 4, 5, 7, 8, 9, 10, and 11. The five missed frames are repeated, and are joined by three new ones. Of course, sequence numbering cannot be infinite. If we number up to 64, for instance, then when we begin again at 1, we must ensure that there are no outstanding frames bearing the sequence numbers that we are about to reuse.

Note that with this simple scheme, bit-stuffing is not needed. We know in advance exactly where each frame begins and ends (once we have recovered the initial frame sync flag), and false flags are not a problem. Strictly speaking, flags are not required to delimit the individual frames; however, retaining them would make the protocol a bit more robust. If the initial frame sync were missed or a clock slip occurred, these additional flags would allow resynchronization to take place so that some of the frames in the transmission could still be recovered.

In addition to the two overhead bytes carrying the CRC parity bits, and the overhead bits that contain the sequence number and frame-type information, it would be useful to devote a small amount of overhead to identifying the originating station. Although the protocol is intended for a single point-to-point link on a clear channel, rather than a multiple-access shared channel, some protection is needed against reception and acknowledgement of packets from interfering stations. A one- or two-byte field containing an identification number selected at random at the beginning of the session may provide adequate protection. A full callsign field in each frame is wasteful; relegate it to the header frame described next, or insert it periodically by a suitable means as required by regulations.

If we wish to make use of memory ARQ techniques and soft-decision decoding, there is still one ingredient missing from our protocol. If a frame is received with errors (according to the CRC), we cannot determine its sequence number with confidence, since there may well be errors in the sequence number field. Lacking this vital information, there is no reason to save a soft-decision version of the corrupted frame for processing. The solution is to include a separate short frame at the beginning of each transmission that contains information frames. This "header" frame would contain the sequence numbers of the frames which follow. If we decode the header frame successfully, then we can save all the corrupted frames for processing. If not, we must discard them and use only the error-free frames from that particular transmission.

Perhaps the most serious objection to the protocol just outlined is that it uses a fixed block length, which is not optimum for most channel conditions. It is my opinion that a fixed, compromise block length can be extremely effective when used with an efficient protocol and some of the other signal processing "tricks" described earlier. At least one commercial HF data communications system successfully uses a protocol with fixed block length similar to that described here. Nevertheless, for those who just cannot bear to "keep it simple," one can envision an extension involving three or four different block lengths and a simple adaptive algorithm that selects the best block length based on retransmission rates. The header frame could be used to carry the length information in this case.

The foregoing is by no means a detailed protocol design. It simply suggests some starting points. Additional details are available on the design of selective-repeat ARQ protocols and their performance relative to Go-Back-N and other strategies.[22,23,24]

Conclusion

The performance of amateur HF data systems can and should be improved. Considerable improvement in the performance of the present AX.25 system is possible through the design of better modems and the use of diversity reception techniques. Much better performance is possible, however, through the use of a protocol designed specifically for HF use. I believe that a well-designed selective-repeat ARQ protocol is easier to implement and more effective than one which depends heavily on error-correction coding. An outline of such a protocol has been sketched, in the hopes of stimulating further discussion and experimentation in this direction.

Notes

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Computer-Aided Design of RF Circuits—An Introduction

This month's column could also be called "How the big boys do it." RF circuit design used to be easy, though it seemed to be hard. The problem for the RF designer was to match one impedance to another at a specified frequency or over a specified frequency range. Inductors and capacitors (or the distributed form of both—the transmission line) can be described using relatively simple mathematics. The designer just had to obtain an impedance match using the proper mathematical formulas. The Smith Chart is a graphical method of doing the same thing, and an experienced designer could crank out a matching network in a flash by walking his way around the chart.

The easiest design was making something to match fixed impedances—for example, filters with specific band-pass and rejection characteristics. Even matching to active devices—with input and output impedances that vary over a wide range—was fairly simple in a design for a single frequency. The designer matched 50 ohms (for example) to the input impedance of the device and matched the output impedance back to 50 ohms. Then he built the circuit (assuming the design didn't contain 300-farad capacitors or the like) and tweak it up a little on the bench.

Things weren't so clear-cut when the design had to work over a wide range of frequencies. The normal method for developing a broadband circuit (say 137 to 175 MHz) was to create a design with very low Q at the high end of the band, build it, put it in a swept test setup on the bench and *tweak like crazy.* Designing a broadband circuit on a Smith Chart involves designing the circuit at one frequency and then taking the same component values, seeing what they do at another frequency within the band, and adjusting component values for a match at that frequency. Continuous reiteration of this process might lead to an acceptable circuit design—assuming the band was not too wide and the transistor parameters did not vary too much with respect to frequency. Otherwise forget it. . . you'd need a *computer* to do something like that!

Computers in the RF Lab

In the old days (10 or 15 years ago), engineering schools were turning out computer guys. RF engineers were rare, and they *hated* computers (no black magic there—supposedly). Slowly, the pocket calculator started to creep into the lab—harmless enough, it seemed. Little did we know what these things were going to evolve into!

I guess there were a couple RF engineers out there who had been keeping up with their bits and bytes, though. Around the beginning of this decade, we started to see some *serious* design software. Among the first computer-aided design (CAD) programs for designing RF and microwave circuits, Compact, and the later version Super Compact, synthesized, analyzed and optimized circuits—containing scores of variables—over octave and greater bandwidths. Communications Consulting Corp came out with CADEC around the same time. Oh no. . . now we've gotta have one of these things!

Eventually, powerful CAD packages were developed for popular microcomputers. Some of you are probably familiar with Touchstone™ from EEsof® that runs on an IBM® PC or compatible. And, there are more copycats than you can shake a slide rule at. What does all this stuff do—and why are all the microwave and RF design engineers so excited about it?

The Software

Basically, CAD software does three basic things: synthesis, analysis and optimization. Let's take a brief look at each.

Synthesis. Here, the designer enters the desired circuit performance parameters. For a band-pass filter, these parameters might include frequency response, in-band ripple and termination impedances. The computer grinds away and spits out component values for one or more circuits that will perform as specified.

Analysis. Here, the designer enters into the computer a specific circuit (maybe the filter designed in the previous example, but built with readily available component values), and the computer analyzes the performance of the circuit over a specified frequency range. Usually, results are displayed in tabular form or in graphical form—either linearly (for example, gain versus frequency) or on a Smith Chart.

It is important to remember here that these synthesis and analysis routines are only as good as the mathematical model that represents the circuit elements. These days, on the high-class (read: *expensive*) programs, the models are extremely good and the computed circuits work very much like the real world—even at frequencies in the tens of gigahertz. Components available to the designer include inductors, capacitors, transmission lines of all types (including microstrip), transformers, coupled coils, resistors and active devices including bipolar and field-effect transistors. All these elements have been modeled mathematically so that the computer can accurately combine the components and predict the overall system performance. The big programs can handle up to a hundred separate elements at one time, as well as keep on file the performance characteristics of your favorite transistors. Let's see, we'll try an MGF-1402 this morning. Why worry about static electricity blowing up the device while you're futzing around with the circuit when you can do your futzing on the computer!

Optimization. The most exciting part of the new RF design software is the optimization mode. Here, the designer specifies a circuit and the desired performance. For example the circuit might be a broadband GaAsFET amplifier operating from 1200 to 2400 MHz. Desired performance might be better than 20-dB input return loss, flat gain over the band and unconditional stability with varying input and output terminations.

The designer plugs in a "first shot" circuit design (probably based on past experience or a quick mid-band Smith Chart design). The computer analyzes the circuit, compares the calculated response to the desired response, and sets up an initial "error function" (a measure of how close the initial design comes to the desired performance). A small error function means we're close, and a large one means we're not.

Now hit the "optimize" key, and the computer varies circuit-element values and looks for a lower error function. There are a number of ways the computer does this—random searching and gradient searching are a few of the terms used—but basically the machine perturbs a component value one way and then the other and analyzes to see if the error function decreased. If so, the computer heads in the "good" direction. This continues until either the error function reaches zero or the computer blows up. You can see how complex this procedure can be if the optimization includes 20 or so variables and 20 or so frequency points! Well, I guess that's why we invented the computer in the first place!

Summary

If you ever looked in one of the microwave trade magazines and saw the types of packaged circuits that are available today, you'd realize what this CAD stuff has done for us. It's not uncommon to find multi-octave amplifiers with flat gain across the band. For example, Mini-Circuits advertises a 1-W amplifier with 30-dB gain from 0.7 to 4.2 GHz—with unconditional stability. This baby was *not* designed on a Smith Chart! Packaged software is available to do oscillator design, PLL design, filter design and analysis, antenna evaluation, crystal-filter design, mixer analysis, noise-figure and intercept-point optimization, and MMIC design and optimization. Some of the software actually draws the microstrip artwork (and, I suspect, will even etch the board for the designer if it doesn't already!).

Of course, it's important to remember that a computer-designed circuit is only as good as the model, and even the best model can break down at some point. It helps to know a little about RF circuit design, even when the computer is doing all the work. Otherwise, the designer might end up with ridiculous circuits (say 40-wavelength-long, 0.5-ohm microstrip lines) and not know why the thing can't be built until it's too late. The old maxim "garbage in, garbage out" still holds true!

At any rate, there is a ton of software out there now—including some very inexpensive design and optimization software. Keep your eye on the ads because the stuff is getting cheaper all the time. If you don't need all the frills, you can design circuits on your very own PC with relatively "simple" software. I guess it was inevitable that computers and RF got back together. CAD is one way, and there are others (packet radio, or how about gigahertz logic?). I guess as long as we have these infernal things sitting on the desk to type letters with, we might as well use them for circuit designing. . . See you next month.

Bits

Over-The-Horizon-Radar

The first book describing Soviet design techniques for expanding radar operating ranges over the horizon has been translated into English by William F. Barton. Edited by A. A. Kolosov, *Over-The-Horizon-Radar* focuses on the derivation of the radar equation for HF radar, the differences in propagation conditions encountered by shortwave, HF signals, and by the VHF signals of conventional radar systems. Learn how operating frequency is optimized to minimize propagation loss, or to identify useful signals from the clutter that results when radar illuminates large areas of the earth's surface. Over 300 equations and 118 diagrams clarify the text's range-enhancing procedures. An in-depth theoretical coverage of US OTH radar systems is also included. This 332 page hard-cover book sells for $60. The book order no. is 233233 (ISBN: 0-89006-233-1). For further information contact Artech House, 685 Canton St, Norwood, MA 02062.—*KA1DYZ*

Call for Papers: *The ARRL Antenna Compendium, Volume 2*

Antennas are my favorite subject. They are also one of the more popular topics in on-the-air conversations, as well as in Amateur Radio literature. Just tune across any active amateur band and copy or listen to the exchanges; you'll probably find antennas being discussed on more than one frequency. Further evidence of this fascination is exhibited by the continuing popularity of *The ARRL Antenna Compendium, Volume 1.* More than 6000 copies have been sold since its appearance in June 1985.

Volume 1 of the *Compendium* contains 31 papers, none of which had previously been published. The topics range literally from A (antennas) to Z (impedance matching). Several papers present ideas and information that even today are not covered in other amateur literature—information that is very pertinent if you want to know about or like to experiment with antennas.

For example, in my opinion (as one of the editors of the book), the paper by Roy Lewallen, W7EL, "Baluns: What They Do and How They Do It," is a classic—"must read" material for antenna experimenters. Another is "Optimum Design of Short Coil Loaded High-Frequency Mobile Antennas," by the late Bruce F. Brown, W6TWW. I could go on, but then this write-up would end up looking like the table of contents for the book. (By the way, you *do* own a copy of *Volume 1,* don't you?)

So much for *Volume 1.* Plans are already being laid for a new publication, *The ARRL Antenna Compendium, Volume 2.* The book will be typeset rather than computer printed, as was done experimentally for *Volume 1.* Drawings will be prepared for publication by our drafting department instead of directly duplicating author-submitted drawings. Yes, based on the success of *Volume 1,* we're planning to make *The ARRL Antenna Compendium, Volume 2* a first-class publication—one that will shine among other antenna publications, and one that its contributing authors will be proud to show off. And, of course, one that will be bursting with really good information about antennas and related subjects. As with *Volume 1,* it will contain all new material, no reprints of old stuff. Editing work on the book has already begun. Our plan tentatively calls for appearance of the book in late 1988 or early 1989.

Right now is the time for you to think about submitting material for *Volume 2* of the *Compendium,* so you can become a part of these exciting plans. Is there a subject near and dear to your heart related to antennas, transmission lines or propagation effects, one about which you'd like to write a paper? Suggested topics are quads, loop antennas, Yagis, LPDAs, vertical arrays, radial or counterpoise systems, transmission lines, measurements techniques, and results of unusual propagation conditions (especially at VHF/UHF), such as gray-line or solar eclipse effects. We're epecially interested in material related to experience and in construction projects, although tutorial articles will be considered. If your material is accepted for inclusion in *Volume 2,* on publication you'll be paid the standard authors fee set by the ARRL Board of Directors (presently $50 per published page).

Give this idea some serious thought; there is no need for a hasty decision. Maybe you *should* be one of the contributing editors for *Volume 2.* An author's kit is available from HQ to help you prepare your material. Submit your paper to *Antenna Compendium,* Technical Department, ARRL Headquarters, 225 Main St, Newington, CT 06111. Please advise us ahead of time if you plan to submit a paper after June 1, 1988. Thanks!—*Jerry Hall, K1TD, Assoc Technical Editor*

13 Centimeters

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Constructing a 13-cm Station, Part 1

In my last 13 Centimeters column, I discussed commercially available equipment for the 13-cm band. This month begins a series of construction articles describing a state-of-the-art, solid-state 13-cm transverter. Like the commercial equipment described in November 1987 *QEX*, the approach is a modular one. Revisions to the design can be made easily, and parts of the design can be used without building the whole thing (for example, just the receiving portion for OSCAR Mode-S reception). Throughout the project I will try to keep abreast of the state of the art as much as possible without incurring unusual expense. I hope to be able to mention sources for all parts used.

Transverter Block Diagram

The 13-cm transverter consists of a number of separate modules. A basic block diagram is shown in Fig 1. The finished product will be stable, compact, use an IF of 144 or 145 MHz, put out around 2 W, and have a receiver noise figure in the 1-dB range. It would be nice if the rig could be tuned without a great deal of expensive test equipment (read: without a spectrum analyzer), though some sort of low-level power-measuring equipment is needed. Some of the important design considerations are described in the following sections.

The Modules

Local Oscillator

This is probably the most difficult part of the project. The LO frequency is 2160 MHz, and the source must be clean (all spurious and harmonic energy at least 40 dB down from the carrier). Ideally, it should be relatively easy to get on frequency, have two 5-mW outputs for driving transmit and receive mixers, and be simple and straightforward. (Maybe we should quit right here—no let's go on. . .)

Receiving Mixer

The receiving mixer module will contain low-noise amplification before and after the mixer, and it should be well filtered. Our goal is overall conversion gain of about 30 dB and a noise figure in the 3-4 dB range.

Transmitting Mixer

The transmitting mixer needs a pad so that it can be driven with a couple of watts from the 144-MHz IF rig. Output must be well filtered and in the 10-mW range.

Intermediate and Final Linear Amplifiers

The transmit signal is amplified to around 500 mW in the intermediate amplifier. The final amplifier will put out as much as we can get without breaking the bank—probably a couple watts of *clean* linear power. Once again, we want to use good filtering so that all spurious and harmonic energy will be at least 40 dB down from the carrier.

Low-Noise Preamp

The preamp is based on a garden variety GaAsFET. The design goal is a 1-dB noise figure. Gain should be 10 dB or more to mask the noise figure of the succeeding stages. Stability is important, so we will make this design stable when its input is terminated in impedances other than 50 ohms.

Summary

This transverter project will probably take close to a year to complete. The first modules we'll build are the local oscillator and receiving mixer, and then the

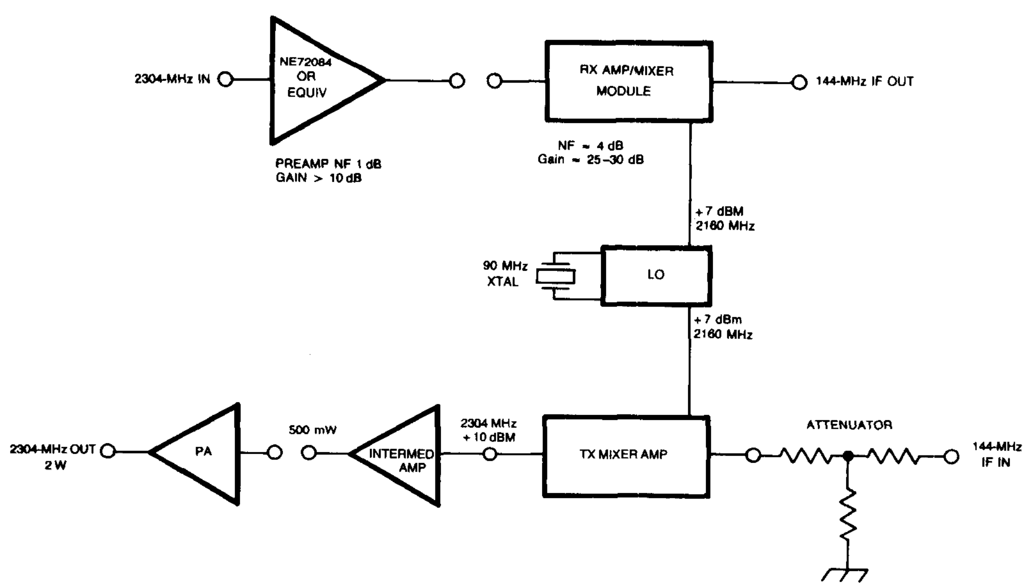

Fig 1—Block diagram of the 13-cm transverter.

preamp, so that you'll have something to listen to OSCAR Mode S with—if Phase III-C goes up on schedule. After that, we'll tackle the transmitter portions. None of the circuits are cast in concrete yet, so if you have a favorite (proven) design for any of the modules, dump it in! Next column, we'll build the local oscillator.

News From Out There

Speaking of OSCAR Mode S, I received a letter from Jerry, KAØOOQ, regarding the Mode-S receiving system mentioned in November's column. The block diagram is shown in Fig 2. Jerry says he did not touch a single tuning slug or capacitor on any of the modules to move the system to 2401 MHz. He changed the LO crystal to 93.958 MHz, and that was that. Enough clean energy came out of the transmit port of the SLO13 local oscillator module to drive the SLM13 mixer, and the mixer is apparently broad enough to cover 2401 MHz without tweaking. The noise figure of this system, measured at the Central States VHF/UHF Conference last July, is 1.09 dB with an overall gain of 41 dB. It's hard to believe that tweaking could improve things any.

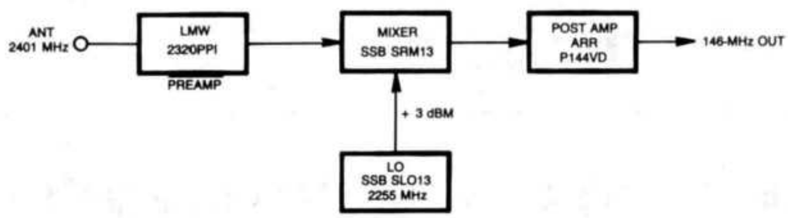

Fig 2—Jerry, KAØOOQ, uses this system for OSCAR Mode-S reception. All of the commercially available modules work fine at 2401 MHz without retuning. The low-noise preamp, which works best mounted at the antenna, gets its dc power through the RF feed line.

Station Reports

The results of the August ARRL UHF Contest show 25 out of 132 stations submitting logs on 13 cm. I guess there are stations on the band, but you wouldn't know it from the number of reports I've been receiving here! This is your column too—drop me a line with a brief rundown of what you've been doing on the band. The only way we are going to get more stations on 13 cm (and presumably more grids and states to work) is to let the world know there's someone to talk to up there!

Mark, AA2Z, reports that he and John, W1XX, did a little grid expedition to Mt Equinox, Vermont (FN33) with 902- and 2304-MHz equipment. With 1.5 watts from an LMW transverter and a single Down East 45-element loop Yagi on 2304 MHz, their best DX was Rick, WB2NPE in FM29—about 250 miles away. Also worked was Ron, WA3AXV (FN20) at about 230 miles. They also gave Ken, W1RIL, his 10th grid to complete 13-cm VUCC.

Bill, WØRSJ, in Easton, Pennsylvania (FN20) reports that he found the problem with his 13-cm system (water in a connector!) and is now back on the air and looking for skeds. So far he's worked WB2NPE, WA3AXV, and WA3JUF with good signals; best DX is 70 miles. Bill is running an LMW transverter and Frontier Microwave Amp (10 W) into four 45-element loop Yagis at 70 feet. Anyone else?

Bits

Why is this Man Smiling?

He is retired and can play Amateur Radio 24 hours a day, unless his wife says otherwise! Lin Cook, W1JRS, poses for this picture in his workshop. Cookie, as he is best known to his friends, worked as a technician for 22 years at WGAN-TV in Maine. He enjoys modifying *QST* construction articles, building station-control devices, portable rigs and mobile antennas (2 meters and VHF) for his travel trailer. *(Photo courtesy of Tom Frenaye, K1KI, and Bill Sheriff, N1ALC)—Maureen Thompson, KA1DYZ*

New Components Marketed by CEL

California Eastern Laboratories recently announced new components of interest to experimenters. High-frequency prescalers, the NEC UPG503B (divide-by-4) and UPG504B (divide-by-2), are capable of operating up to 9 GHz. These dividers use Buffered FET Logic technology, and are available in a hermetically sealed 8-pin ceramic flat package. Performance features include an ultra wideband operation and high input sensitivity. Design features include performance over wide temperature ranges, a dc blocking capacitor at the input, and super-low phase noise characteristics.

The NE345L-10B and NE345L-20B are new L/S band GaAsFETs that are ideal replacements for traveling-wave tubes (TWT) in existing systems. These components deliver MTBFs that are orders of magnitude better than TWTs, allow zero warm-up time, and eliminate heavy power supplies.

The UPG100 and UPG101 are two new GaAs MMIC wide-band amplifiers for 0.05- to 3-GHz applications. They are designed to operate over a wide frequency band so that one device can be used for several different front-end amplifier applications within the frequency range. Input/output power is matched to 50 Ω, low noise in the UPG100 is 2.7 dB typical, at a frequency of 50 MHz to 3 GHz. Medium power in the UPG101 is 18 dBm (typical) up to 3 GHz. The UPG100P and UPG101P cost $34.50 and $41, respectively, in quantities of 100 pieces.

Five new ultra high-speed digital signal processing ICs include the UPG703B 4-stage ripple counter, the UPG704B-15, -20, -25 4:1 multiplexers, the UPG 705B-15, -20, -25 1:4 demultiplexers, the UPG706B-1, -2 decision circuits, and the UPG707B laser driver. Each offers clock rates up to 4 GHz, 50-Ω system operation, typical switching times of 400 ps, and low power dissipation.

The UPG102 is the first in a series of new GaAs MMIC super wideband amplifiers from NEC. The device operates at an ultra wide frequency range of 1 to 20 GHz, with a gain of 7 dB. It is cascadable, has input/output matched to 50 Ω, and is available in chip form and two package styles.

The ND3140 and ND3139 are GaAs Varactor diodes. They feature low conversion loss, high cutoff frequency, low thermal resistance, low junction capacitance, and are designed for millimeter-wave multiplier applications such as doublers from 10 to 20 GHz, and 20 to 40 GHz. For further information and data sheets on any of these components, contact California Eastern Laboratories, 3260 Jay St, Santa Clara, CA 95054, tel 408-988-3500.

Select Your Training Tools From the IEEE

The Computer Society of the IEEE offers a rather lengthy list of available tutorials, proceedings, and conference records. Subject matter includes computer systems, robotics, digital image processing, and software standards.

These tutorial texts are timely, and many organizations choose to promote their material through the IEEE Computer Society because of the opportunity to reach professional audiences. For further information on submitting a proposal for acceptance, or to request a listing of what's available, write The IEEE Computer Society, 1730 Massachusetts Ave, NW, Washington, DC 20036-1903.

The IEEE publications group also offers a host of reading material in the telecommunications and electromagnetic waves area. Several new titles include:

• *Satellite Communication Systems*, B. Evans, ed., cost: $80. Lecture material from the IEE Vacation School series held at the University of Surrey has been compiled to deliver a broad coverage of this topic, as it relates to spacecraft engineering in the United Kingdom and Europe. The book is ideal for undergraduate or postgraduate students, and practicing engineers who are about to enter this field.

• *Spread Spectrum in Communication*, written by R. Skaug and J. F. Hjelmstad, cost: $67. This publication examines spreading techniques, coding for bandwidth spreading implementation, the propagation medium, and code-division multiple-access networks.

• *Data Communications and Networks*, edited by R. L. Brewster, cost: $45. A review of problems in data transmission, a look at an integrated services digital network, a discussion of terminals, multiplexers, concentrators, and the development of information services. The book concludes with a look at possible future trends in the development of data communication and network facilities.

• *Principles of Microwave Circuits*, C. G. Montgomery, ed., cost: $68. This volume contains information on waveguide circuit elements, dielectrics in waveguides, elements of network theory, and waveguides as transmission lines.

• *Microwave Antenna Theory and Design*, Samual Silver, ed., cost: $47. A survey of microwave antenna design problems. Circuit relations and reciprocity theorems are reviewed. Other subjects include aperture illumination and antenna patterns, pencil-beam and simple fanned-beam antennas.

For complete information on ordering any of these titles, or other works related to this field, contact the PPL Dept, IEEE Service Center, PO Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331, tel 201-981-0060, ext 382.

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