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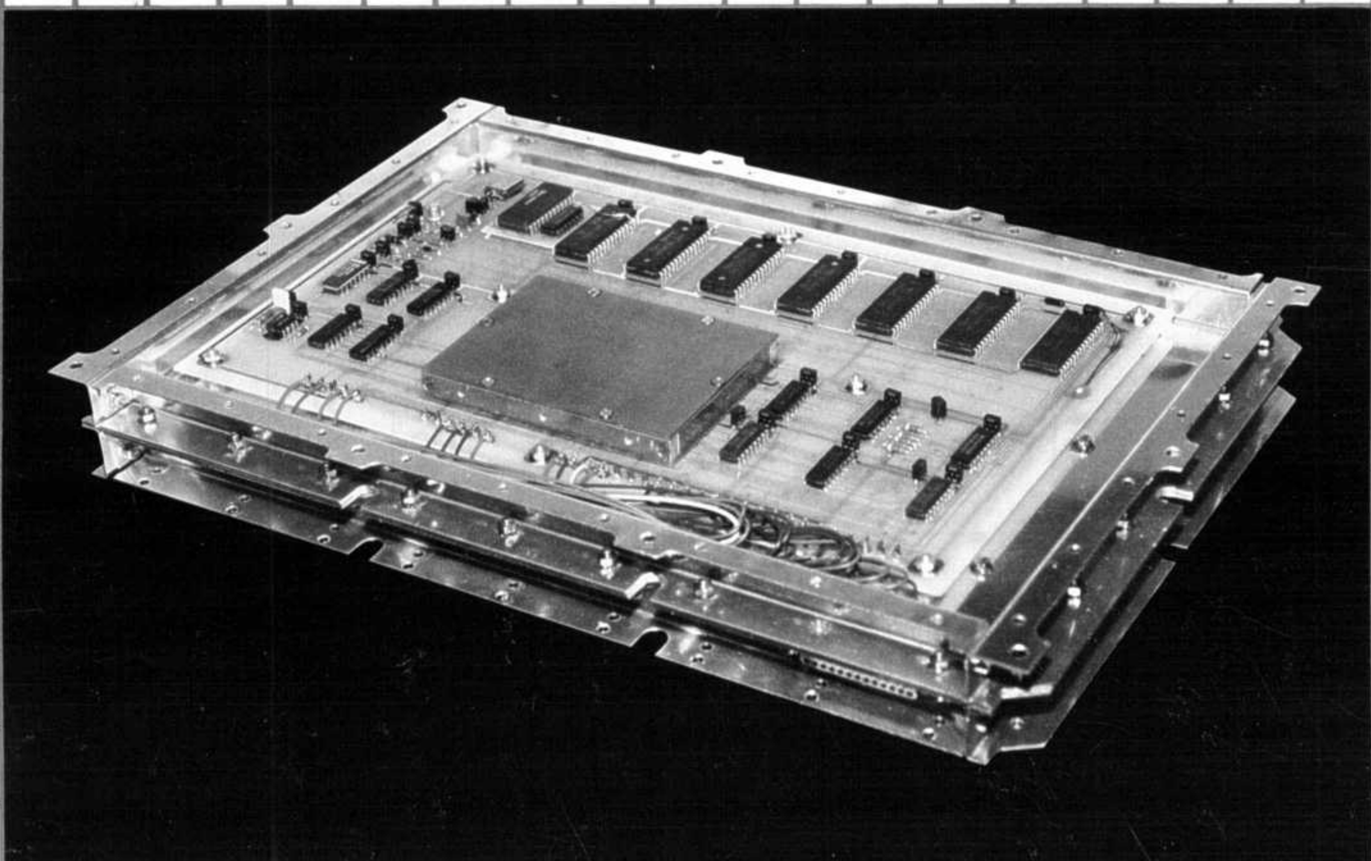

QEX

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ABOUT THE COVER

The RUDAK transponder is part of Phase 3C's hardware and operates similar to that of a digital repeater. The small enclosure shown in the foreground is a radiation shield to protect the memory circuits. (Photo courtesy of AMSAT-DL; W. Gladisch)

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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Purposes of *QEX*:

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

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

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

Empirically Speaking. . .

HF Packet Networking

There are about 40 stations active in the United States on the high-frequency bands with packet bulletin board systems (PBBSs) in what is the beginning of a highly effective autoforwarding net. We owe thanks to Hank Oredson, WØRLI, author of the PBBS software, for *doing* what others simply talked about. If you would like to sample the activity, just set your receiver to lower sideband and tune in 14109 or 7093 kHz. You will hear 300-baud packets flying back and forth from one station to another here in the US and a few stations overseas.

The ARRL Ad Hoc Committee on Amateur Radio Digital Communication began studying the HF PBBS system in mid-1986 with regard to suggesting improvements. One problem was that most stations operated on one 20-meter channel regardless of time of day. This resulted in excessive retries, congestion and delays. Nevertheless, the system worked. A propagation study and network-development task was undertaken by the Digital Committee. Part of the Committee's job was to prepare a request to the Federal Communications Commission for a Special Temporary Authority (STA) for a limited number of stations to operate under automatic control on HF.

The first step was to poll the active HF packet PBBS stations for information. A questionnaire was prepared and mailed to over 50 stations. Between August and December, forty responses were received and analyzed. Accompanying the questionnaire was a rough outline of a plan to have a limited number of stations serve as HF major relay centers. It became clear that these stations would need to cover several frequencies simultaneously. This appeared to be a problem for most Amateur Radio stations, so a "cluster" concept was proposed. The idea is to form a cluster of nearby stations, each of which is capable of covering one HF channel. Two stations would be needed for a national net and one would provide regional coverage, which brings the basic requirement to three positions. Those clusters around the periphery of the US would need a fourth position for international packet communications.

These clustered stations would form a "teleport," a term borrowed from the telecommunications industry. Major cities in the US and elsewhere are building teleports as gateways between their local area networks and various forms of telecommunication. Commmercial teleports are usually associated with working satellites, but include all types of long-haul channels such as fiberoptic cables.

Propagation predictions for paths between 10 US teleports were ordered from the Institute for Telecommunication Sciences, Boulder, CO. In general, what they show is that for Dec-Jan-Feb 5 SSN, the frequency requirements between the 10 locations are: 3.6 and 7.1 MHz (night), 7.1 and 10.1 MHz (transition periods), and 10.1 and 14.1 MHz (day). Frequencies needed for regional coverage are 3.6 MHz with 1.8 MHz coming in a strong second (night) and 7.1 MHz (day). Not too surprising. However, the IONCAP computer printouts provide predicted signal-to-noise ratios (SNRs), which can be converted into reliabilities. Then the SNRs will be mapped into the FWD.TNC files used to route messages in each PBBS. The IONCAP predictions are of the all-season, all-sunspot-number type, so they can be interpreted for long-term network operations.

The next step in the process is to circulate the draft interim operations plan to the HF packet PBBS stations and others involved in the development. We are grateful to the HF PBBS station for their continued constructive comments and positive support in this planning effort.—W4RI

Correspondence

How to Measure Antenna Impedance

For several years I have been obsessed with finding a way to measure antenna impedance. After all, I reasoned, if a person knows an antenna's impedance, then it must be a simple matter to use the Smith Chart. Just plug equations into formulas or run a computer program to provide the figures for a matching network.

The ubiquitous matching network matches the transmitter output to the antenna or transmission line system. Commercially available equipment such as a network analyzer or vector voltmeter can be used to measure impedance, but their cost is prohibitive to most amateurs. Even an older, used General Radio impedance bridge coupled with a good quality RF tight signal generator can be considered expensive if only a handful of measurements will be taken

The popularity and reasonable price of the noise bridge prompted me to purchase two commercially manufactured units. I experienced the same disappointment with each. On 80 and 40 m, the bridges gave good nulls on the R and X scales (20% accuracy when testing a known R and X network), very sharp hard-to-find nulls on 20 m (50% accuracy) and no nulls on 15 and 10 m. Perhaps I was expecting too much from this equipment, or I was using the bridge incorrectly. What I really wanted was a simple, inexpensive way of measuring impedance; accuracy was not required.

The technique that I use to measure antenna impedance is simple and straightforward. On paper, it seems that the theory should work in a practical application, but it doesn't. I don't know why, therefore, I'd like to relate what methods are used to gather my data. If anyone has suggestions or detects what I am doing wrong, drop me a line.

Theory of Measurement

A transmission line or antenna system can be modeled many ways, the simplest of which is shown in Fig 1. The reactance is intentionally drawn as a box and not as a lumped element because it can be either inductive or capacitive.

Let's now add two more elements to Fig 1 and call them *test elements*. By connecting a signal generator capable of delivering 1 to 10 V to the test elements' input terminals at a frequency we wish to use, our configuration now looks like that of Fig 2.

Note that the arrangement order of the test elements is important. X_t is drawn as a variable device. R_t could be fixed or variable, as I will explain later. But now, let's run through several examples using Fig 2.

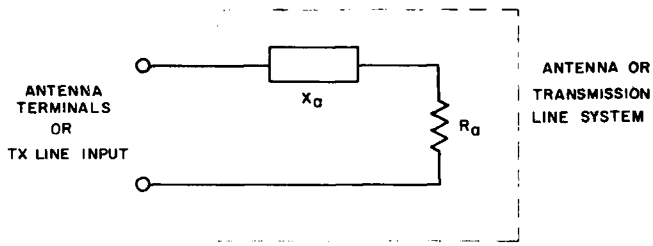

Fig 1—Schematic of an antenna or transmission line system in its simplest form.

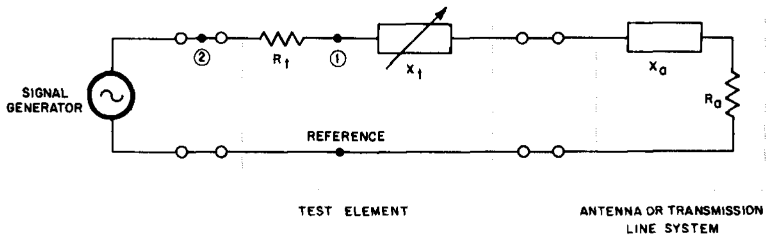

Fig 2—Test elements and a signal generator are added to the antenna system.

Example No. 1

If we assume that X_a is inductive, X_t would be a capacitor. Monitor the voltage at point 1, the junction of the test elements, with an RF voltmeter or probe connected to a dc voltmeter or oscilloscope. If X_t has sufficient range (X_a × 1000 ohms), then as X_t is varied, the monitoring device at point 1 indicates a null (minimum reading) at some adjustment of X_t. At the null point, the reactance of X_t is equal to the reactance of X_a, leaving the total impedance of that three-element series circuit equal to R_a in lieu of $R_a + jX_a$ before the test elements were added.

If X_t is a variable capacitor, measure X_t at the setting at which the null occurred using an RLC bridge, capacitance or dip meter. The value of X_a will be a conjugate of the reactance of the capacitor X_t. We now know the antenna's reactance.

The resistance is just as easy to find. Assume that X_t is still in the circuit and adjusted for a null voltage at point 1. Record that voltage on paper and move the monitor's probe to point 2, the junction of the signal generator and the test element resistor, R_t. Record that voltage. We now have a simple voltage divider of R_t and R_a, since X_t and X_a cancel each other.

Therefore,

$$R_a = R_t \frac{V_1}{(V_2 - V_1)} \qquad \text{(Eq 1)}$$

Had R_t been a variable resistor, then adjusting R_t such that V_1 is one half V_2 means $R_a = R_t$ and calculations would be unnecessary. If we used fixed values for R_t, trying different resistances to get $V_1 \approx ½V_2$ would probably yield the most accurate results by using the equation to calculate R_a.

Example No. 2

For our second example, assume that X_a is capacitive. This would make X_t an inductor. Variable inductors are neither cheap nor easy to obtain. We can make a variable inductor by placing our variable capacitor in series with a fixed inductor of known value (Fig 3).

The amount of inductance should be such that its reactance is a little less than the maximum value of the reactance of the capacitor. Thus, the series combination is effectively a straight piece of wire when the capacitor is fully unmeshed and inductive when the capacitor is meshed. As in the first example, we would install our variable inductor at X_t, monitor point 1, and adjust the capacitor for a minimum reading on the monitoring device. R_a is found in the same manner as in our first example.

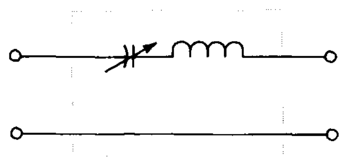

Fig 3—A variable inductor can be created by placing a variable capacitor in series with a fixed inductor of known value.

Afterthoughts

Several reasons exist as to why a null or dip may not appear at point 1 when monitoring and adjusting X_t as a capacitor or inductor. X_a may already be zero, or X_a is very small compared to the resistance of R_a. X_t may not have enough range. To check each situation, adjust X_t for the lowest reading while monitoring point 1. If X_t is maximum reactance, you might have run out of range. If X_t is minimum reactance, short out X_t. Again, if the reading drops, X_a may be very small with respect to R_a, and that X_t was merely adding reactance to a circuit which already had little or none.

To short out X_t, assume $X_a = 0$, then calculate R_a by measuring voltages at points 1 and 2. It may take a couple of iterations of measurements, calculations and substitutions for R_t to obtain a value for R_t such that $R_t \approx R_a$, our ideal measurement situation. Now go back and determine X_a. These procedures require trial and error and some thought on the part of the experimenter.

Test Results

Attempts were made to apply my simple theory to two antennas which had been in use for several months, but which were not close to 50 + *j*0 ohms. SWR meter indications were no better than 3:1. After measuring each antenna's impedance and designing a matching network for each, SWR measurements remained high.

I decided to run tests on known elements. Using 10 MHz as a test frequency, a 91-ohm, 2-W resistor and a 2.5-μH air-core inductor in series, I conducted several tests using an RF probe as the monitoring device at points 1 and 2. Later, I again tested the known elements with a Tektronix oscilloscope with X10 probes. Each time I came within 50% of the expected values—not much different from the noise bridge tests. Attempts with a ¼-W resistor (carbon film) and a capacitor were worse.

Conclusion

Why were my experimental results such a disappointment? Perhaps my monitoring devices were loading the circuit. I used the differential mode on the scope as well as the single-ended input. Maybe above some nominal frequency, like 1 MHz, stray capacitance effects and capacitive loading by monitoring devices becomes a major factor in the measurement process and can not be accounted for. If any *QEX* readers have had similar experiences, I would be happy to hear from them.—*Clifford J. Appel, WB6AWM/5, New Mexico State University, PO Box 3987-UPB, Las Cruces, NM 88003*

Bits

National Semiconductor Products

Free datasheets and reference guides are available from National Semiconductor. When requesting this information from the company, use the complete product name.

- *TP5088 DTMF Generator for Binary Data*—(datasheet) this CMOS device provides low cost tone-dialing capability in microprocessor-controlled telephone applications. Four-bit binary data is decoded directly, without the need for conversion to simulated keyboard inputs required by standard DTMF generators.
- *TP5089 DTMF (Touch Tone®) Generator*—(datasheet) a low threshold voltage, field-implanted, metal gate CMOS IC. It interfaces directly to a standard telephone keypad and generates all dual tone multi-frequency pairs required in tone-dialing systems.
- *National's EEPROM Databook*—a comprehensive collection of information on advanced non-volatile memory products.
- *New Cross Reference Guide*—a component list of all major EEPROM and EPROM manufacturers. Device characteristics are stated. The company also has available literature on a micropower regulator for battery systems. Named the LP2950/LP2951, the regulator's purpose is to extend battery life and shrink the system size and weight of a variety of battery operated equipment. Write to National Semiconductor at PO Box 70818, Sunnyvale, CA 94086.—*KA1DYZ*

An SWLer's Bible

If you thought that Radio Database International published just a table of SWL frequencies, look again. Other than their annual listing of major world-wide broadcast stations, their 1987 edition contains advertising, a buyer's guide and over a dozen articles written to assist each SWLer to get the most out of their hobby. With over 300 pages of information compiled in one place, every SWLer should have a copy. Publication cost is $12.95. Write to Radio Database International, PO Box 300, Penn's Park, PA 18943 for details.—*KA1DYZ*

Computer Magazines And Disks—Big Business

Many publishers of computer-specific magazines have been packaging disks with their publication. The disks contain software programs from the editorial pages of the magazine. Cover prices for both items hover around $10-$12 and are a popular item at the newsstand (80% success rate). The programs are not as sophisticated as those sold at computer stores, but this does not inhibit sales—it is a bargain for some computer enthusiasts who may spend up to 30 hours typing in eight to 10 programs.

Because this style of selling computer journals is increasing in popularity, many publishers have overcome production and mailing problems. Some printers package the disk and magazine in a shrink-wrapped format; others place the disk in a sleeve outside of the magazine, then the shrink-wrap technique is applied. Postage costs can be as high as $1.08 per copy or as low as 25 cents. [This information was excerpted from *Folio Magazine*, Nov 1985, p 25.]—*KA1DYZ*

Use of the Helical Antenna on ATV

By Domenic M. Mallozzi, N1DM
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Watertown, MA 02172

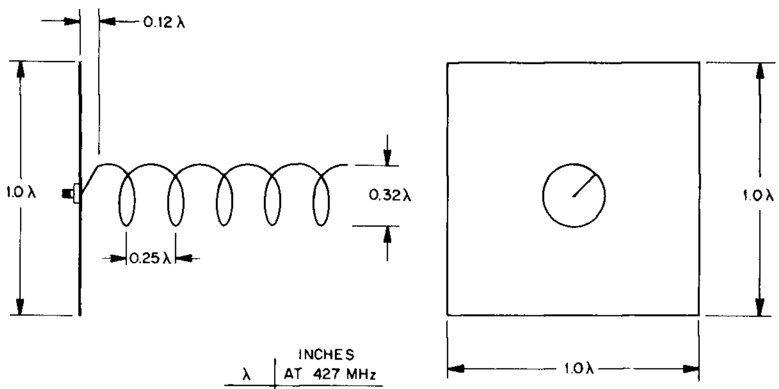
My friend, Bob Vota, WB1FDY, and a small group of his friends became interested in 70-cm ATV. The group was doing well until they tried to exchange QSOs over a nonoptical path; most failed. In some cases, stations could work close in, with simple antennas. When the transmitting stations switched to high-gain antennas, those on the receiving end reported that the balance between the audio and video levels was noticeably poor. Other stations using high-gain arrays made up of Yagis and quagis received reports that their signals were poorer than stations using lower-gain antennas. This particular situation existed over both optical and nonoptical paths. Those stations that operated successfully used antennas such as log periodics.

At this point, Bob questioned what gain antenna that was simple to construct might work for him. Having recently completed research on helical antennas, I remembered two articles that could help.

One article suggested the helical antenna be used for UHF TV reception.[1] Another study indicated that commercial experiments in long-haul TV reception in the UHF bands had shown the use of the helical as a polarity diversity antenna had given good results.[2]

Based on this data, I suggested Bob try using 5-turn helicals with right-hand circular polarization. (The suggestion of right-hand circular sense was totally arbitrary, but it is essential that all stations use the same polarization sense.)

Several weeks later, Bob told me his results were phenomenal. Stations on both the nonoptical and optical path were heard with crisp, clean signals and properly proportioned audio. These results were even more unusual when it is noted that some of the arrays previously tried had greater gain than the 5-turn helicals. This got me thinking of what conditions could explain this situation.



λ	INCHES AT 427 MHz
0.12	3.32
0.32	8.85
0.25	6.91
1.00	27.65

Fig 1—A configuration of the helical antenna as discussed in the text. A table of dimensions for 70-cm operation is given in wavelengths and inches.

Considerations

VHF and UHF signals propagate over nonoptical paths and can change polarization. These polarization changes are not always uniform and often vary with seasons or other conditions. The helical antenna reponds to linearly polarized signals at all angles and also to the circular polarization for which it was designed. A polarization shift reduces the effective signal strength over a particular path, resulting in a deterioration of the signal-to-noise ratio (SNR). The SNR for TV signals should be at least 45 to 55 dB[3] to obtain broadcast-quality results. In essence, the helical antenna maintains the SNR in spite of indeterminate angles of polarization.

Bob's helical antenna did not exhibit a balance problem between the video and audio levels. This may be accounted for by the fact that the helical is a wideband antenna which has a relatively uniform gain over a wide frequency range. This means that the ATV signal, which is wideband (approximately 6 MHz), is transmitted with its relative video and audio RF levels preserved. In comparison to the helical, Yagis and quagis are designed for maximum gain. Because of their design, it is difficult for such an antenna to maintain gain flatness over the wide bandwidths required for an ATV signal at 450 MHz. Stacking these antennas makes the situation even worse. The bandwidth of an array of Yagis or quagis will generally be less than that of a single antenna and will exhibit poorer gain flatness over the required bandwidths. This situation could be considered analogous to paralleling multiple parallel tuned circuits. The result is a higher Q than that of a single tuned circuit (in cases where the circuits are tuned to the same frequency). The gain flatness of a 5-turn helical with a 1-wavelength circumference at the center (design) frequency will be less than 0.5 dB (calculated). With careful design and construction of a Yagi (or similar antenna), gain could be sacrificed for gain flatness. Unfortunately, the mechanical requirements are quite demanding. The helical is much more forgiving of tolerance errors. My conclusion about Yagi and quagi antennas is that they may have been acting as bandpass filters with nonuniform passband gain.

Conclusion

This analysis indicates that the use of the helical antenna for ATV (and possibly wideband data links) may result in noticeable system improvement, with no other equipment changes. For the enterprising experimenter with the proper facilities available, evaluation of the gain flatness of various commercial and amateur antenna designs might be useful. Also, if someone could provide data of the required passband fidelity (gain flatness) of a TV signal, it might provide a good guide for antenna selection when combined with the information above.

For those wishing further information on the design and construction of helical antennas, excellent articles have been published by DeMaw[4] and Bridges.[5] An excellent survey article by George and Hiatt[6] points out the advantages of circu-

[1]Notes appear on page 6.

lar polarization for UHF TV and might prove to be interesting reading.

Acknowledgements

I thank Bob Vota, WB1FDY, for providing me with information about his helical antenna. This information may prove useful to the experimenter and benefit the Amateur Radio community.

Appendix

This appendix presents basic information on the 5-turn helical antenna. Fig 1 shows the configuration of the antenna and a table of dimensions for 70 cm. A calculated helical antenna radiation pattern is shown in Fig 2. Though the ground plane is represented by a square, a circular configuration with a diameter of 0.8 to 1.0 wavelength is sufficient. This ground screen does not have to be solid. In my antennas, the ground screen is constructed of 1/2-inch mesh chicken wire on a wooden frame. A circular ground screen in the form of a spoked wheel would be just as effective.

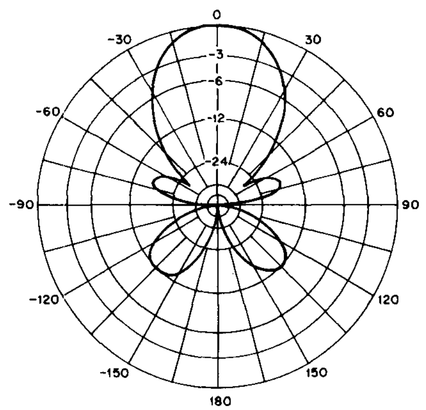


Fig 2—The radiation pattern of the 5-turn helical antenna. Note that the pattern is a result of calculations and not actual measurements. The gain is 12.7 dBi and the half-power beamwidth is equal to 46.5°. In this pattern, C = 1.0 wavelength and S = 0.25 wavelength, where C is the circumference of the winding and S is the spacing.

The size of the conductor of the helical element should be in the range of 0.006 to 0.05 wavelength.[7] At 70 cm, a convenient size is 0.25 inch. I have used both a piece of RG-58 cable (with its center conductor and shield shorted at both ends) and ¼-inch copper tubing for the conductor of my helical element. No difference in performance was noted.

For matching the helical 140-ohm feed point to a 50-ohm transmission line, I prefer to use the single-stub coaxial tuner presented in The AMSAT Newsletter.[8]

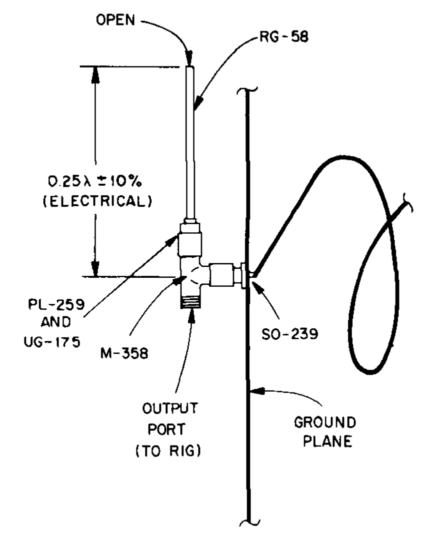


Fig 3—The single-stub, coaxial tuner.

Fig 3 shows one form of the tuner. To use it, start with a stub about 10% longer than ¼ wavelength. Then, with an SWR meter at the output port, slowly trim the stub for minimum SWR. Be careful to trim with the RF off! Do not short the end of the stub when trimming. After finding the final length, cap the open end of the stub with a weather sealant.

Be cautious not to introduce any metal (or other element) into or directly in front of the helical winding. The metal would have a detrimental effect on the helical's performance. Most helicals are mounted from the rear at the ground plane.

To obtain right-hand circular polarization, the conductor should be wound in a clockwise direction out from the feed point. Wind five complete turns after the 0.12-wavelength stem. This will achieve a gain of approximately 12.7 dBi. If an increase in gain is desired, add more turns being careful to wind the wire with identical spacing and of the same diameter.

Notes

[1]W. Blair, "Putting the Helical to Work," *Radio and TV News*, Nov 1958, pp 66-67.
[2]W. Smith, "The World Above 50 Mc," *QST*, Jun 1974, p 88.
[3]A. B. Carson, *Communications Systems: An Introduction to Signals and Noise in Electrical Communications*, 2nd ed, McGraw Hill Book Co: New York, 1975, p 149.
[4]D. DeMaw, "The Basic Helical Beam," *QST*, Nov 1965, pp 20-25; Feedback, *QST*, Apr 1986, p 42.
[5]A. L. Bridges, "Really Zap OSCAR With This Helical," *73 Magazine*, Jul 1975, pp 59-64; Aug 1975, pp 12-20; Sep 1975, pp 83-88.
[6]D. L. George and J. F. Hiatt, "Circularly Polarized UHF-TV Transmission," *Proceedings of the IEEE*, Nov 1982, pp 1300-1303.
[7]J. D. Kraus, *Antennas*, McGraw Hill Book Co: New York, 1950, p 210. Chapter 7 is the basic reference on helical antennas.
[8]W. Allen, "A Mode-J Helix," *The AMSAT Newsletter*, Jun 1979, pp 30-31.

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PacTec Offers A Natural Selection Of Enclosures

That's the description of a line of enclosures manufactured by PacTec, LaFrance Corp, of Philadelphia, PA. The natural selection enclosure is a standard square or rectangular enclosure consisting of a molded-through color, impact resist, flame retardant surface which shields against EMI/RFI.

PacTec also designs a "brief-case" style popular for hand-held electronic devices, a sloped-top cabinet, enclosures with expandable sides and keyboard and CRT ingredients. PanTec doesn't stop here. The company will also electroform nameplates to meet your company's identification requirements. Die cast zinc, injection molded plastic or nameplates manufactured with a copper base are available. Control panels and decorative trim may be obtained as well. For a complete catalog of PacTec products, write to LaFrance Corp, PacTec, Enterprise and Executive Avenues, Philadelphia, PA 19153.—*KA1DYZ*

Generator Feedback

If you are thinking of constructing the two-tone generator as presented in the December 1986 issue of *QEX*, p 10, here is important information. The generator produces 900- and 2100-Hz signals. Referring to Fig 1, P1 = R10, P2 = R21 and P3 = R25. The last sentence of Fig 3 should read: Frequency shifts are made with the bandwidth and gain held constant.

Po, as stated in the last paragraph on p 11, column 1, refers to the author's experimental data. In F1BBI's experiments, Po equaled R1 + R4 and R12 + R15. In his schematic of Fig 1, these resistor values are fixed.—*KA1DYZ and G. Allen, N1BEP*

The Great Radio Aurora of February 1986

By Emil Pocock, W3EP
41 Lewiston Ave
Willimantic, CT 06226

One of the best observed radio auroras of the decade occurred during February 7-9, 1986.[1] Many North American Amateur Radio operators were on hand to take advantage of this natural phenomenon, which can propagate VHF (30-300 MHz) and some UHF (300-3000 MHz) signals much farther than normal. Aurora activity lasted for more than 19 hours, giving amateurs from the Gulf Coast area to southern Canada the opportunity to make several thousand contacts on the 50, 144, 220 and 432-MHz bands. Attempts to communicate on 1296 MHz were unsuccessful. Many two-way paths over aurora scatter on 144 and 432 MHz exceeded 1500 km, measured as the great-circle distance between two stations.[2] Several dozen contacts over 2000 km were reported on 144 MHz, including a new aurora-distance record of 2169 km. The longest reported 432-MHz contact was 1900 km.

[1]Notes appear on page 10.

To facilitate study of this unusual event, logs containing the date, time, station call and grid-square locator of US and Canadian VHF/UHF Amateur Radio stations that made aurora contacts were solicited.[3] More than 70 stations responded with usable logs, the majority of which contained 144-MHz contacts. The descriptive analysis that follows is based primarily on 59 station logs that reported 144-MHz activity and represents over 1000 separate contacts. Fig 1 shows grid-squares with at least one 144-MHz aurora contact between 2100 UTC, Feb 7 and 0600 UTC, Feb 9. Additional data derived from 11 logs of 432-MHz stations compliment the analysis. Fig 2 shows the distribution of 432-MHz aurora activity for the same time period.

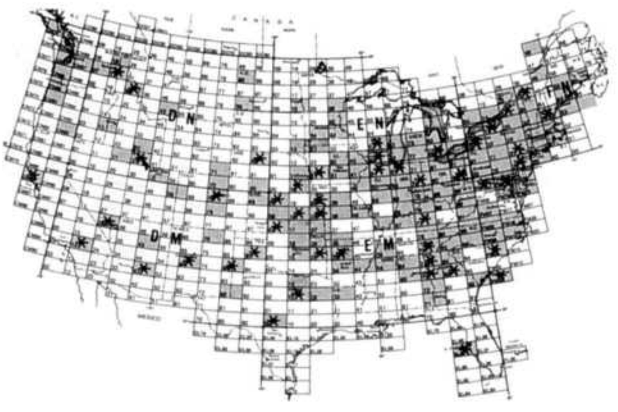

Fig 1—Total aurora activity on 144 MHz. Shaded grid squares represent the location of at least one reported 144-MHz aurora contact during Feb 7-9. Logs were received from the squares marked with an asterisk.

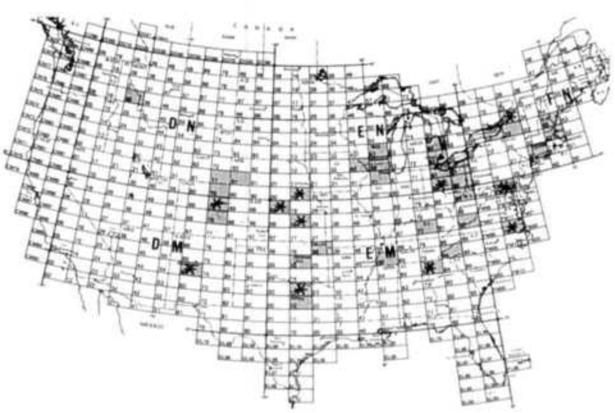

Fig 2—Total aurora activity on 432 MHz. Shaded grid squares represent the location of at least one reported 432-MHz aurora contact during Feb 7-9. Asterisks mark the squares from which logs were received.

The Radio Aurora Through Time

Aurora conditions on 144 MHz seemed to appear and to disappear suddenly, and nearly simultaneously, over a wide geographical area. This phenomenon made it possible to identify five distinct sessions of auroral activity (Fig 3). The associated level of geomagnetic activity, as measured by the K index, was 5 or greater during each session. All contacts are assumed to be 144-MHz activity, unless otherwise indicated.

Session 1 (Feb 7-8, 2045-0110 UTC)

Only a few stations, particularly in the northeastern part of the US, reported aurora activity during this initial session. Station activity was sparse and the geographical extent was limited. The K index was unusually high, having reached 7 at

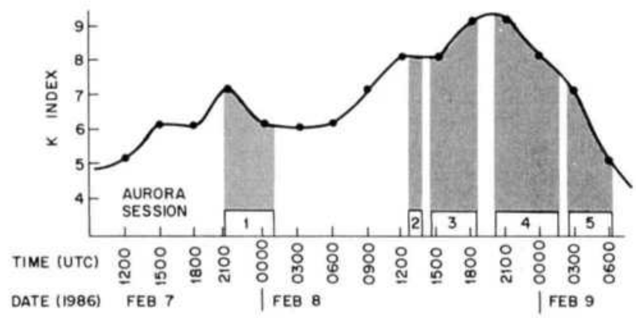

Fig 3—Aurora sessions and the K index. Five distinct aurora sessions were evident from the received logs of 59 144-MHz stations. The smoothed Fredericksburg K indices are from *Preliminary Report and Forecast of Solar Geophysical Data*, 11 Feb 1986, Space Environment Services Center, Boulder, CO.

the beginning of the session. No further contacts were reported through the early morning hours, although aurora conditions could have passed unnoticed.

Session 2 (Feb 8, 1245-1335 UTC)

The K index held at 8 during the morning (local eastern time), but only three stations reported aurora contacts. Activity was evident as far south as Virginia and west to South Dakota (Fig 4). Aurora is most uncommon before noon local time, and it may have caught even the most experienced aurora operators by surprise. From data received, the aurora disappeared for nearly an hour, but this hiatus may have been the result of a sparsity of reports.

Session 3 (Feb 8, 1448-1833 UTC)

As the K index rose from 8 to an incredible 9, stations from the Great Lakes region, as far south as North Carolina and Oklahoma, and west to Colorado reported aurora soon after 1500 UTC. The first contacts in the Pacific Northwest were reported during the following hour, but activity remained confined north of a line running across the US from the North Carolina-South Carolina border, to the state of Washington, as shown in Fig 5. A few isolated 432-MHz contacts were reported from New England and the Great Lakes region. The geographical extent of aurora contacts remained unchanged after 1700 UTC, until all radio aurora activity abruptly ceased at 1833 UTC.

Session 4 (Feb 8-9, 2020-0151 UTC)

Aurora returned with a vengeance at 2020 UTC as the K index was declining from a peak of 9 (at 1800 and 2100 UTC). Within 30 minutes of the first reported contact, radio aurora conditions were evident throughout the eastern two-thirds of the country from the Great Lakes to the Gulf Coast. See Fig 6.

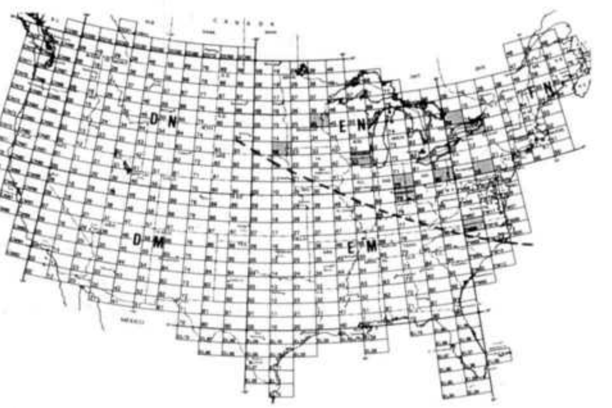

Fig 4—Maximum extent of aurora activity on 144 MHz during Session 2, 1245-1335 UTC, Feb 8. Grid squares from where at least one 144-MHz aurora contact was made are shaded. The dashed line marks the presumed southern limit of radio aurora activity. No contacts of at least 1500 km were reported.

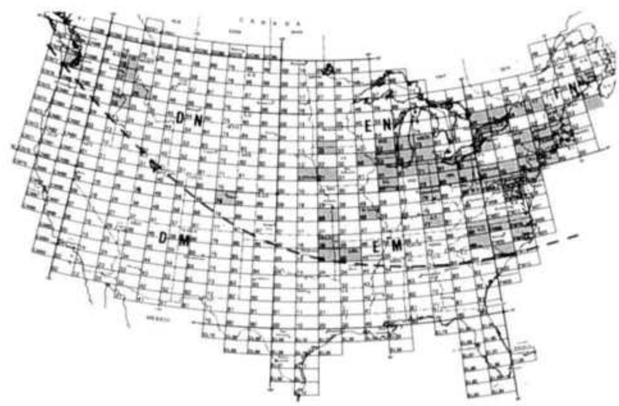

Fig 5— Maximum extent of 144-MHz aurora activity during Session 3, 1450-1830 UTC, Feb 8. No contacts of at least 1500 km were reported.

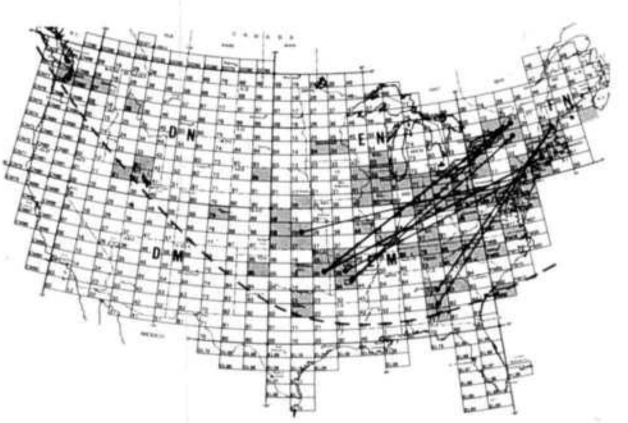

Fig 6—Maximum extent of 144-MHz aurora activity during the first hour of Session 4, 2020-2159 UTC, Feb 8. No contacts of 1500 km were reported.

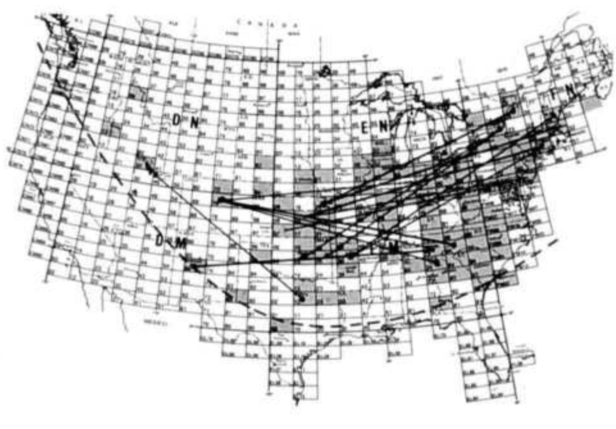

Fig 7—Maximum extent of 144-MHz aurora activity during the second full hour of Session 4, 2200-2259 UTC, Feb 8. Lines indicate the great-circle path of contacts estimated at 1500 km or longer. Thicker lines show the direct paths of contacts in the 2000-km range.

Soon after 2200 UTC, stations in central Florida and south Texas reported hearing aurora stations for the first time (Fig 7). Simultaneous 432-MHz aurora activity extended south to a line running from northern Georgia to north Texas.

The first 144-MHz contacts near the theoretical maximum distance of 2000 km were logged after 2100 UTC, and at least a dozen such contacts were made by 2300 UTC. Included in the station logs were a pair of 2169-km contacts between grid squares EM18 and FN31. These contacts were completed at 2248 UTC and 2251 UTC, respectively, and each constitutes an all-time 144-MHz aurora distance record. The longest reported 432-MHz contact was about 1900 km, made at 2151 UTC between grids EM13 and FM19.

By 2330 UTC, aurora conditions had expanded westward to the California coast (Fig 8). The aurora then began to recede slowly northward in the East during the first hour of the new UTC day. At the same time, conditions were just peaking in the West (Fig 9). After 0100 UTC, the aurora showed signs of deterioration everywhere and no contacts were reported after 0151 UTC (Fig 10).

Session 5 (Feb 9, 0248-0616 UTC)

Aurora suddenly returned at 0248 UTC, allowing stations as far south as northern Alabama and north Texas, and west to the Rocky Mountains, to communicate once again. Many stations reported that conditions were erratic, spotty, and not as consistent as they had been earlier in the day. See Fig 11. Conditions appeared to deteriorate after 0400 UTC as the K index fell from 7 (at 0300 UTC) to 5 (at 0600 UTC). Only stations north of North Carolina and Tennessee, and east of central Nebraska and South Dakota, were still reporting aurora conditions. Fewer contacts were made after 0500 UTC and those were restricted to the northeast (Fig 12). The last contact was made at 0616 UTC.

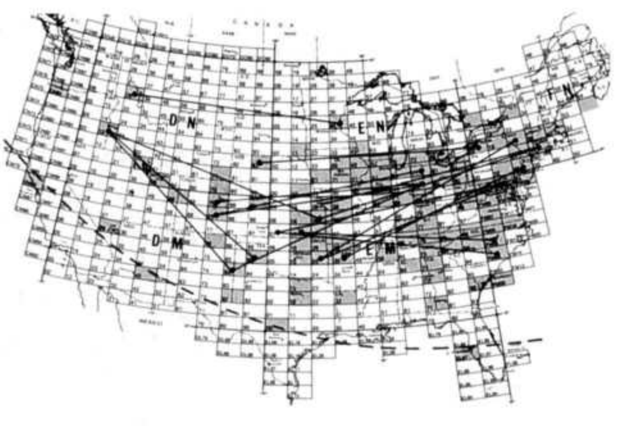

Fig 8—Maximum extent of 144-MHz auroral activity and long-path contacts mid-way through Session 4, 2300-2359 UTC, Feb 8.

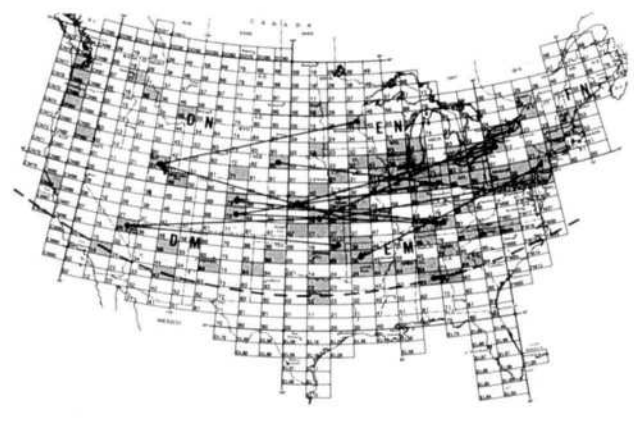

Fig 9—Maximum extent of 144-MHz aurora activity and long-path contacts late in Session 4, 000-0059 UTC, Feb 9.

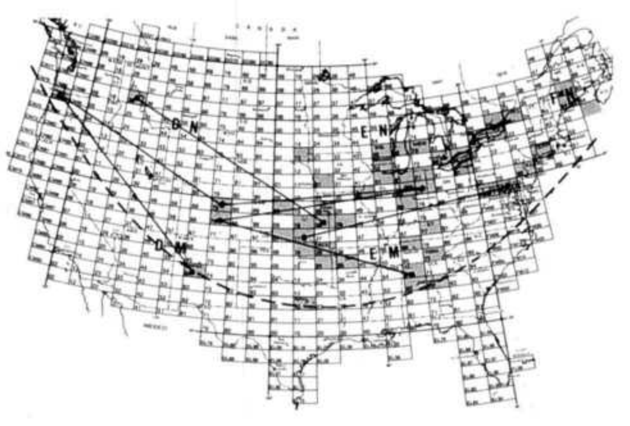

Fig 10—Maximum extent of 144-MHz activity and long-path contacts during the final hour of Session 4, 0100-0151 UTC, Feb 9.

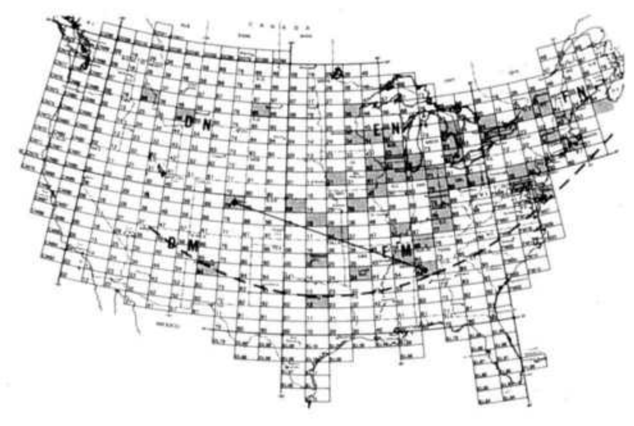

Fig 11—Maximum extent of 144-MHz activity and long-path contacts during the first half of Session 5, 0248-0359 UTC, Feb 9.

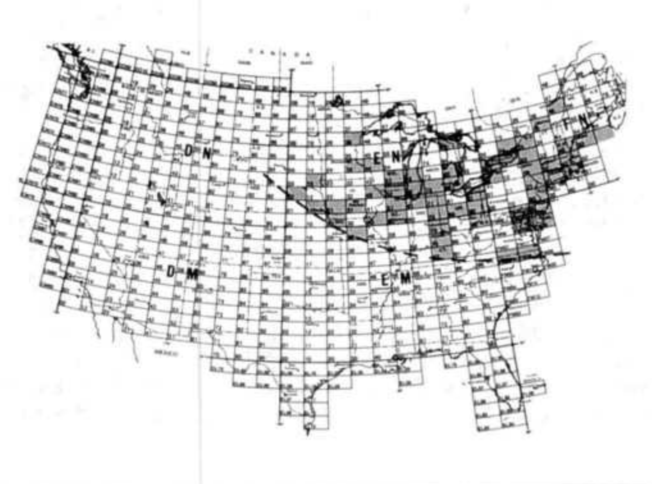

Fig 12—Maximum extent of 144-MHz activity during the second half of Session 5, 0400-0616 UTC, Feb 9. No contacts of 1500 km or longer were reported.

Conclusions

In some respects, this aurora followed patterns long familiar to radio amateurs.[4,5,6,7] Recorded observations also suggest the following possibilities for further study that might prove useful in predicting and making more efficient use of aurora propagation:

1) The aurora coincided with geomagnetic storm conditions, indicated by a K index of 5 or greater. This relationship has long been observed, but the data also suggest that radio aurora conditions may have corresponded more closely to a falling K index. (Session 3 took place while the K index was rising, but the unusually high level of geomagnetic activity may have masked this general tendency.) Observations of other and less spectacular aurora, with their corresponding K-index values, could clarify this relationship.

2) Past experience has suggested that radio aurora conditions appear and disappear simultaneously over a wide geographical area, as if turned on and off by a switch. During the five sessions of Feb 7-9, aurora conditions were reported over a wide area within minutes after the first contacts were made, supporting this general observation. The data also suggest that aurora conditions spread slowly southward after the initial onset, but there may have been little actual expansion to the South. This apparent movement was more likely the result of differences between regional operating habits.

VHF operators in the North probably detected the aurora as soon as it appeared. Several northern amateurs indicated that they were alerted to the possibility of VHF aurora conditions by the hourly reports of geomagnetic activity from WWV or by the deterioration of high-frequency communications. Many discovered the aurora as a result of continuously monitoring 50 and 144 MHz. Radio aurora is rare in the South, and southern VHF amateurs were less prepared for aurora conditions. Most were alerted by telephone calls from northern friends who were already making aurora contacts and sensed that conditions were unusually good. Other southerners heard more northerly aurora stations well after the sessions had commenced.

Analyses of this series of aurora sessions suggest that the radio aurora expanded rapidly to nearly its full southerly limit within 30 minutes of inception, but retreated somewhat more slowly. This generalization also needs confirmation by more careful observations, especially by stations in the southern part of the country.

3) There was a more clearly distinguishable tendency for the aurora to move westward at an apparent velocity of about 1000 km per hour. This phenomenon has been implied in previous amateur reports and may have a theoretical basis as well. Its predictive applications are obvious.

4) The geographical extent of 432-MHz aurora was somewhat more restricted than what was evident on 144 MHz. Several operators in the southern part of the country mentioned that there were times when they could hear 144-MHz aurora stations, but none on 432 MHz. These observations are consistent with the theoretical considerations. During a particular aurora, 432-MHz signal strength could be expected to be more then 30 dB weaker than 144-MHz signals, given the same station gains. Under marginal conditions near the geographical limits of 144-MHz aurora scatter, 432-MHz signals would be too weak to be detected.

5) Long-distance contacts (1500 km and longer) were made when the aurora expanded deep into the southern regions. Contacts in the 2000-km range occurred only during the first two hours of Session 4, the most intense period of aurora activity, even though aurora conditions continued to expand westward and remained strong for at least three additional hours. The longest 432-MHz contacts also occurred early in Session 4. These observations suggest that conditions for long-distance contacts may peak early in an aurora session for all affected frequencies. This, too, needs confirmation by further observations.

Acknowledgements

Many thanks to those who contributed complete 144-MHz logs, including W1ENE, WA1OUB, VE1UT, W2AUD, N2BJ, K2LWR, W2RS, W9IP/2, VE2DUB, W3CWG, K3ONW, WA4AHZ, N4AR, W4GJO, W4HR, K4KAE, N4MM, KS4S, W2GU/4, W3EP/4, KA5EBL, W5FF, W5SFW, K5SW, K5UGM, W5VY, K5YY, WA6LHD, K6PVS, WA8LLY/6, WA7ADK, W7HAH, K7ICW, W7IDZ, W7IUV, N8CKH, WB8TEI, AA9D, K9HMB, KU9L, K9MRI, WB9UQE, K9VGE, WB9WMM, AF9Y, WBØBWE, WBØDMK, WBØDRL, WØEMS, WØETT, KBØHH, NØLL, WBØQMN, WAØTKJ, KØTLM, KØUS, WØVN, KFØY, and WBØYSG. Logs of 432-MHz aurora activity were provided by W9IP/2, W3IP, W4GJO, K4QIF, W5FF, WB5LUA, NI8O, NØLL, WBØQMN, WAØTKJ, and KØUS.

Notes

[1]Bill Tynan, "Record-Breaking Aurora," *QST*, May 1986, pp 68-69, 71. A more general compilation of station reports can be found in this article.

[2]km = statute mi × 1.609, nautical mi × 1.852; m = ft × 0.3048.

[3]A grid "square" is actually a rectangular area 1 degree latitude by 2 degrees longitude. For easy identification, each "field" of 10 degrees latitude and 20 degrees longitude is given a two-letter designation. Each field contains 100 grids, numbered sequentially beginning with 00. Radio amateurs on the VHF and UHF bands have become used to exchanging grid-squares to designate station location. Grid-square maps of the US are available from the ARRL.

[4]G. R. Jessop, ed., *VHF/UHF Manual*, (Potters Bar, Eng: Radio Society of Great Britain, 1983), pp 2.20-2.27.

[5]Richard Miller, "Radio Aurora," *QST*, Jan 1985, p 14-18.

[6]R.K. Moore, "Aurora and Magnetic Storms," *QST*, Jun 1951, pp 14-19, 110.

[7]R. Dyce, "More About VHF Auroral Propagation," *QST*, Jan 1955, pp 111-115, 117-118.

RUDAK: A Status Report

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Lindenstrasse 2, 8045 Ismaning
West Germany
Translated by George Elliott Tucker, WA5NVI†

The Phase 3C Amateur Radio satellite will carry an on-board Mode-L Packet System known as RUDAK (Regenerativer Umsetzer fur Digital Amateur-Kommunikation). RUDAK was constructed by the AMSAT-DL team with several goals in mind: (1) the transponder should be compatible with the existing AX.25 protocol and TAPR boards; (2) communicate with RUDAK using existing Amateur Radio equipment and; (3) moderate-to-small antennas, sufficient for low-bit error rates, will be the only requirement.[1]

This article was written by a team member during the transponder test period. Three weeks remain for testing RUDAK before the ready-to-fly version is shipped to Boulder, CO for its thermal vacuum test. The story focuses on both the hardships and breakthroughs that were overcome to make the RUDAK project successful.

The RUDAK group met during January 1986 in Marburg, West Germany, and again during the Easter vacation. Both occasions presented an opportunity to bring the group together to discuss any remaining questions about the project. Group members consisted of project director Hanspeter Kuhlen, DK1YQ, Peter Gulzow, DB2OS, Stefen Eckart, DL2MDL, Gerhard Metz, DG2CV, and myself.

The Tests Begin

The team first embarked on a mission to organize the electronic components on hand. Parts lists were updated using a computer. This system enabled us to purchase new components on short notice when necessary. This data came in handy after the test results of the digital processor board, the 2400 bits/s BPSK (binary phase-shift keying) demodulator and the switching network module were reviewed.

DK1YQ then installed the three modules with a completed RUDAK board in a commercial housing, so they could be tested interactively. Trials of all modifications, and the operating stress and temperature experiments were first performed. Pin assignments of the DB-25 connector on the commercial housing were identical to the connector on the ready-to-fly version. For testing purposes, however, the buffered LEDs and switches were installed to simulate the satellite interface.

Murphy Shows Up

Next, a previously unexplained phenomenon was investigated. During one test, while several stations were QSOing through the RUDAK transponder, the TAPR TNC-1 software crashed after handling several packets. It was also observed that the crash occurred more frequently as the transmitting baud rate (HBAUD) increased.

The TNC used in the RUDAK tests is operated differently than it would be in an Amateur Radio station. The built-in FSK 1200-bits/s modem is disconnected from the modem plug and a PSK demodulator is substituted. Judging from the received data, the 400 bits/s BPSK demodulator delivers clock and data on separate lines. Because the reception of data occurs with the clock pulse, it is not necessary for the TNC to generate the receive clock. Thus, HBAUD, the packet baud rate, is set at 2400 bits/s. This is the speed at which RUDAK talks.

Different baud rates for both transmit and receive work successfully with RUDAK's Z80® -SIO. With the TNC-1 set at HBAUD = 600 bits/s, the tests remained successful. At 1200 bits/s, reception of a few beacon texts was possible, but with higher baud rates, the time until a crash occurred clearly diminished. It was surprising that a similar problem happened with the TAPR 3.2 version and the WA8DED software.

The group set out to look for the cause of these crashes. DL2MDL used his Apple® //e computer to examine, more carefully, one of the TNCs linked over RUDAK. The status port of the TNC, which also gives information on interrupts to the 6809 CPU, was read by the computer at every change along with a time indication. After a study of these number columns, it was established that the WD1933 HDLC controller caused a receive interrupt, though no data was present to confirm this. The WD1933 was suppose to remain inactive and wait for data during this time, but it was noted that the interrupt frequency rose with higher HBAUD settings.

Because of the false interrupt, the software encountered an empty receive buffer, which then led to the observed crash. This explanation was corroborated further with the substitution of the WD1935, an improved successor to the WD1933. The WD1935 brings out the inverted REOM (Received End of Message with no Errors) signal to the previously unused pin 1. It is at this pin that the interrupt in the RUDAK configuration could be observed easily.

The discovery of WD1933's malfunctioning taught the group a well-learned lesson: Never blindly trust a data sheet. With a patch in the software and a flip-flop to synchronize the RX and TX clock, the WD1933 is no longer a problem. Thereafter, the TNC-1 worked as expected. At the same time, a new version of the WA8DED software that allows for excellent RUDAK operation became available. After these two holes in the system were mended, placing the components on the PC boards and other detailed work progressed rapidly.

Software Capabilities

Before any component was soldered to the board, each was tested. This procedure prevented damaging the PC boards from soldering and unsoldering inoperable parts. All work on the RUDAK project had to be performed twice because a second ready-to-fly bird would be used if the first version failed.

While the group was working with the hardware, software development proceded at full speed. DG2CV wrote the ROS (ROM Operating System) program, which resides in a 2-kbyte × 8-bit CMOS fusable link PROM. The program allows RUDAK to perform its basic functions, and load the operating software into memory after power is applied. The ROS program also runs a nondestructive memory test and will send telemetry values.

The operating software created by DL2MDL is loaded by the ROS software into the RAM of RUDAK. The program handles decoding of satellite telemetry and transmits those reports consisting of the most important telemetry values. The reports are transmitted in the 70-cm downlink passband in 400 bits/s, BPSK modulation.

To test the software under realistic conditions, a RUDAK prototype was installed

Continued on page 13.

[1]Notes appear on page 13.

Xerox 820-1 Compendium—Part 6

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In this final installment of the Xerox 820-1 Compendium, I discuss my design of a composite video board for the Xerox 820.[36] The design originated with my wanting the Xerox computer to be capable of feeding a signal to both a TTL-video monitor and a composite monitor. R. Dunbar, WØPN, originally suggested such a modification, but his method could not be used here. Fig 8 shows the schematic of my small sync-and-video mixer.

The unmodified Xerox board supplies V drive, H drive and video at pins J7-3, 4 and 5, respectively. On my composite video board, the positive-going horizontal drive is first inverted and then fed to a half-monostable circuit. The 33-kΩ resistor holds the gate input high. The negative-edge pulse turns the gate off for a time determined by the 220-pF/33-kΩ RC time constant, after which the gate returns to its high input state.

Similarly, the negative-going vertical drive is fed to another gate that has a longer time constant. Both vertical- and horizontal-derived pulses are fed to an OR gate and then mixed with the positive-going video signal from the Xerox board. The resulting composite video signal is finally connected to the video monitor through an emitter follower. No output capacitor is required and the output is short-circuit proof.

[1]Notes appear on page 13.

My Xerox-based computer is portable with a built-in 5-inch TTL monitor. Since V drive, H drive, video and 12-V dc are available at the monitor connector, I have built my composite video circuit on a small, 2-inch square board epoxied to the rear of the monitor connector. The on-board 7805 regulator is used to produce the +5-V bus line. The composite video output is connected to a Sanyo DM2212N 12-inch amber monitor which displays a rock-steady picture. Incidentally, adjusting the value of the 33-kΩ resistor in the H-drive circuit allows for some horizontal centering. Although I used a 4001 from my junk box, a 74LS02 would have done just as well.

Conclusion

From time to time, the surplus market offers the experimenter a real workhorse (remember the BC-221 frequency meter or the family of AN/ARC-5 "Command Set" equipment?). The Xerox 820-1 is of the same breed: well built and low priced. The Xerox appears to be an ideal computer for the amateur who wants to be a bit more adventurous (technically) without risking a lot of money. The board, cables, power supply and one monitor will enable you to see the famous Xerox "turn on" message for about $125. When that much works, add a keyboard and check your memory banks. Then, add one disk drive. When everything operates properly, complete your system with a second disk drive, a cabinet, double-density daughter boards, real-time clocks[37], packet state machines, EPROM burners, modems, speech synthesizers, 16-bit co-processors, RAM disks, 4-MHz upgrade[38], reverse video cursor, and a host of other peripherals.

Literally thousands of the 820-1 boards have been sold to experimenters. Thus, you may expect a steady stream of add ons, smart improvements and clever modifications. If you need to be in touch with the latest developments, you may want to check these two 24-hour bulletin boards. Both run on 300 and 1200 baud.

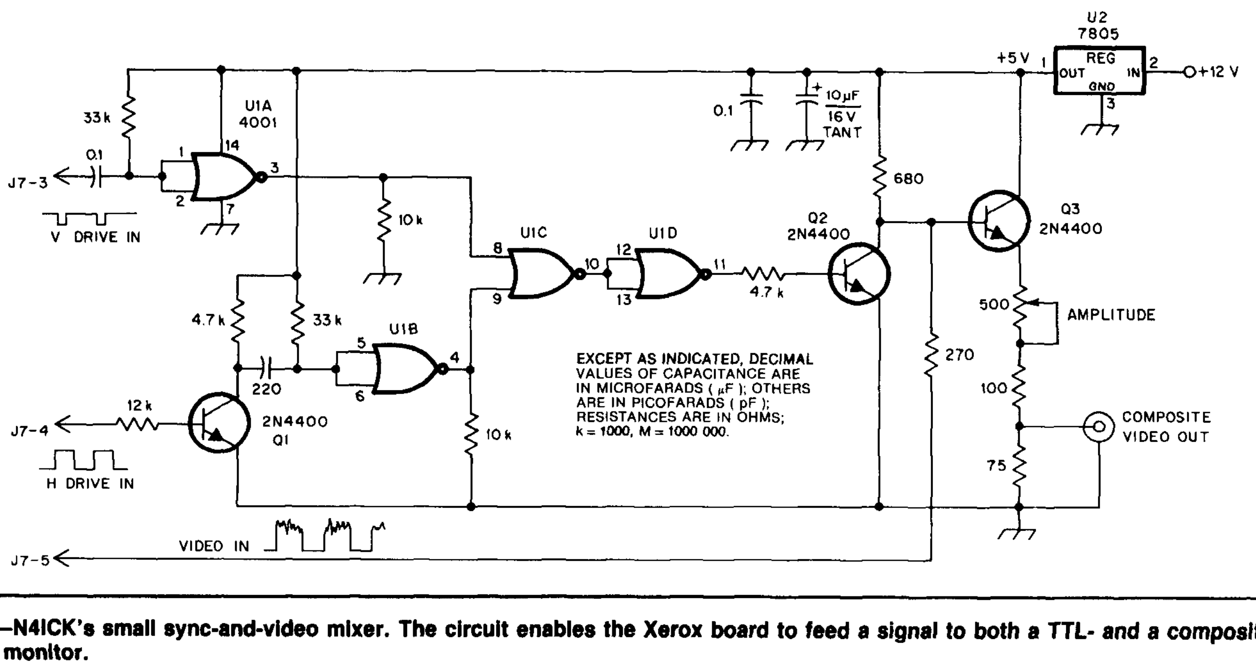

Fig 8—N4ICK's small sync-and-video mixer. The circuit enables the Xerox board to feed a signal to both a TTL- and a composite-video monitor.
Q1, Q2, Q3—2N4400 NPN transistor. U1—CD4001BC quad 2-input NOR gate.

- Americare (Connecticut): 203-232-3180
- Stu Anthony (California): 714-599-2109

Most packet-radio bulletin boards presently operating on the East Coast use a Xerox 820-1 board and the WØRLI software.[39] If you have an 8-inch disk drive, the *MicroCornucopia*[40] has a wealth of good public-domain software. (Xerox 8-inch disks are initialized in the IBM 3740 format.) If, on the other hand, you opt for 5¼-inch diskettes, the original Xerox single density format is compatible with Cromemco and at least one of the double-density boards (from Emerald Microware[41]) will read most Kaypro software.

It is AMRAD's intention that the material in this Compendium appeal to either the old pro, totally at ease with computers, or just a ham wondering how and when to take the first step in computer hardware hacking. We hope this Compendium gives enough information to convince you that the Xerox 820-1 is indeed worthy of consideration.

Notes

[36] Parts 1 through 5 of this Compendium appear in *QEX* issues for Jun, Jul, Aug, Sep and Dec 1986.

[37] Mitchell Mlinar, "Xerox 820 Column," *MicroCornucopia*, No. 20, Oct 1984.

[38] Jim Mayhugh, "Xerox 820 Column," *MicroCornucopia*, No. 19, Aug 1984.

[39] Andre Kesteloot, "A Martian in the Packet World," *AMRAD Newsletter*, Mar 1985.

[40] *MicroCornucopia* is published six times per year. For subscription information write PO Box 223, Bend, OR 97709, tel 503-382-8048.

[41] Emerald Microware, PO Box 6118, Aloha, OR 97007, tel 800-223-EPIC.

RUDAK: A Status Report

Continued from page 11.

on the Ismaning water tower (QRA locator: JN58UF) at DLØISM. The RF equipment necessary for the 24-cm BPSK uplink and the 70-cm BPSK downlink was built and made available by Hermann Hagn, DK8CI, the operator responsible for DLØISM. The 435.614-MHz signal was clearly heard in the Munich area and allowed the software developers to load and test new programs from home.

Conclusion

The ready-to-fly version of RUDAK has since been shipped to Boulder, CO for integration with the rest of Phase 3C. After that, the complete, operational satellite will undergo a thermal vacuum test. In a test such as this, the satellite repeatedly passes through a different temperature range in a vacuum. The environment conditions are set to provoke premature failure of parts and test interactively all components under realistic conditions.

Once this testing is completed, the satellite will again travel to West Germany to pass a vibration test at Garching, near Munich. The vibration test agitates the modules. This test allows the engineers to make any last-minute circuit modifications that may be necessary.

While most of the work on the RUDAK project took place near Munich, Karl Meinzer, DJ4ZC, Werner Haas, DJ5KQ, and their collaborators continue to work on transponder sections. The frame, with cable harness, on-board computer and a few other modules are already in the US.

Notes

[1] AMSAT DL, "AMSAT DL Specifies Mode L Packet System," *AMSAT Satellite Report*, Jun 19, 1985, no. 104. Subscription information for AMSAT Satellite Report is available from Satellite Report, 221 Long Swamp Rd, Wolcott, CT 06716. Annual rates are $22 for US, Canada and Mexico, and $30 Foreign.

† K. Brenndörfer, "RUDAK—Statusinformation," *cq-DL*, Jun 1986, p 341.

Bits

A 903-MHz Beacon On The Air

As of July 1986, The Pack Rats' *Cheese Bits*, the newsletter of the Philadelphia, PA Mt Airy VHF Radio Club, Inc, reported that Dave Hackford, N3CX, has activated a 903.070-MHz beacon. The beacon will be a good signal source for anyone in the Philadelphia area to tweak up their converters with or to follow propagation on that new band. The arrangement is 5 W into a horizontally polarized big-wheel antenna. The ID is N3CX - FN20, Pennsburg, PA. Reception reports are welcome. Send them to Dave Hackford, PO Box 138, RD 2, Pennsburg, PA 18073.

Other news from the club is that member Charles Osborne, WD4MBK, has placed into operation the first known US multiband phase locked beacon. The beacon was put on the air June 1, 1986 and is capable of operating on the following frequencies.

432.0715 MHz	1 W EIRP OMNI
1296.2145 MHz	2 W EIRP OMNI
2304.3575 MHz	100 mW EIRP beamed SW
3456.572 MHz	not operational yet
5760.9295 MHz	8 W EIRP beamed SW
10,369.716 MHz	not operational

All beacons are identified by CW as "de K4MSK/BCN EM85md EM85md".

The beacons are phase locked to a 108.01788-MHz crystal oscillator. Drift will be ±3ppm, 0-60°C per year. Tuning is performed as necessary to maintain a frequency near 432.0715 MHz, the prime frequency. WD4MBK uses an unequal power division method and then triples the resultant frequency to get the 1296-MHz beacon. When transmitting, operation should take place on the 432-MHz beacon's frequency zero beat, then look for the signal on the third harmonic (1296 MHz). The beacon will be exactly on frequency. This procedure reduces tuning time and allows CW filters to be used more effectively to locate signals in a narrow search zone. Future plans include 10-GHz, 902-MHz and 220-MHz operation.

If you are interested in what future issues of *Cheese Bits* have to say, contact Harry B. Stein, W3CL, Mt Airy VHF Radio Club, Inc, 2087 Parkdale Ave, Glenside, PA 19038.—*KA1DYZ*

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Solid-State Construction Practices

If you are reading this, you are probably a builder or at least interested in building amateur gear. For the next couple of months, I will be discussing everything (I hope) that you need to know to duplicate a VHF/UHF/SHF construction project from a book or magazine. At the end of this miniseries, I'll present a surprise construction project so you can test your new skills.

Construction articles abound in the amateur press. Some of these are "cookbook" articles that show where every specified component goes. When built exactly according to the "recipe," the unit will work as described. There are exceptions, of course. Sometimes the designer uses nonstandard components or hand selects some of the devices. The usual result is a project with low gain or output, or some level of instability. Rarely does a published project not work at all if built exactly as described. If you build something and it doesn't work, it may not be your fault. Don't get discouraged; you will learn more about a particular circuit by trying to troubleshoot it anyway. Besides, the next one will probably work better. Press on!

Cookbook articles are fine and guarantee a moderate level of success, but eventually we must strike out on our own. This can mean trying to build something from scratch or from a schematic drawn on the back of an envelope last year at Dayton... Undoubtedly the schematic will contain inductors, capacitors, resistors, solid-state devices, and maybe some microstrip lines and connectors. Of course the thing has to go into a box, and it might even have a heatsink attached. This is where you have to learn how to specify the proper component for a particular job and figure out how to stick everything together so it works.

The design process can be taken a step at a time. For convenience, I'll divide the discussion into eight parts: 1) component considerations; 2) circuit layout; 3) enclosures and connectors; 4) thermal considerations; 5) transistor handling; 6) microstrip techniques; 7) tools; and 8) locating components.

Component Considerations

If we look inside solid-state gear these days, there are a few trends that quickly become obvious. As we go higher in frequency 1) the components get smaller, 2) the leads disappear and 3) the components get more expensive (shinier?). The reason for the first two tendencies is that parasitic reactances (inductances and capacitances) must be small in comparison to the component reactance. For instance, capacitor leads represent inductive reactance and at some frequency (the series resonant frequency). The capacitor isn't a capacitor anymore, and above this frequency it is actually an inductor! Resistors look like nice inductors at higher frequencies and *everything* looks like a capacitor at some frequency. Parasitic (stray) inductance and capacitance should be kept to a minimum, or at least taken into account in a design.

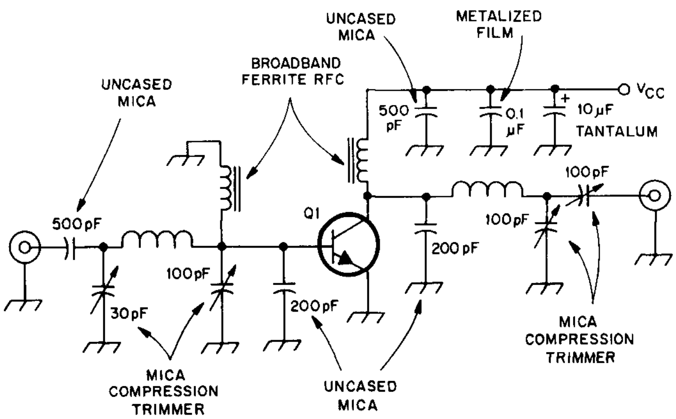

Fig 1—Typical circuit for a VHF class-C amplifier. Mica compression trimmers, uncased micas, and broadband ferrite chokes work well at these frequencies.

Point 3 above is paradoxical. Why should we pay more for something smaller? The first reason is that miniature manufacturing techniques require special machinery and skilled assemblers. Second, as we go higher in frequency, *loss* becomes a factor. We must use materials with lower dielectric loss and lower I^2R losses. Unfortunately, these lower loss materials are often quite expensive. Some examples are Teflon® instead of bakelite, ceramic instead of plastic, gold and silver plating instead of tin plating, Teflon-fiberglass PC boards instead of glass-epoxy.

Luckily we live in a time when technology is running wild. Most of this stuff is available at affordable prices to the well versed scrounger. More on this later.

Capacitors

Capacitors are used in coupling, bypass, tuning and matching applications. In active solid-state circuits we can find a whole range of different capacitor types. Even at microwave frequencies we use electrolytics to bypass low-frequency parasitics. There are metallized film capacitors (the modern equivalent of the old foil/wax paper job) and various ceramic types for medium frequency bypassing (low megahertz range). We use ceramic and mica capacitors for coupling and bypassing in the HF to low UHF range, uncased mica "sandwich" capacitors and ceramic chips for VHF and UHF applications, and of course all types of little chip capacitors that work well up into the gigahertz range. In the variable department there are air variables, mica compression trimmers, rotary film and ceramic trimmers, and tubular glass and ceramic piston trimmers.

Fig 1 shows a basic VHF amplifier circuit and demonstrates where in the circuit specific capacitor types might be used. Note that the base and collector power-supply leads are bypassed with multiple capacitors. Since an RF power device can have 30 dB or more gain at low frequencies, there is a tendency for oscillation because the power leads become a feedback path. For this reason, we must have a good RF ground at the power supply leads for all frequencies from the audio range through the frequency of use. Most designs use three bypass capacitors here—one at the signal frequency, one in the low RF range and one in the audio range. In some instances, especially at microwave frequencies, more bypassing may be necessary to stabilize an amplifier.

Feedthrough capacitors are used to get the dc into a circuit without letting the RF out. They are available in solder-in and threaded versions. Although we generally see fixed values (470 pF, 1000 pF, and so on), better feedthroughs contain LC networks. Generally called EMI filters, these LC networks are specified not as a capacitance, but for decibels of attenuation over a specific frequency range. They are the best choice at microwave frequencies.

Table 1

Capacitors Typically used in RF Circuits

Fixed Capacitors

Type	*Frequency Range*
Electrolytic, aluminum or tantalum	ac-audio
Metallized film	audio-5 MHz
Disc ceramic	1-500 MHz
Uncased mica, large	5-500 MHz
Uncased mica, small	100-1000 MHz
100-mil chip	50-4000 MHz
50-mil chip	0.5-10 GHz

Variable Capacitors

Type	*Frequency Range*
Mica compression trimmer	2-500 MHz
Rotary film	100-1500 MHz
Rotary ceramic	50-1300 MHz
Glass tubular piston	400-2000 MHz
Ceramic tubular piston	400-3000 MHz
Sapphire piston	1-10 GHz

Table 1 shows approximate frequencies of use for various capacitor types. Obviously, the *value* of a component also determines its usable frequency range. This table meant only to show the general trends.

RF Chokes

For the same reason we use broadband bypassing in solid-state amplifiers we must use broadband RF chokes for power-supply decoupling. There are a number of methods of achieving this. One way is to use RF chokes in series. Another is to use a broadband ferrite choke, and a third is to use a choke with a ferrite bead slipped over the lead. See Fig 2.

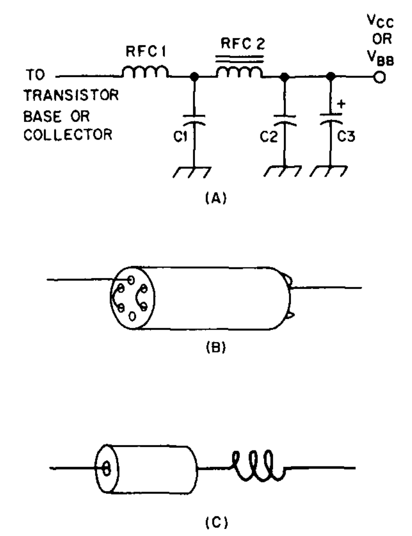

Fig 2—Use of various RF chokes. At A, RFC1 and C1 are decoupling at signal frequency and RFC2 and C2 are for low frequencies. C3 is an audio bypass. At B, a broadband RF choke can be made from a six-hole ferrite bead (Ferroxcube VK200 or equiv) with two turns of wire running through it. Such chokes are normally used in the 50-400 MHz range. At C, a choke with a ferrite bead on one end looks like a choke with a series resistor at higher frequencies. The resistance tends to damp out parasitic oscillations.

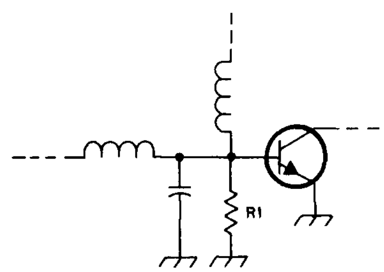

Fig 3—R1 lowers the gain of the amplifier stage and tends to hold down the input impedance of the device. Both tend to stabilize a high-gain stage. Resistor values are usually in the 10 to 100 ohm range. Lead length should be kept to a minimum for greatest effect.

Resistors

While resistors are normally used in dc networks, there are a number of applications where they are used in RF paths, such as attenuator networks or RF loads. In these applications, care must be taken to keep inductances low. At lower frequencies this means keeping the lead lengths to a minimum and possibly paralleling many resistors to achieve the necessary value. Resistors can also be used as lossy RF chokes and are often placed between the base and emitter to stabilize an amplifier stage. See Fig. 3.

Carbon-composition resistors seem to work best as RF resistors because they have lower inductances than metal or carbon film types. At frequencies above 500 MHz, chip resistors are probably best.

Semiconductors

Since I covered RF power transistors in previous columns, I won't go into that subject here. I will, however, talk about some other semiconductors.

One device finding its way into lots of solid-state equipment is the three-terminal voltage regulator. These devices are quite amazing and are great for stabilizing voltages on local oscillators or bias networks. Three-terminal regulators come in positive or negative, fixed or variable configurations at many different current ratings. They *all* suffer the same problems, however, in regard to oscillation. There is a high-gain feedback amplifier stage in the device. Unless the input and output leads are properly bypassed, the thing will oscillate—often in the HF range or higher. Many a builder has spent hours trying to track down a pesky parasitic oscillation in an amplifier circuit, only to find it coming from the three terminal regulator. While a 0.22 μF ceramic on the input and a 1 μF tantalum on the output usually does the trick, check the manufacturer's recommended circuit. Be sure to keep all lead lengths as short as practical.

Diodes are the other semiconductor we see often in RF circuits. There are mixer diodes, multiplier diodes, detector diodes, bias diodes, idiot diodes; silicon, germanium and GaAs diodes; Schottky, step recovery and point contact diodes—you get the picture. Solid-state diodes will be covered in detail in a future column.

Next month I will discuss the layout and actual construction of RF circuits in the VHF/UHF/SHF range. In the meantime start gathering those parts!

Bits

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