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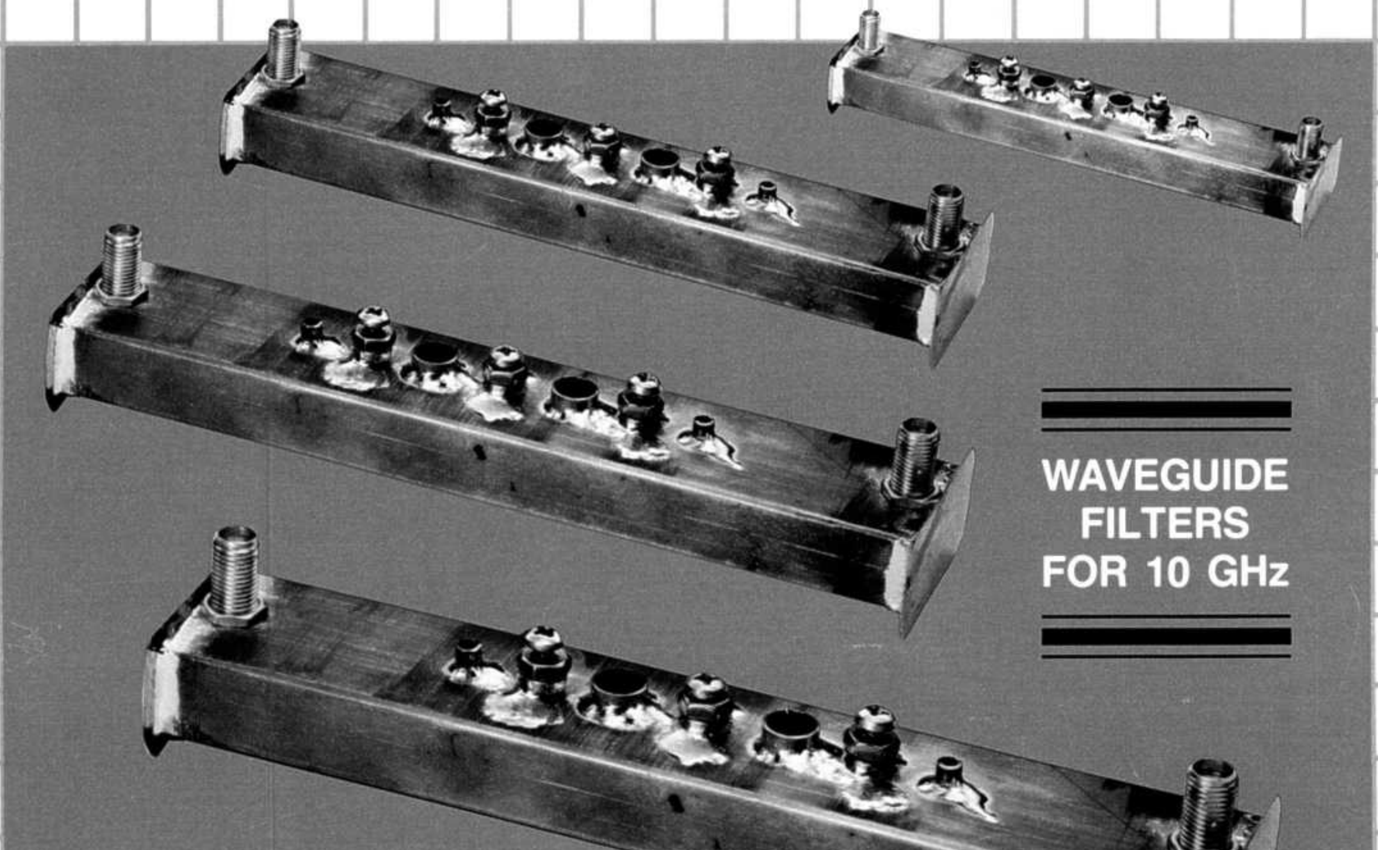

WAVEGUIDE FILTERS FOR 10 GHz

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What's the latest on 9 cm? It's quickly becoming a popular band, and the good news is that commercial components manufactured for TVRO service can be converted for amateur use. Any enterprising UHF/microwave experimenter can get on 3456 MHz with little expense and effort using surplus components. Here's how!

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Rectangular Spectrum Modulation—this new modulation scheme minimizes signal bandwidth without affecting transmission quality. Details of the patent and how the system operates is explained.

ABOUT THE COVER

The 10-GHz low-loss bandpass filter. The filter's center frequency relies on the spacing between the posts, and the tuning is performed by adjusting the screws. See page 3 for details.

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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.

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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. . .

Two Worlds Meet: NTS and Packet

It makes for interesting conversation when different cultures meet to pick bones and take marriage vows. That's about what happened in Hudson Division Director Steve Mendelsohn's back yard on June 6. Steve invited a virtual "who's who" of NJ/NY and thereabouts National Traffic System and packet radio for a barbeque. The idea was to develop some common ground for smooth operation of the two systems. To start with, there are at least N + 1 opinions expressed at such a gathering, where N = the number of hams present. One might think that such a meeting would be a prescription for a disaster. Not so!

What was abundantly clear was that NTS needs packet and vice versa. The traffic handlers use packet to move messages throughout the country, almost untouched by human hands. The packeteers want their considerable investment in technology and facilities to be of public service. So the will to integrate is there, but the understanding and compatibility lag somewhat. To underscore this, the present NTS has its roots in the 1940s, is structured, and is a labor-intensive operation with strong peer socialization and discipline. Packet, on the other hand, is high techie, automated, topologically amorphous, and rapidly evolving. The development is so fast that we agreed that the situation would be different by the time we all got home after the meeting.

The most immediate problem is getting people to take traffic off packet bulletin boards and deliver it to addressees in their areas. There have been instances where messages have made it across the country in minutes, only to sit for a day or more a few miles away from the addressee for the lack of someone to service the PBBS. Packet and traffic people in some areas have recognized the problem and developed an organized plan for delivery of messages. (This is one step that requires human handling; perhaps someday someone will write a computer program that will dial a phone, verify that the intended addressee is on the line, and read the message.) The Section Traffic Manager needs to be kept apprised of traffic bottlenecks throughout the Section. Automation can help by generating packet traffic status reports for daily review by the STM.

Message formats used for NTS traffic and those associated with packet radio have been different in some respects. The ARRL Board of Directors has asked the Ad Hoc Committee on Amateur Radio Digital Communication to study the problem and report back to the Board in January 1988. There are numerous models to examine: NTS radiogram, military communications procedures, electronic mail, etc. Complicating the problem is our need to have a message protocol that is appropriate for multimedia use; eg, CW, packet, and phone. Undoubtedly, the solution lies in an analysis of what the originator and addressee needs in a message format, followed by medium-specific protocols, and a protocol for translation between media.

The League filed with the FCC on June 3 for special temporary authority for 45 stations to use unattended automatic operation of their HF packet stations for a period of 6 months. That should provide the HF packet net with virtually 24-hour coverage within the constraints of ionospheric propagation without the necessity for an operator to be present. If the experiment is successful, a permanent rule change could result. This would permit full exploitation of HF for long-haul connections between VHF local area networks.

It is gratifying to see packeteers eager to provide a true public service by operating VHF and HF PBBSs for NTS traffic. It is equally encouraging to see the died-in-the-wool brass pounders getting TNCs and discovering how this new medium can play its role in message handling. The keys to success are education, experience and cooperation. It's happening.—W4RI

A Simple and Effective Filter for the 10-GHz Band

By Glenn Elmore, N6GN
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On the road to improved station performance at 10 GHz, it becomes desirable to choose a narrow-band, weak-signal mode in favor of the more prevalent broadband operation. Besides attaining accurate frequency control, whether by direct phase lock or by multiplied crystal-derived local oscillators, it is necessary to provide a means of removing the image signal that is generated as a result of the mixing process. On receive, the image noise (and signals) degrade the system noise figure and sensitivity. On transmit, half of the transmit power is in an unwanted sideband—which may even lie outside of the amateur band.

One way around the image problem is the use of an image-reject mixer. Such a mixer can provide 20 to 30 dB of rejection, but it may be more complex to build than is desired.

As an alternative to this approach, an easy-to-build, low-loss band-pass filter is presented here. The design intent for this filter was a 10,368-MHz passband center and insertion loss considerably lower than 3 dB (since 3 dB is the amount to be gained by removing the image). Also, I wanted it to reject an image as close as 100 MHz by at least 10 dB. Finally, I tried to keep fabrication as simple as possible and to use readily available materials.

Different Approaches

In an effort to come up with a simple solution, I investigated a number of approaches. The microstrip and stripline filters I tried were not easy to adjust, and they generally seemed to have high attenuation. Finally, I tried waveguide filters; the results were better than expected.

Lynn Rhymes, WB7ABP, and I built two types of waveguide filters. Both were 3-section, 0.1-dB-ripple, Chebyshev response. One used inductive posts in the broad wall of the waveguide, the other inductive irises. The posts were made from sections of standard brass tubing available at hobby stores; the irises were cut from standard 0.010-inch brass shim stock. See Fig 1.

As a relative newcomer to waveguide use, it was a pleasant surprise to see how nice waveguide is to work with. Losses are extremely low, and performance seems to be directly related to construction accuracy and tolerance. For the post filters, I had the luxury of a milling machine to accurately drill the holes in the broad wall of the waveguide. Since the frequency response of the filter is directly related to the spacing between the posts, this needs to be done accurately.

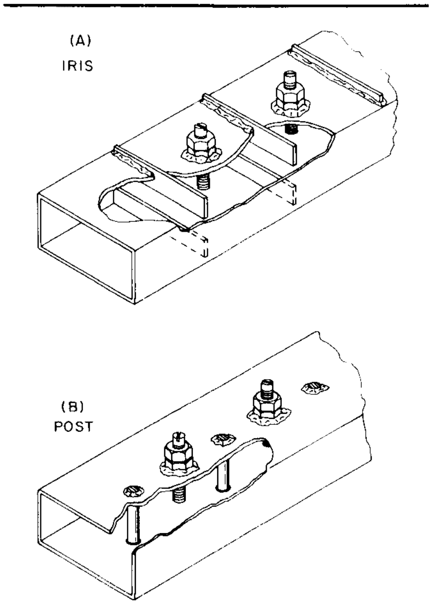


Fig 1—The drawing at A shows a cutaway view of an iris-type waveguide filter. The drawing at B shows construction of a post-type filter. The post-type filter proved to be easier to build and adjust.

Not everyone has a mill available and hams love to "tweak," so I added tuning screws in the center of each section. These screws only lower the frequency of the resonators, so if you are going to make an error in dimensions, make the post spacing too small, not too large! Note that the screws distort the fields inside and are lossy, so minimum protrusion of the screw into the guide is desirable. If close tolerances are held, very little adjustment is required.

The inductive iris filters did not work quite as well as the post-type. They showed slightly higher insertion loss, perhaps because of the larger amount of poorer conductor (brass and solder) in the guide. In addition, the cuts in the guide are difficult to make accurately. Ideally, the cuts should be no wider than the shim material. I finally settled on the post-type filter because it worked better and was somewhat easier to build than the iris type.

Construction

Fig 2 shows the filter design and construction details. Fig 3 shows the completed unit. The post diameters determine the coupling between sections, and exact equations were not available for a filter of 1% bandwidth. Since the brass hobby tubing comes in steps of 1/32 inch, I used the nearest-to-calculated size and adjusted post spacing slightly to center the filter response.

The advantage of this type of filter lies in the fact that the hard part has been done by the waveguide manufacturer. Waveguide tolerances are so good that the outcome probably rests in how precisely the post holes can be positioned. Errors in post positioning primarily affect the tuning.

All filter posts were soldered in place, but a press fit might be possible for those with the equipment. Be careful not to deform the guide, particularly in the area of the resonators. Do not substitute different tubing diameters unless you are prepared to redesign the filter!

It takes a little careful layout work to build this filter successfully. A magnifying glass or microscope is handy to correctly position the holes. I used a microscope and a hand center punch to position each hole prior to drilling. In the case of the larger post holes, I drilled with a smaller size bit first. Be careful to center the posts in the broad wall of the guide. Off-center posts will lower the frequency of the resonator, possibly below 10,368 MHz and out of tuning range. I have an excellent filter centered at 10,225 MHz with this problem!

I soldered the filter together with a high-voltage iron. Soldering is not particularly difficult since the posts are a good fit in the holes. Use enough heat to get solder to flow and make a good contact, but don't use so much solder that there is any excess inside the guide.

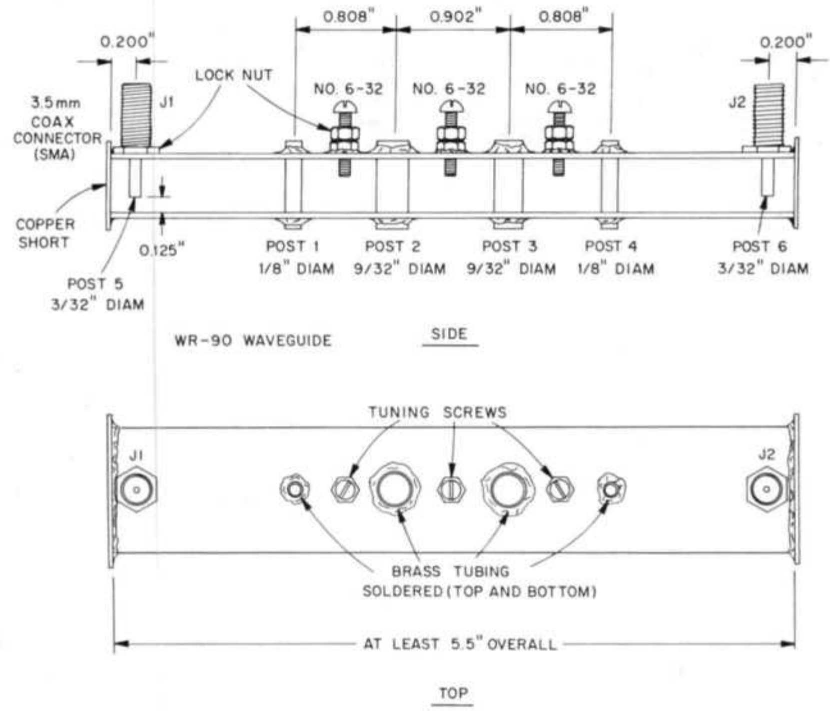


Fig 2—Design and construction details of the post-type 10-GHz filter. Materials required are:

1) J1, J2—Flangeless 3.5-mm SMA connector (M/A-COM 2058-0000-00 or equiv).

2) Post 1, Post 4—1/8-inch OD, 1/32-inch wall brass hobby tubing, 0.75 inch long.

3) Post 2, post 3—9/32-inch OD, 1/32-inch wall brass hobby tubing, 0.75 inch long.

4) Post 5, post 6—3/32-inch OD, 1/32-inch wall brass hobby tubing, 0.275 inch long, soldered onto J1 and J2 center pins.

5) 5.5 inch (or longer) section of WR-90 waveguide. Inner dimensions are 0.4 × 0.9 inch.

6) Three no. 6-32 brass tuning screws, with nuts.

7) Two pieces of copper flashing, each 1.2 × 0.6 inches, for the end caps. Brass is usable with slightly higher insertion loss.

If the correct brass tubing is not available, brass or copper rod stock could be used and turned down to dimension on a lathe. Soldering might be a little more difficult, but should still be possible. Use of a hot plate or stove top might make the job easier.

Brass is the preferred material for the tuning screws, although there is very little difference between brass and steel if only a little tuning is necessary. The broad wall is drilled and tapped for the screw. Alternately, you could drill the hole in the broad wall to pass the screw body and solder a nut on the outside of the wall. This is actually what I did on most of the filters built. In either case, use a locking nut to secure the tuning screw position once tuning is completed.

Coaxial Connectors

If the filter is going to be used in a coaxial system, waveguide-to-coax transitions must be included at both ends. The transitions to coax are made by extending the center-pin length of a 3.5-mm flangeless connector with 3/32-inch-diameter brass tubing to form a probe into the waveguide. Trim the Teflon® dielectric material back until it is flush with the body of the connector before soldering the tubing to the pin.

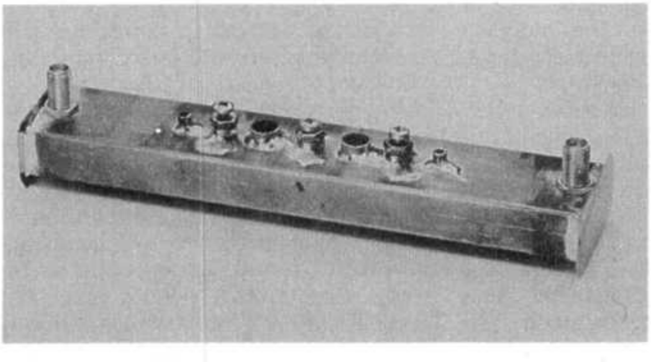
Drill and tap the broad wall of the guide for the connector and probe assembly. It is screwed into the wall 0.20 inch from the shorted end of the guide. The gap between the end of the probe and the far wall of the guide should be 0.125 inch; this means that the probe protrudes 0.275 inch into the guide. Use a locking nut to hold the connector in position.

The final assembly step is to short each end of the guide. Solder a cap made of copper flashing to each end. Be sure that the end of the guide is cut square so that there is a good fit. Remember to use enough heat to get good solder flow, but try to keep excess solder out of the inside of the guide.

Filters With Homemade Waveguide

If standard WR-90 guide is not available, it is possible to build the waveguide at home. This is more difficult and loses much of the simplicity of construction, but good performance is still possible.

For fun (?) I made two filters, one out of 1/16-inch PC board material and another from 0.05 inch copper sheet, just to see what was possible if waveguide was not available. With PC board, this was particularly difficult because I had to wrap shim stock around two of the edges of the narrow wall prior to soldering the second broad wall. Also, I soldered "rivets" made from the next size of brass tubing to both sides of one broad wall to ensure contact of the posts. This is necessary since the inside of the broad wall is inaccessible when all four walls are assembled.



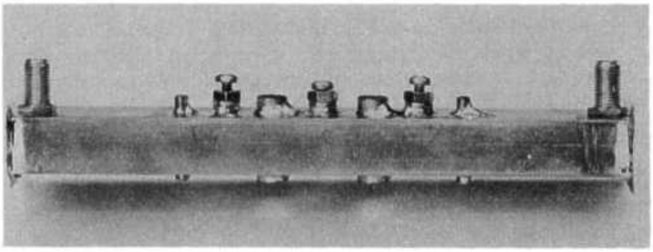


Fig 3—The completed 10-GHz filter is soldered together. Locking nuts prevent the tuning screws from moving once the filter is aligned.

If you decide to build your own waveguide section, try to punch, rather than drill, the holes for the posts. Be very careful in centering the drill bit or punch. A tolerance of 1/32 inch is not close enough! I found that building a 0.4 × 0.9 × 5 inch rectangular aluminum block was a great aid to aligning the pieces prior to soldering. Remember that accuracy here is as important as accuracy in post spacing.

Both filters were really pretty good. For the PC filter, insertion loss was between 1 and 2 dB, the extra loss probably caused by the large amount of solder necessary to tie the whole thing together. Passband shape was a little more rounded than the other filter, probably from additional losses, and ultimate rejection was only 30 to 40 dB instead of the greater than 60 dB performance of the filter made from waveguide sections.

The all-copper filter worked very well, although constructional accuracy was such that it barely tuned as high as 10,368 MHz. Insertion loss, including coax transitions was under 0.5 dB.

With the availability of WR-90 waveguide at ham fleamarkets, a little scrounging will probably save a lot of effort and provide the best performance.

Tune Up

Tuning the filter is fairly simple even with minimal equipment. Generally, tuning for maximum signal, whether using a weak signal source and receiver, or a power meter, will give very nearly optimum results. Because the coupling is automatically set by post diameter, the passband is very flat. If a lower frequency image is to be rejected, the filter can be tuned favoring the high frequency side of signal frequency by backing all screws out slightly. This will put the unwanted signal furthest down the filter skirt. If a swept measurement system is available, a very good technique is to adjust for lowest SWR on both input and output. This also gives the lowest insertion loss.

When building a coaxial filter, if possible, tune it up in waveguide first. Then lock the tuning screw in position. This will allow the coax-to-waveguide transitions to be set properly. Adjustment of the probe depths is actually the more difficult aspect of tuning the filter. Setting the probe depth with a measure before final assembly and soldering and marking threads on the 3.5-mm connector to allow proper reassembly is a good idea.

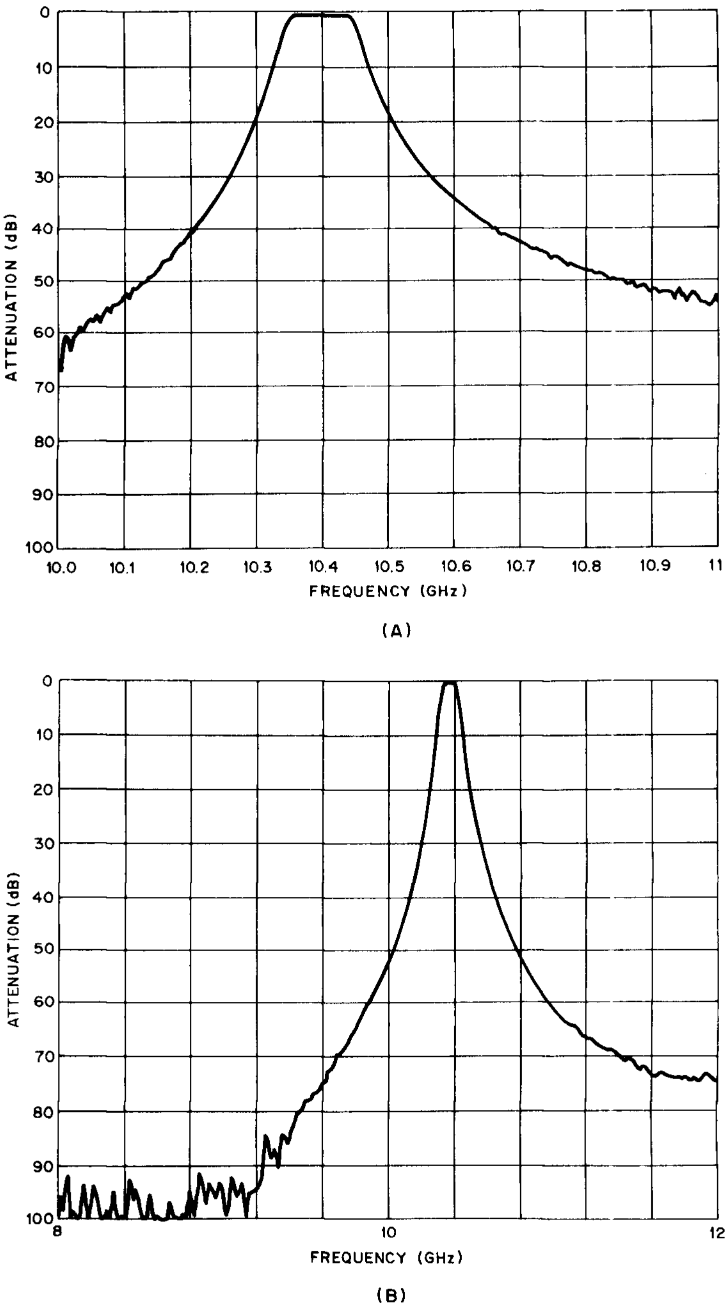


Fig 4—The plot at A shows the performance of the 10-GHz filter close in. At B, a broader frequency view of a second filter shows the excellent stopband performance.

Performance

The plots in Fig 4 show the measured results. This includes the coax-to-waveguide transitions. When measured in waveguide, prior to addition of the transitions, the insertion loss was below 0.5 dB and the ripple around the design goal of 0.1 dB. The transition dimensions are the result of some previous experimentation with PC board horn feeds for the 4-foot station antenna at N6GN and have not been carefully chosen. These transitions account for the bulk of the loss; if someone has some better designs, please publish them. More effort here should improve overall performance. Incorrect probe depth makes the passband and insertion loss look terrible. On every occasion that a completed filter showed a problem, the trouble was traced to the probe setting.

If your 10-GHz station uses only waveguide, the coax-to-waveguide transitions may be omitted and performance will be even better. In such a case, this filter can be built right into the feed line to the antenna since the system degradation from insertion loss is negligible. To

Continued on page 15.

Experiments In Signal Improvement With Fractional-Wavelength Diversity Reception

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By erecting two close-spaced antennas to feed dual receivers, a significant improvement ratio (× 22) in sustaining effective communication during marginal fading conditions can be had, as compared to a single antenna/receiver setup. This arrangement is known as *diversity reception.* Diversity reception with small antennas is an area generally unexplored by Amateur Radio operators.

The Nature of Fading of HF Signals

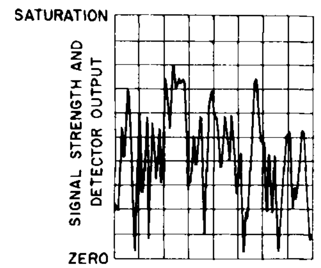
Radio operators frequently despair when their signal gets lost in the noise floor of CW, AM, RTTY (FSK), SSB or FM. Each mode has a different lower limit of its signal-to-noise (S/N) ratio. AM is the worst because, in addition to background noise, distortion in the detected audio can render a link unintelligible even when the carrier is evident.[1] SSB, FSK and FM have significantly higher S/N ratio limits than AM.[2]

New techniques used in AMTOR and packet operation solve some of the effects of fading by use of automatic error correcting encoding. Spread-spectrum transmissions multiply the S/N ratio by the process gain (typically 20 dB), but a lower noise limit may arise from multipath signal propagation.[3] Diversity reception, on the other hand, can help the "old" modulation methods.

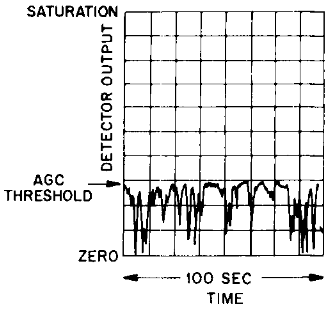
Fig 1A shows a 100-second recording of the detector output voltage, or average AM demodulation, produced by a typical communications receiver. The AGC is disabled to show the true variation in signal as a result of fading effects. The recording in Fig 1B was taken over a similar time interval and shows the result of AGC action compressing all signals above the threshold. Each trace excursion from the AGC threshold toward zero results in maximum receiver gain and deteriorated S/N characteristics.

Causes of Fading

There are three general categories of fading: deep, selective and polarization. Deep fades occur when one or more skywave reflections between the transmitter and receiver completely disappears. Usually a broad band of frequencies is affected, and the fluctuations in the received signals may be described as similar to a Gaussian noise source.[4] The horizontally layered nature of the atmosphere can also contribute to deep fading by virture of variations in the atmospheric refraction.[5]



(A) WITHOUT AGC



(B) WITH AGC

Fig 1—AM detector average output voltage, or carrier level for a 20-m signal. The receiver at A has a fixed RF gain. The dots on the scope trace are the sampling values used in the statistical analysis. B is the same as A, but with the receiver's AGC active. Signals below the threshold occur at maximum receiver RF gain.

The undulating reflective nature of the ionosphere creates moving areas at the earth's surface where there are zero signals. As these nulls pass an antenna, loss of signal or fading can occur. One practical solution to this problem has been to apply *space diversity* with antennas and receivers located many wavelengths apart, with use of the output from the receiver displaying a greater signal strength.[6] Some early installations used three antennas at the vertices of a 1500-foot triangle.[7] (Obviously impractical for an average ham station.)

Selective fading is a narrow-band phenomenon. Especially noticeable with AM is the audio distortion that occurs when fading affects one sideband more than the other, or even the carrier proportion, thereby upsetting the demodulation process in the receiver detector.[8] SSB exhibits great immunity to this kind of audio distortion; this is one reason SSB remains popular.[9]

Selective fading is highly localized and is most frequently the result of signals following multiple paths to an antenna. The signals combine in various amounts of additive or subtractive interference. Patterns of maxima and minima constantly move by an antenna, and frequent fades with durations of 15-150 seconds exist. Ground reflections are another source of multipath.

One transmitter's signal may arrive simultaneously at an antenna from two or more angles and path lengths. By doing so, the signals can add to zero because of phase cancellation in the received radio waves. Because spatial dimensions are involved, a signal at a slightly different wavelength may not result in a null, even if the ray-path geometry to the antenna is the same. *Frequency diversity* is employed to minimize this effect. It requires using two or more transmitters to send the same modulation on different frequencies. Multiple receivers are needed, although the single necessary receiving antenna affords a simplification over space diversity. In diversity receivers, the best signal is used as the output.

One other source of fading is caused by rotated polarization of the received radio wave. Although interaction with the earth tends to favor incoming signals with vertical polarization, skywaves may arrive with various polarizations. *Polarization diversity* systems involve at least two antennas: One antenna is oriented for maximum pickup of vertically-polarized signals and the other for horizontal.

Commercial communications systems use a combination of diversity systems. Quadrature diversity, for example, uses two spaced antennas and two frequencies.[10]

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[1] Notes appear on page 9.

Fractional Wavelength Space Diversity Experiments

Deep fades are a problem for Amateur Radio operators, but are accepted as an inevitable part of communicating. Selective fading often produces frequent signal losses that operators erroneously interpret as short term.

Experiments were conducted to learn if small-dimensioned space diversity systems could be effective in reducing the traits of selective fading. Two four-foot untuned vertical antennas spaced five feet apart were used with two identical communications receivers (Yaesu FRG-7700s) centered between the antennas at the level of their bases. Signal reception was measured for various signal frequencies ranging from 7-18 MHz.

Receiver linearity is demonstrated in Fig 2A when one antenna fed both receivers. The AGC in each FRG-7700 was disabled and the detector voltage, with the audio modulation filtered out, was used to give an X-Y deflection on the screen of a storage oscilloscope. One receiver detector deflected the trace vertically; the other in the horizontal. Both receiver outputs were sampled simultaneously by pulsing the scope beam intensity once per second, and the resulting deflection registered as a dot on the screen. (Sampling points appear as "beads" on the trace in Fig 1A.)

Note the linear result extended from zero signal (at the lower left of the pattern) to maximum (at the upper right end of the line of dots.) When each receiver was connected to a separate antenna, the received signals were poorly correlated as shown by the scattering of dots in Fig 2B. It is precisely the lack of correlation at low signal levels that makes diversity receivers effective: Both signals do not fade to zero at the same time. The data shown in Fig 2B, as a basis for diversity, was similar for SSB, FSK, RTTY and CW.

The circuit shown in Fig 3 was used to gather comparative data for the analysis of many reception conditions. The AGC circuit of each receiver was disabled. The RF gains were carefully balanced and adjusted for each recording so that the maximum received signals did not saturate either receiver. The detector pick-offs to the op amps did not affect the normal operation of the receivers.

Because of the continuously varying nature of the received signals, statistical means were used to evaluate the data. The premise of space diversity to be proved was that the output of receiver 1 OR receiver 2 would be, on the average, higher than one receiver alone. A germanium diode, D1, coupling receiver 1 to the receiver 2 output, served as a linear OR function. A relay was synchronized with the scope sweep such that the signal strength samples, taken each second, would be sorted on the screen. A typical recording is shown in Fig 4A. Receiver 1 samples appear on the top half; the OR samples are displayed on the bottom half.

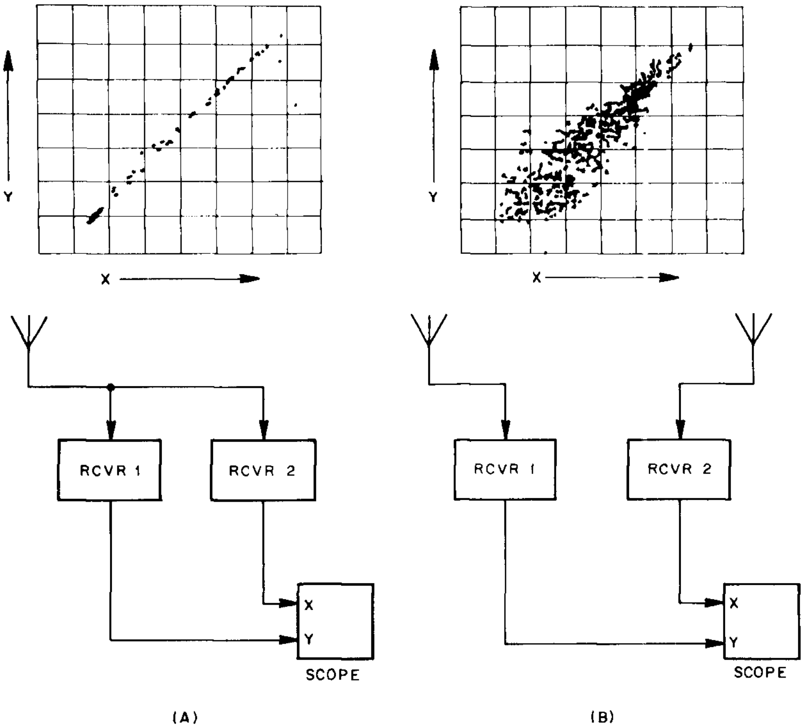


Fig 2—The linearity of two similar receivers is displayed on a storage scope at A. Each dot is a sampled detector output representing the signal level present at the antenna terminals at a given instant. At B, two antennas separated by five feet show poorly correlated signal levels—the basis for space diversity. Lower signals at one antenna occur at an instant of higher signals at the other. The RF gain of the receivers was constant in both figures.

In Fig 4B, the differential distributions of signal strengths, derived from the samples in part A, show an increase in the proportion of samples from the OR combination, which have higher signal strengths than those from one receiver alone. An important measure of performance improvement is obtained from the drop-out occurrences, or signal levels below the threshold of AGC action (AGC reference), in Table 1.

Averaged results from many measurements are shown in Table 2. The signal strength sample percentages are directly proportional to the total *time* the signal reception was sustained at those levels.

The linear OR combining of the two receiver/detector outputs resulted in S levels at or above the AGC threshold 91% of the time. (For signals from zero up to the AGC threshold, the receiver has constant maximum gain. [S = 1 dB on the FRG-7700 S meter.] Greater signals caused a decrease in gain.)

Table 1

Signal Drop-Out Comparison

Receiver 1 only	17%
Both receivers with OR	3%
Improvement Ratio	5.7

The S/N ratio decreases rapidly when the signal drops below the threshold of AGC action as in Fig 1B. The second column of Table 2 shows nearly a third of the signals (29%) had a decrease in its S/N ratio when a single receiver was used, but only 9% displayed a decrease when both receivers were used.

Complete loss of communication occurs when the signals drop to zero. This happened 19% of the time for a single receiver, but less than 3% for two receivers. The improvement ratios are valid for fast fades because the data samples were measured during five-minute periods.

Diversity Receiver

Measurements were made with the functional diversity receiver system shown in Fig 5. Low-pass RC filters function to strip modulation and noise from the detector outputs. The filters couple the detector outputs to op amp drivers to provide noise suppression by cross coupling

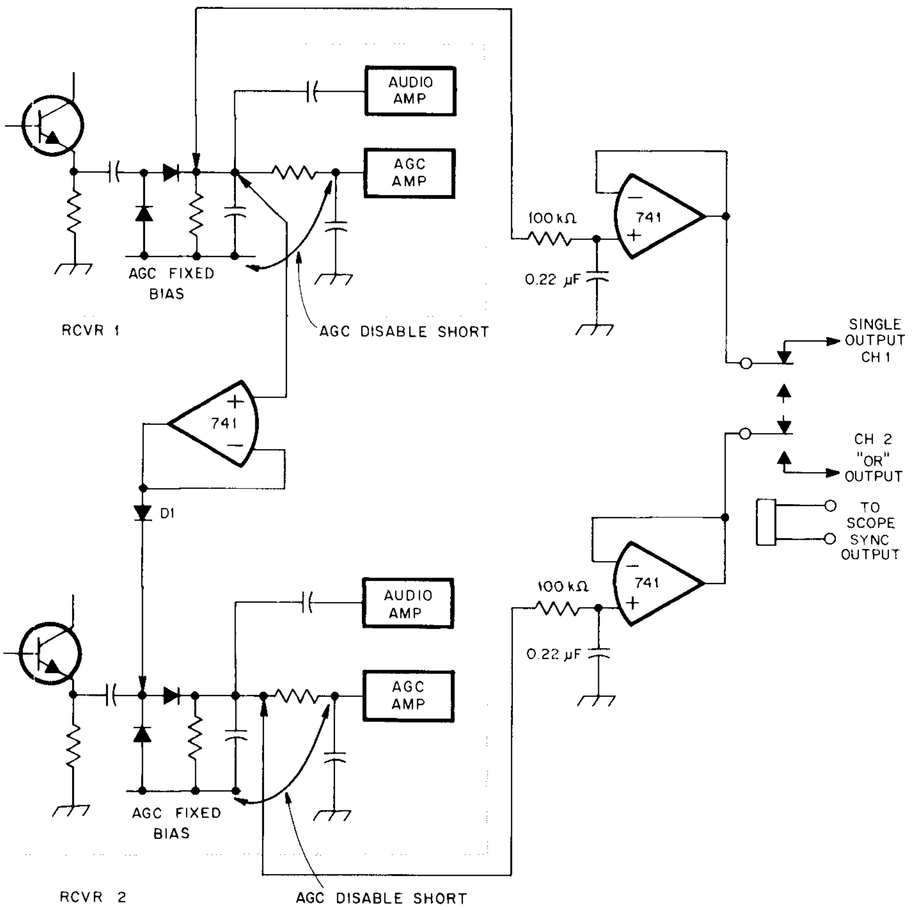


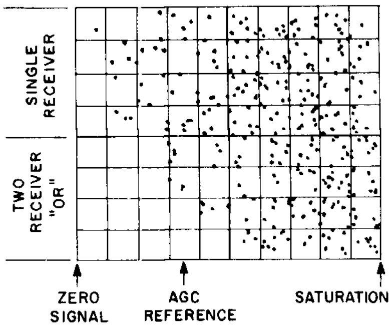
Fig 3—This circuit was used to gather comparative data for the analysis of many reception conditions. It was attached to the detector circuits of two similar receivers that were operated with fixed RF gain. The relay provided samples every second from the single antenna and receiver output, then alternated with the second receiver output that contained the linear combination of its antenna signal OR the first receiver.

Table 2

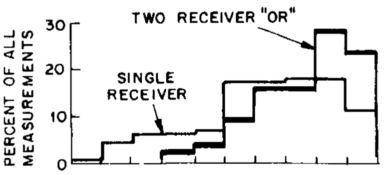
Summary of All Signal Measurements

		S ≥ AGC Threshold	S < AGC Threshold	S = Zero
No AGC [fixed gain]	One RCVR	71%	29%	19%
	Two RCVR OR	91%	9%	3%
	Improvement Ratio	1.3	3.2	6.3
Fast AGC	One RCVR	14%	86%	32%
	Two RCVR	43%	57%	1%
	Improvement Ratio	3.1	1.5	32

(S refers to signal strength at the time of sampling.)



(A) SIGNAL STRENGTH SAMPLES



(B) DISTRIBUTION ANALYSIS

Fig 4—A shows the data obtained with the circuit of Fig 3 using a storage scope sequenced to separate the two outputs of the circuit. At B, the distribution of signal levels. The OR samples show a shift of outputs toward higher levels most of the time.

through germanium diodes, D1 and D2, to the opposite receiver's AGC circuit.

For example, if detector 1 has more +dc (stronger signal) developed than detector 2, the circuit will decrease the gain of receiver 2 and reduce both the weaker signal and noise appearing in the receiver 2 output. Conversely, a larger output from detector 2 will suppress the receiver 1 output.

The normal audio channels of the two receivers may be electrically combined in an audio mixer to provide an electrical output. The diversity effect may be also derived from listening to the sound from both speakers simultaneously: The gain reduction of the receiver with the weaker sound output effectively transfers all of the perceived sound to the "good" receiver output. (This is a psychoacoustical effect. Along the same lines, a 0.2 dB difference in sound level between the two speakers will cause the weaker sound to appear to be as much as 13 dB fainter.)[11]

D3 and D4 in Fig 5 are not needed for diversity action. Instead, they output data for direct comparison with the previous experiments summarized in the top of Table 2. The average performance of the circuit is shown in the bottom half of Table 2. There is a large increase in the

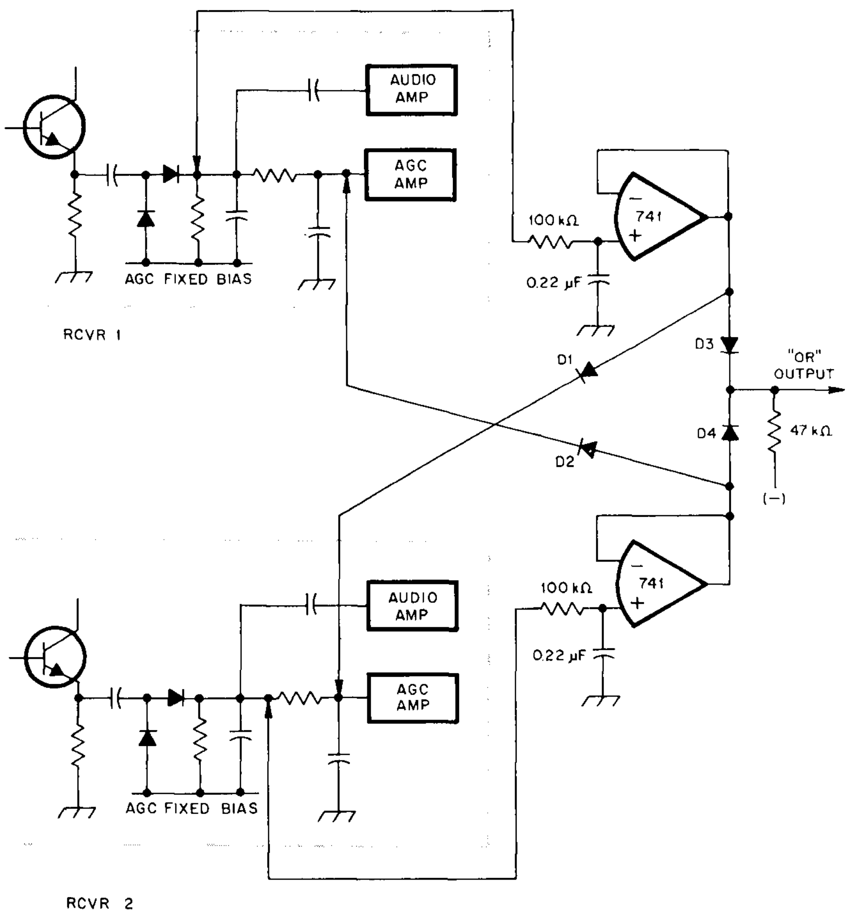


Fig 5—Diversity receiver interconnection features cross-coupled RF gain control through D3 and D4 to drive the AGC circuits of the opposite receiver. The receiver with the higher output reduces the signal and noise in the other receiver, leaving the system output to come from the receiver exhibiting a better S/N ratio. The OR output was used only to obtain performance data recordings.

number of times the signal is less than the AGC threshold (86%) as compared with the fixed gain condition above (29%). This is attributed to the AGC response that produces a rapid decrease in gain during a signal increase, followed by a relatively slow restoration to higher gain. (The FRG-7700 fast AGC attack time constant [gain reduction] is 0.1 second; gain restoration time is 1 second.) This causes frequent lowering of many marginal signals to below the threshold voltage.

Despite the skewed statistics, as a result of AGC action, the comparisons are valid. Note the reduction of instances of zero signal from 32% with diversity to but 1% with the circuit. Depending upon the S/N ratio of the radios used and propagation conditions at the time of the experiments, that extent of dramatic improvement may not always be realized.

Single tuning was easily accomplished by disconnecting the first local oscillator (PLL) of the slave receiver and connecting the LO output of the master receiver to both first mixers. Exactly the same LO frequency was thus used in both receivers. If fixed crystal-controlled BFO is used in the receivers, a common BFO is not needed.

Summary

This study included many 40- to 80-meter stations. Close-spaced, untuned vertical-whip antennas connected in a space diversity system provided significantly better signal level more than 90% of the time, as compared with a single antenna and receiver. The most dramatic improvement is that of clarifying fast fading AM signals. All modulation modes, including CW, SSB and RTTY had fewer drop outs to zero signal.

Modern receivers with a synthesized frequency setting are easy to couple to achieve single-dial tuning for diversity operation. To achieve optimum performance, AGC characteristics of the receivers may have to be altered. Overall, space diversity systems with close-spaced antennas may put new life into our current communication modes.

Notes

[1] Noise includes receiver, environment, atmospherics, and so on, exclusive of heterodynes.

[2] D. Roddy and J. Coolen, *Electronic Communications*, 3rd ed, (Reston: Reston Publishing Co, 1984), pp 313-15, 373.

[3] R. Dixon, *Spread Spectrum Systems*, 2nd ed, (New York: John Wiley & Sons, 1984), pp 10, 38.

[4] S. Rice, "Distribution of the Duration of Fades in Radio Transmission," *The Bell System Technical Journal*, Vol 37, No. 3, 1958, p 582.

[5] J. Strickland, "Site Diversity Measurements of Low-Angle Fading and Comparison with a Theoretical Model," *Annals of Telecommunication* (France), Vol 36, No. 7-8, 1981, pp 457-463.

[6] M. Tant, *The White Noise Book*, (Luton, England: White Crescent Press, Ltd, 1974), p 16.

[7] W. Everitt, *Fundamentals of Radio & Electronics*, 2nd ed, (Englewood Cliffs: Prentice-Hall, 1958), p 473.

[8] R. Shrader, *Electronics Communication*, 3rd ed, (New York: McGraw-Hill Book Co, 1975), p 416.

[9] E. Pappenfus, W. Bruene, and E. Shoenike, *Single Sideband Principles and Circuits*, (New York: McGraw-Hill Book Co, 1964), p 21.

[10] See note 6.

[11] J. Roederer, *Introduction to the Physics & Psychophysics of Music*, 2nd ed, (New York: Springer-Verlag, 1975), p 81.

Bits

New Product Allows High-Speed Transmissions Over Telephone

Teltone Corp recently introduced a component set that allows OEM design engineers to add data communications to telephone wiring. Designated the M-922 Data-Over-Voice (DOV) device set, the product uses carrier techniques to transmit and receive full duplex data on a single pair of wires—without interfering with telephone use. With an M-922 set at each end, asynchronous data speeds of up to 9600 bps can be achieved over distances of a mile on regular 26-gauge telephone wiring.

The set consists of a modem IC, a line transformer and a special pair of filter inductors. Teltone plans to add synchronous capability through the use of a sync/async converter chip that incorporates channel testing circuitry and microprocessor control features. For more information, contact Teltone Corp, PO Box 657, 10801-120th Ave, NE, Kirkland, WA 98033-0657, tel 206-827-9626.

Satellite Tracking Using A Single Axis

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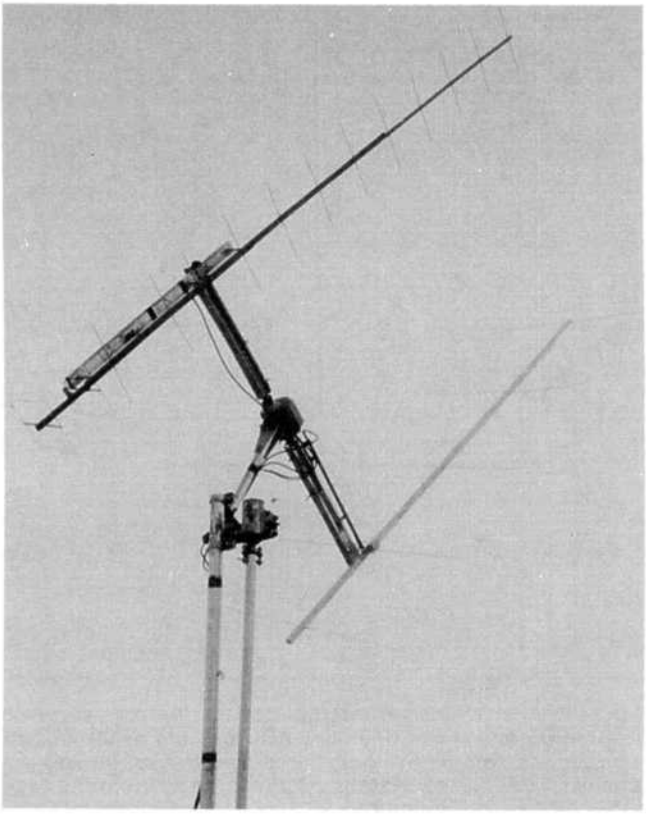
Tracking the J-band FO-12 satellite is difficult. FO-12 has a high angular rate of up to 16 degrees/minute, and it is necessary to use a relatively narrow-beam UHF down-link antenna of 30 degrees or less. Under these conditions it is difficult to optimize antenna position by simply adjusting for maximum signal strength. Also, signal strength variations caused by satellite instability and antenna polarization cause additional errors.

In this article, I describe an alternate approach. A single axis sector scan is positioned in line with the predicted satellite trajectory, and an electronic programmer sequences the scan rotator such that the satellite is tracked to within 10 degrees of its actual position. A particular satellite pass is set up using OSCARLOCATOR data, and the scanning sequence is initiated by switching the programmer on when the bird arrives at the line-of-sight position.

The mechanics for positioning the single axis in line with the trajectory is shown in Fig 1. Elevation and azimuth are set from OSCARLOCATOR spiderweb data. Elevation is the angle resulting from the closest satellite trajectory point, and azimuth is a line normal to the trajectory. As an example, one 90-degree elevation trajectory from my location indicates a spider web entrance of 310 degrees, and an exit reading of 130 degrees, making an azimuth set point of 40 degrees. The programmer is turned on when FO-12 is at the horizon, a 310-degree location, and it automatically tracks to 130 degrees, the opposite horizon.

Programming is accomplished by first delaying the actual scan for a predetermined period, followed by a step scan with equal time intervals between each step. My Alliance U100 antenna rotator circles in 10-degree increments and dictates the step scan size. The controller provides an adjustable delay period of up to five minutes and an adjustable stepping period of 56 seconds



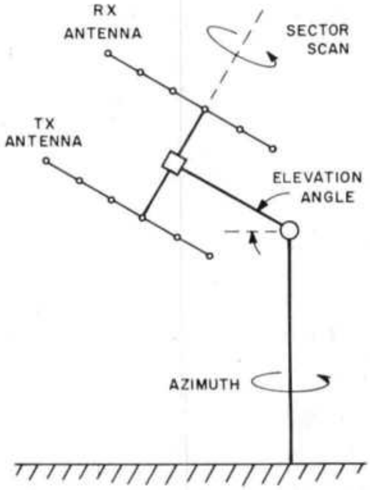


Fig 1—A single axis sector scan is positioned in line with the predicted satellite trajectory. An electronic programmer sequences the scan rotator in 10-degree increments to track FO-12.

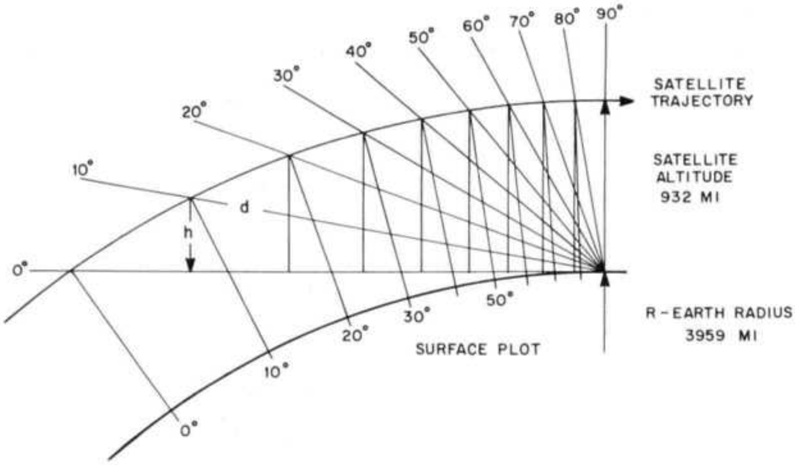


Fig 2—This master graphic was used to develop satellite tracking data for Figs 2-5. Line d is the minimum satellite distance referenced to the elevation angle; h is the satellite altitude referenced to line of sight.

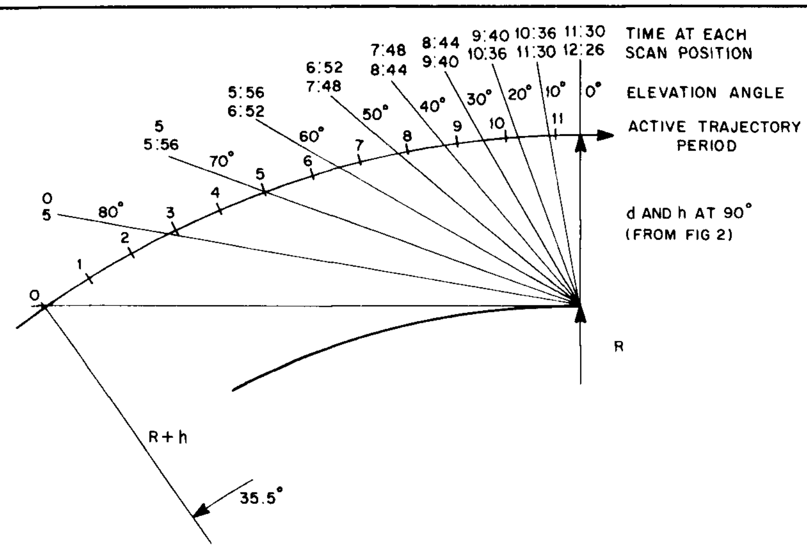


Fig 3—Conditions for a 90-degree elevation angle. The rotator is held in this position for 5 minutes. It has a scan rate of 10 degrees/56 seconds, a scan sector of ±80 degrees, and an active period of 23 minutes.

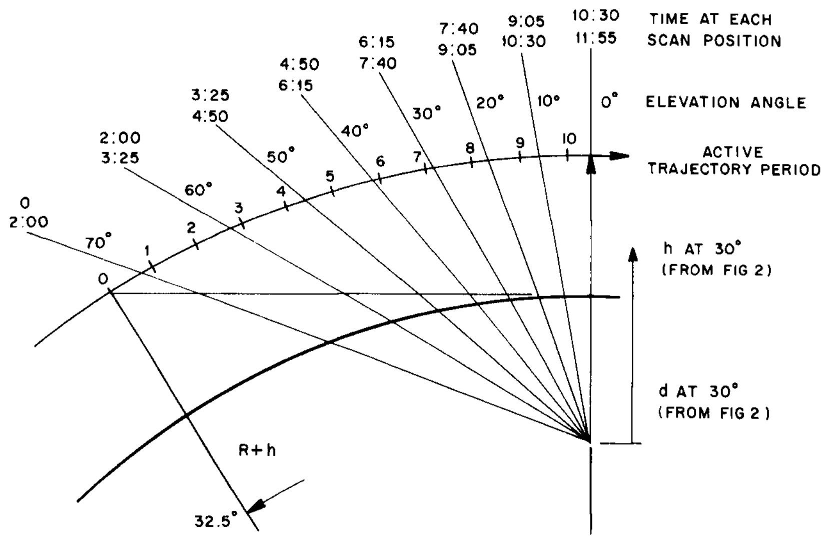


Fig 4—Conditions for a 30-degree elevation angle. The rotator is held in this position for 2 minutes. It has a scan rate of 10 degrees/85 seconds, a scan sector of ±70 degrees, and an active period of 21 minutes.

Table 1
Set Point Data

Elevation *in degrees*	**Hold** *in minutes*	**Scan* Step Period**	**Sector** *in degrees*	**Period**
90	5:00	0:56	±80	23
70	4:30	1:00	±80	23
50	3:30	1:04	±80	22
30	2:00	1:25	±70	21
20	2:00	1:30	±60	18
10	2:00	2:00	±40	16
5	1:00	2:30	±30	12

*Alliance U100 rotator with 10-degrees scan/step.

to 2.5 minutes. These adjustments are labeled in terms of elevation angle, where elevation is defined as the maximum angle for a given trajectory. In the 90-degree example, the controller is set for a five-minute initial delay followed by a 56-second scan stepping sequence.

Scanning Parameters

Scanning parameters were gathered using simple graphics. Approximations involved in using this method were not considered critical because these variances were small as compared to the antenna beam width and the 10-degree resolution of the rotator. Fig 2 is a master graphic that was used to develop satellite tracking data for Figs 3, 4 and 5. They show the antenna position as compared to the satellite position for any time during the active trajectory for elevation angles 90, 30 and 10 degrees. Table 1 shows complete set data for a number of elevation positions.

Sector scanning has an inherent error because horizon-to-horizon scanning is possible only with a 180-degree sector. Fortunately, the error is acceptable. The worst case is the 30-degree condition where the limited 140-degree scan ends up 10 degrees above the horizon. This error can be partly compensated for by setting the elevation value to 25, rather than 30 degrees.

Figs 6 through 9 show how to use an OSCARLOCATOR for obtaining the necessary tracking data. For example, Fig 7 assumes the satellite crosses at 170-degrees west. At my location in California, this crossing will result in a line-of-sight entrance eight minutes later with an azimuth reading of 260 degrees. As the satellite passes overhead, the maximum elevation reading will be 50 degrees, and it will exit at 55-degrees azimuth, 30 minutes from the crossing time. To track the bird, I first set the elevation to the 50-degree maximum satellite elevation position, and the azimuth to a line normal to the trajectory, or, to 340-degrees. The tracker controller has two panel potentiometers: One varies the hold period, and the second varies the scan step period. Both are calibrated in terms of elevation and, in this example, they are set to 50. The controller also has two panel switches. One switch overrides the controller, and the other initiates the sector scan sequence. The override switch is momentarily turned on to permit slewing the sector-scan rotator to the +80-degree position. The switch is then turned off and the rotator position knob is turned to the −80-degree position. The final step is to turn on the sector-scan initiation switch when the bird is at the line-of-sight entrance—in this case the crossing time plus eight minutes. No

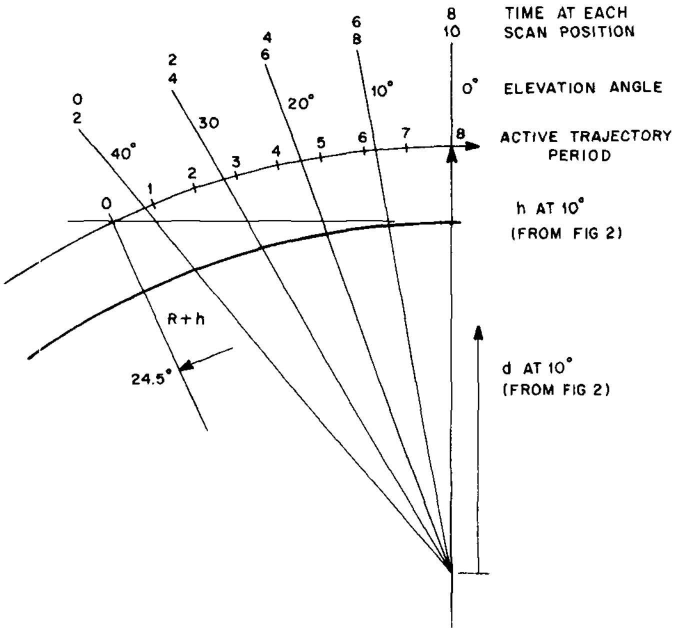


Fig 5—Conditions for a 10-degree elevation angle. The rotator is held in this position for 2 minutes. It has a scan rate of 10 degrees/2 minutes, a scan sector of ±40 degrees, and an active period of 16 minutes.

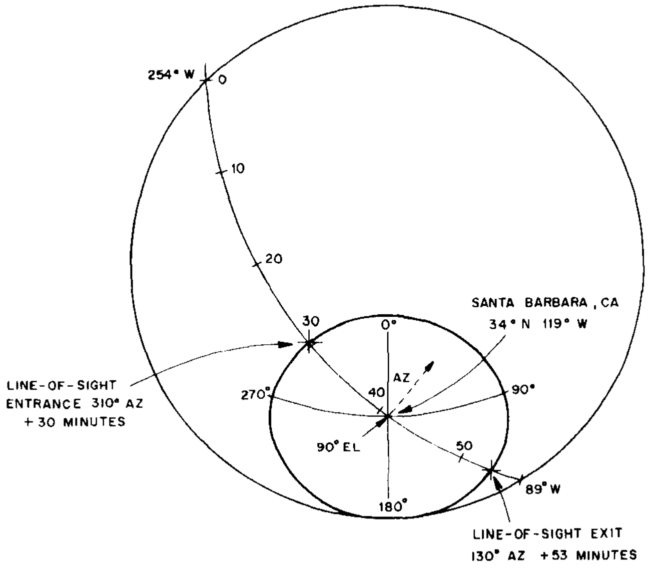


Fig 6—An OSCARLOCATOR will help supply the necessary tracking data for the satellite. In this Fig, we see a 90-degree elevation and a north-to-south trajectory. Azimuth is 40 degrees, the sector scan is ±80 degrees, and the initiate sector scan is +30 minutes.

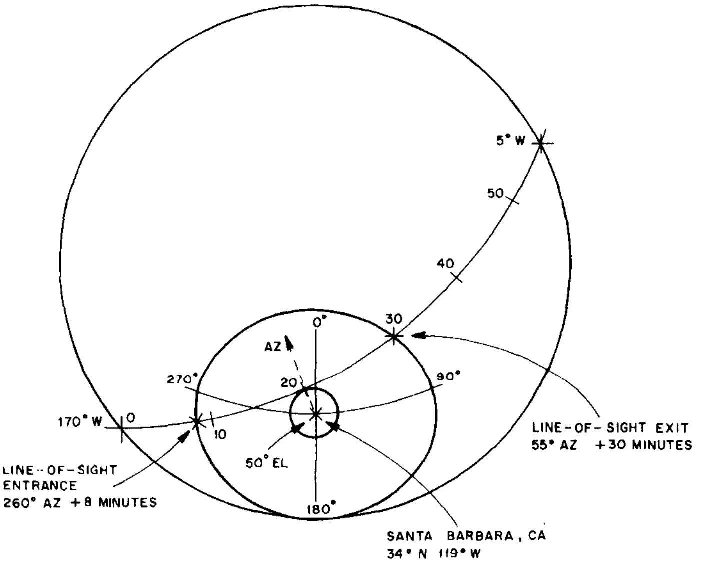


Fig 7—OSCARLOCATOR data shows a 50-degree elevation and a south-to-north trajectory. Azimuth is 340 degrees, the sector scan is ±80 degrees, and the initiate sector scan is +8 minutes.

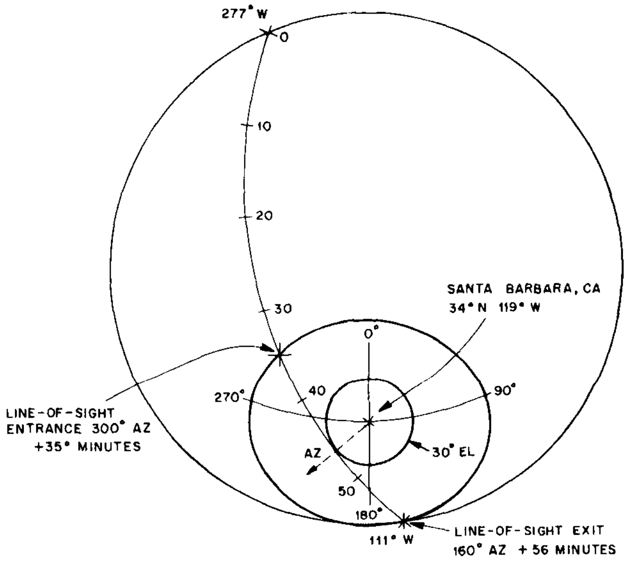


Fig 8—OSCARLOCATOR data shows a 30-degree elevation and a north-to-south trajectory. Azimuth is 230 degrees, the sector scan is ±70 degrees, and the initiate sector scan is +35 minutes.

further adjustments are required during the line-of-sight pass.

Controller Circuitry

A schematic of the controller is shown in Fig 10. It uses two dual-CMOS timers, U1 and U2. Timer 1 is the initial delay timer, variable from 1 to 5 minutes. Timer 2 is triggered on by timer 1 and provides the scan step rate, variable from 56 seconds to 2.5 minutes. Timer 3 is triggered on by timer 2, turning on the U100 rotator power. The rotator power is turned off by the 10-degree scanner marker pulse. On the Alliance U100, the marker pulse is 50 V ac that contains a notch when the rotator passes through a 10-degree position (Alliance U100 cable terminal no. 4). Referring to Fig 11, D1, D2 and Q1 full-wave rectify the ac voltage; Q2 and Q3 amplify and clip this signal to produce a clean positive gate during the 10-degree marker period. This marker gate triggers on timer 4, which makes a 0.8 second pulse; the trailing edge of the pulse turns off the scanner driver, timer 3. The purpose of timer 4 is to time the scanner turn off so that it stops midway between two marker positions. This prevents angular readout errors when the scan direction is reversed. The 0.8-second delay is based upon the con-

Continued on page 15.

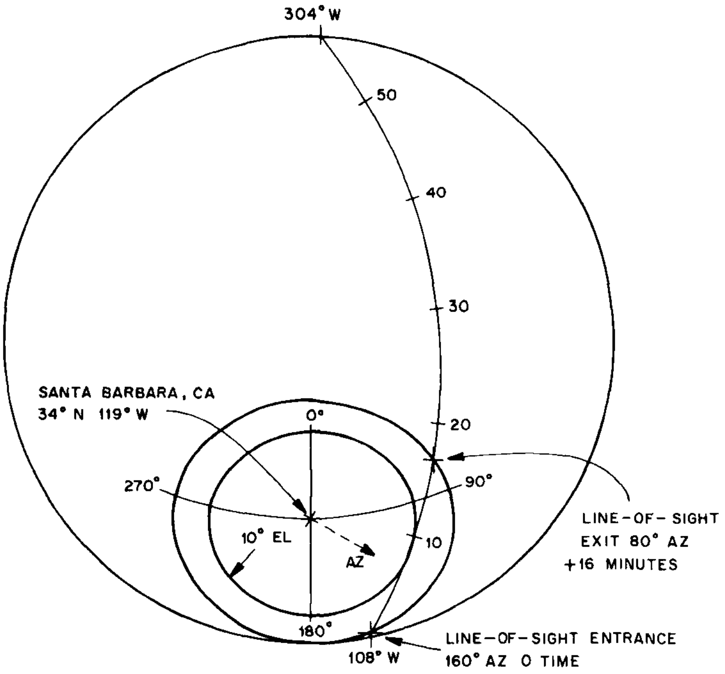
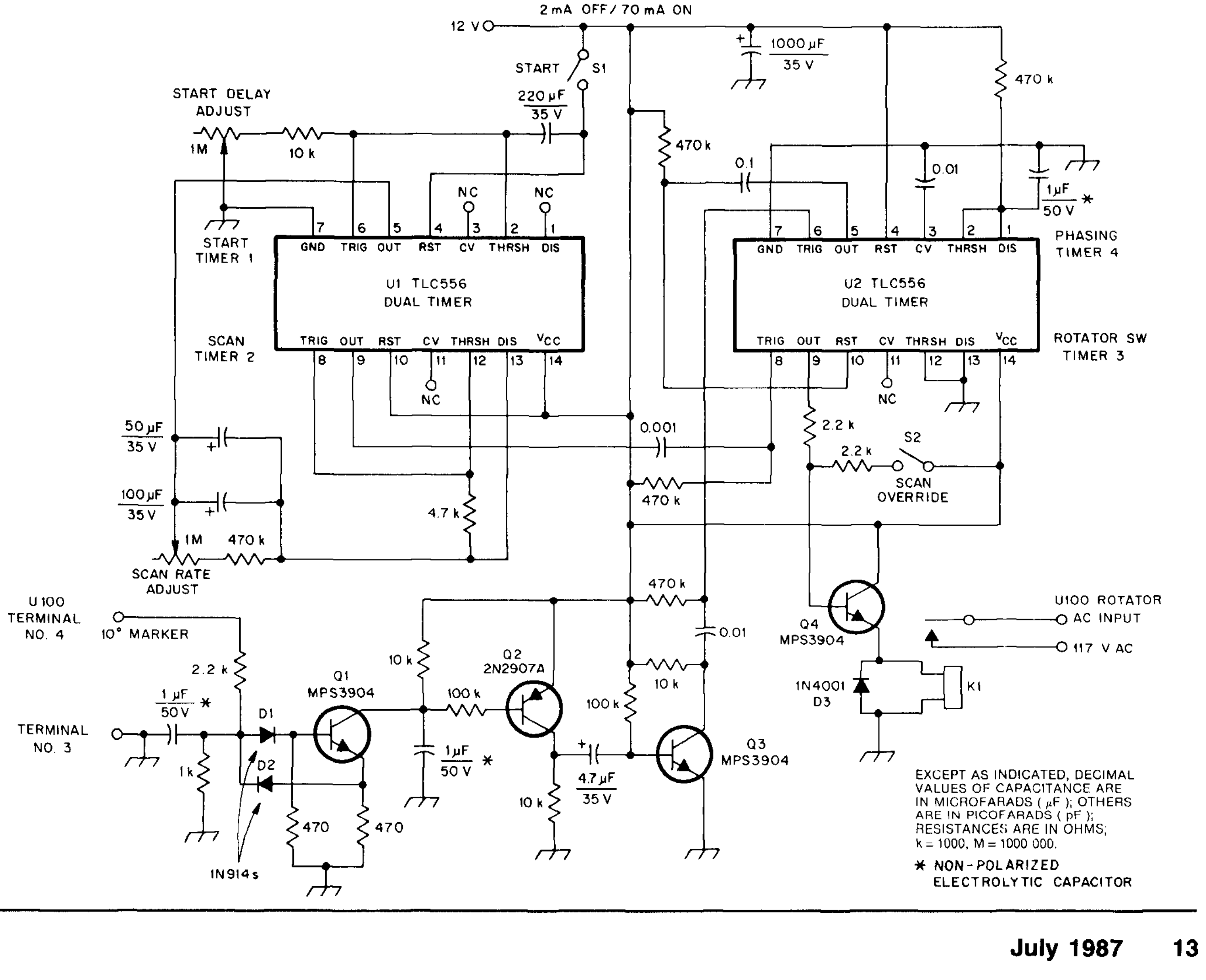


Fig 9—OSCARLOCATOR data shows a 10-degree elevation and a south-to-north trajectory. Azimuth is 120 degrees, the sector scan is ±40 degrees, and the initiate sector scan is at 0 time.

Fig 10—The controller schematic. The PC board measures 3 3/8 × 2 7/8 inch (RS 276-168). Small value capacitors are 50-V disc ceramic. Large value capacitors are 35-V electrolytics. Fixed resistors are ¼-W, 5%. Parts are available from your local Radio Shack outlet or Mouser Electronics, 11433 Woodside Ave, Santee, CA 92071, tel 619-449-2222.

Parts List
D1, D2—1N914 diode (RS 276-1122).
D3—1N4001 diode.
K1—12 V relay (RS 275-206).
Q1, Q3, Q4—MPS3904 NPN transistor (RS 276-2016).
Q2—2N2907A PNP transistor.
S1, S2—SPST switch.
U1, U2—TLC556 dual-CMOS timer (RS 276-1704).



>50
Focus on technology above 50 MHz

By Bill Olson, W3HQT
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Burnham, ME 04922

Introduction to 9 cm

With plenty of commercial equipment available for all bands through 2304 MHz and also 10 GHz, the frontier for rolling your own equipment would seem to be the 9-cm (3300- to 3500-MHz) band. The narrowband calling frequency is generally accepted to be 3456 MHz (3 × 1152 MHz) or conveniently enough, 1296 + 2160 MHz. This month, I'm going to describe some of the current happenings at 9 cm and present practical schemes for getting on the band.

Activity on the 9-cm band is springing up all over the US and Europe, as well as in other areas of the world. The first EME contacts have already occurred on the band using relatively small antennas and less than 100 W of transmitter power (congratulations to W7CNK, WA5TNY, KD5RO and K0KE). By the time you read this, who knows what the terrestrial record will be! If the right stations had been equipped with only simple gear last November, a 1000-mile contact would easily have been made in the US, judging from what was accomplished on 1296 and 2304 MHz. Of course, the only way we're going to find out what can be done is to get more stations on the air.

There are plenty of equipment possibilities for this band because of the close proximity of the TVRO satellite downlink band at 3.7 to 4.2 GHz. A lot of commercial components manufactured for TVRO service in consumer quantities (and therefore at inexpensive prices) can be used for amateur service as well. The 9-cm band is at the crossover point where silicon devices start to run out of steam and GaAs devices are loafing along, so we find both in designs at this frequency. The following, by no means a complete treatment, is meant to impart a few ideas and show how simple it really is to get on the band. The rest is up to you.

Circuit Concepts

Work yourself schemes. Some of the bigger VHF contest stations have been using schemes for years where they use a crystal-controlled RF source as both transmitter and receiver LO. A keyed oscillator lineup in the 500 to 1200 MHz range is used in conjunction with a transistor or diode multiplier and filter to generate a signal at, for example, 3312 MHz. The transmitter feeds this signal into the antenna, while the receiver mixes an incoming signal at 3456 MHz with the 3312-MHz signal to provide an IF output at 144 MHz. The "remote" station transmits on 3456 and receives at 3312 using the same scheme in reverse. This technique is simple and effective for contest stations with remote "rovers." Working a third station becomes a bit difficult, though...

Transverter schemes. Although quite a few transverter schemes have been devised, most take advantage of the fact that a 1296-MHz signal can be mixed with the 2160-MHz LO signal from a 2304-to-144-MHz transverter to get to 3456 MHz. A block diagram of a typical transverter is shown in Fig 1. With a little ingenuity, a simple transverter may easily be pieced together from existing equipment.

On receive, the circuits often use readily available TVRO doubly balanced mixers and LNAs to provide a low-noise receiver. Used, working TVRO LNAs with GaAsFET front ends and four or five stages of gain are available dirt cheap these days. They come with waveguide input and a built-in ferrite isolator, but they can be modified for amateur use by removing the waveguide flange and isolator. Another popular mod is the use of a waveguide-to-coax transition (the "easy way out"). Since power is normally supplied to the LNA through the RF output connector, a bias "T" must be inserted in the output line, or the unit must be modified to bring out a separate power line. You should be able to realize a 1.5 dB or better noise figure and 40 dB or more gain with very little trouble.

The transmit side of the transverter can use the same TVRO doubly balanced mixer, and then low-level gain can be obtained through the use of silicon MMICs. The Avantek MSA series and other silicon MMICs will work at 3456 MHz up to around 10 mW. The next stage could be a Siemens CGY 40 GaAs MMIC, which will run about 50 mW at this frequency.

From this point on, the schemes vary considerably. There are internally matched power GaAsFETs that will work nicely at this frequency. Al Ward, WB5LUA, has developed a nice circuit using Avantek IMFETs for up to 10-W output at 3456 MHz. For CW or FM service (class C), there are a number of bipolar common-base devices that can provide 1, 3 or 5 W at 3456 MHz. These devices go by the generic names like 3001, 3003 or 3005 and are manufactured by many microwave transistor houses.

A tube amplifier using a 416B planar triode (remember the old W2AZL 2-meter converters?) has been employed by K0RZ and K0KE in their latest transverter scheme and is apparently available from Fair Radio Sales. This amplifier will put out up to 5 W at 10-dB gain!

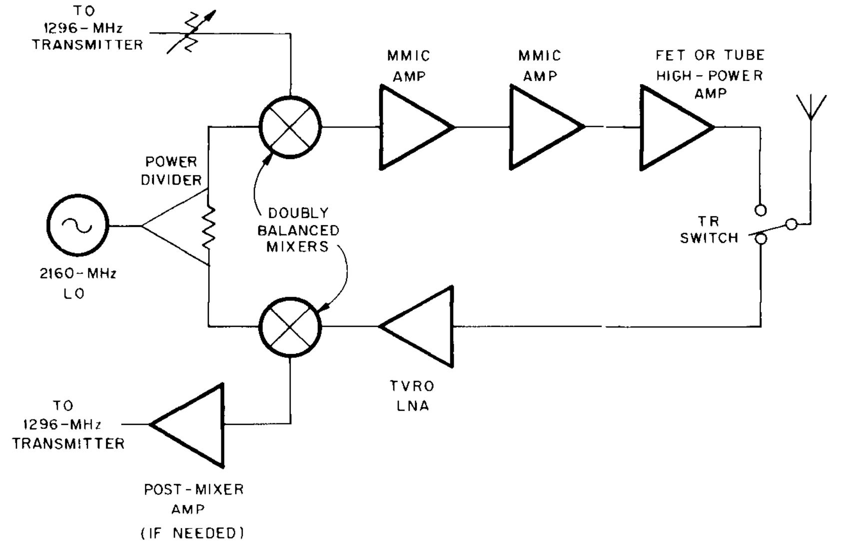

Fig 1—A typical transverter scheme for 3456 MHz relies heavily on existing, inexpensive pieces.

A 2160-MHz local oscillator can be built from a number of published circuits, or one can be purchased from an SSB Electronics distributor (model SLO13). Another possibility for an LO, especially if you want to use an IF frequency other than 1296 MHz, is a phase-locked source manufactured by California Microwave, CTI, Frequency West, Englemann Microwave and others. These sources, sometimes available on the surplus market, lock an oscillator in the 1-GHz range to a stable reference oscillator and then multiply up using an SRD. If you're lucky enough to find one of these gems in the 3-4 GHz range, it makes an excellent LO.

There are so many components available that your transverter scheme will vary depending on what components you have on hand. Here's one example. Dave Mascaro, WA3JUF, had a TVRO LNA and figured that the 45 dB of gain was really more than he needed for his receiver. He dug into the LNA and brought out coax connections between the 2nd and 3rd stages of a 4-stage LNA. He uses the "front end" for the receive preamp and the "rear end" for the low-level transmit stages! What will your ingenious scheme be?

Components

TVRO LNAs are just about everywhere. A used working unit can be obtained from Amateur Electronic Supply. Mixers designed to work in the 2 to 4.2 GHz range can be obtained through Mini Circuits distributors; the most cost effective are model ZAM-42 (with SMA connectors) or model PAM-42 (without connectors). Silicon MMICs are available through Avantek distributors, Mini Circuits and others, and the CGY 40 is available through Microwave Semiconductor Corp. The "magic" 416B amplifier module is available through Fair Radio Sales (part no. ED63919-31).

Antennas and Feed Lines

Although dish antennas are the obvious choice for high gain at 9 cm, the popular loop Yagis and DL6WU Yagi designs have been scaled successfully to 3456 MHz. These antennas represent a way to get moderate gain (18-21 dBi) with very low wind loading. At this frequency, coax losses must be kept to a minimum, so use the lowest loss stuff you can find. Remember, however, that the bigger diameter lines (over 7/8 inch) cut off below 3300 MHz and are therefore not usable. It's best to keep the transmitter close to the antenna in any case! Connectors almost have to be SMA or type N, and most of the popular Transco style 24-V relays will work acceptably at this frequency.

Conclusions

Although the preceding certainly doesn't impart enough knowledge to go out and build a rig for 9 cm, I hope it has started some wheels turning. The enterprising UHF/microwave experimenter should be able to get on 3456 MHz with very little expense and effort using mostly surplus components. I will be glad to provide readers with information on sources or to answer any questions. Please include an SASE.

New 13-cm Column

In addition to >50, I will soon be writing a bimonthly column specifically dedicated to the 13-cm (2304-MHz) band. I would appreciate hearing from any readers active on 13 cm. Any information regarding operating activities, DX, new equipment ideas, new stations getting on the air and so on would be appreciated. See you all next month.

Satellite Tracking Using A Single Axis

Continued from page 13.

dition that the scanner takes 1.6 seconds to scan a given 10-degree sector.

My antenna arrangement is simple. A 15-foot TV mast is rotated by hand for azimuth control, and a worm drive gear box (junk car steering mechanism) is mounted on top for elevation control. Turning a small rod alongside the mast adjusts the elevation position. The U100 rotator is mounted on a two-foot arm connected to the elevation gear box. The down-link 15-element quagi antenna I use is described in *The 1987 ARRL Handbook.*[1] Performance has been good and I hear a reasonable signal from the FO-12 100-mW beacon any time it's in the spiderweb. Antenna position adjustments are not required following the initial set up.

Conclusion

Although the described method requires a second elevation control mechanism, it is far simpler and less expensive to implement than a system based on real-time digital computer computation and control. The ideas presented could be applied to other antenna-rotator arrangements, for example, a Kenpro KR-500 continuous scan elevation rotator. In this case, the electronics controller would differ from the step controller used with the U100.

Notes

[1] M. Wilson, ed., *The 1987 ARRL Handbook*, (Newington: ARRL, 1986), p 33-25.

A Simple and Effective Filter for the 10-GHz Band

Continued from page 5.

eliminate image noise, however, you may need a filter after the preamplifier (for those that have one).

Different Center Frequencies

All filter dimensions change as different frequencies are required. Not only do post spacings change, but the optimum post diameters change, too. For small variations around 10,368 MHz, scaling only the post spacings will probably still provide a good filter. The tuning screws may be used to tune considerably lower, but remember that insertion loss increases as more and more screw threads protrude into the guide. For this reason I suggest scaling the dimensions and building a new filter rather than trying to tune down a great distance.

One application that may be of interest is a local oscillator filter for those who are generating LO signal by multiplication of a lower-frequency crystal-derived source. A 10,080-MHz filter, for example, could be made by simply increasing post spacings to (10368/10080) × 0.808 inch = 0.831 inch and (10368/10080) × 0.902 inch = 0.927 inch.

This type of scaling is not exact, but it should be close enough to provide acceptable performance. This is particularly true if the nearest unwanted harmonic of the fundamental is several hundred megahertz or more away, as is often the case. These dimensions also give an idea of the construction tolerances necessary to achieve good performance.

Simply tuning a 10,368-MHz filter lower with steel tuning screws only resulted in an additional 1 dB of insertion loss, so for many applications redesign may not be necessary.

Summary

This filter is easy to build and adjust to provide excellent performance for amateur 10-GHz work. Several "well placed" holes in the broad wall of a section of standard waveguide and a few minutes of soldering readily available brass tubing posts can give very satisfying results with a minimum of adjustment.

I hope that this design will help to promote narrow-band operation in a truly interesting and exciting portion of the amateur radio spectrum. The ease of construction and adjustment make this approach very useful throughout the amateur microwave, and possibly even into the millimeter range. I would be happy to hear of improvements or extensions of this type of filter for amateur use. Thanks to Lynn Rhymes, WB7ABP, for calculating initial post diameter and spacing values.

Intellectual Properties

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Rectangular Spectrum Modulation

As more and more demands have been placed on the limited radio spectrum, the need for efficient modulation techniques has become acute. Previous attempts at efficient modulation have successfully reduced signal bandwidths, but at the expense of transmission quality. This month's column discusses a digital data FM transmission scheme recently patented by Karl Meinzer, DJ4ZC, that minimizes signal bandwidth without affecting transmission quality, thereby yielding an important improvement in spectrum economy.

Because a digital data signal changes states within very short time periods, it occupies a very broad frequency spectrum. The data being conveyed, however, is transmitted at a finite rate and technically requires only a relatively narrow bandwidth proportional to the data transmission rate. Unfortunately, existing techniques for limiting the bandwidth of digital data signals have had the undesirable effect of reducing the signal's signal-to-noise (S/N) ratio (or more properly, the ratio of energy/bit to spectral noise power). Conversely, attempts to optimize the S/N ratio have resulted in increased signal bandwidth.

In modulation schemes, such as minimum-shift keying (MSK) and various pulse-formed versions of quadrature phase-shift keying (QPSK), bandwidth is minimized by optimizing the shapes of the data pulses. While this approach results in an improved spectral decay at frequencies away from the center frequency, it is achieved at the expense of an increased bandwidth close to the center frequency. Symbol duration in these systems is necessarily considered to be shorter or equal to the bit duration, so an extended spectra for MSK and variants of phase-shift keying has been deemed acceptable.

In prior systems, such as those involving correlative coding and Nyquist filtering, bandwidth has been reduced by symbol expansion beyond a singular bit width. However, this technique necessitates symbol separation by using a suitable linear combination of adjacent symbols, thereby reducing the signal's S/N ratio.

In the Meinzer system, termed by him as Rectangular Spectrum Modulation (RSM), the bandwidth limitation is effected by demodulation of the transmitted narrow-band signal spectrum using periodical zeros of an autocorrelation function of the transmitted spectrum. The effective duration of this function is limited to be less than a predetermined multiple of the pulse duration. The resulting signal spectrum allows channel spacings of about 0.6-0.7 times the inverse bit duration. This represents a three- to six-fold improvement over existing modulation schemes that require channel spacings of 2-4 times the inverse bit duration.

The heart of the Meinzer system is the filters employed in the transmitter and receiver. Before filtering, the transmitter generates a spectrum approximating a Delta function with pulses 5-10 times shorter than the data stream bit duration. The transmitter and receiver filters are designed so that the pulse response of their series-connected combination exhibits zeros after each bit duration. The zeros are then used to decouple individual symbols. This decoupling eliminates crosstalk between symbols since at each bit-sampling point all other responses are zero (provided the data rate has been matched to the filter zeros). The slope selectivity of the filters is chosen so that their pulse response decays exponentially beyond ± 5 bit periods.

To aid in theoretical insight, Meinzer explains that his system can be viewed as reversing the conventional roles of time and frequency. That is, while the spectral function for a data pulse of unit duration is a decaying sine wave, the spectral function in his modulation system is a unit pulse. It is the time function in his system that varies as a decaying sine wave. Although these time functions are theoretically infinite in duration, they do not interfere with each other's demodulation because of the coincidence of their zero crossings, their natural period of decay and the exponential period of decay in the pulse response of the system filters.

Fig 1 shows a block diagram of a transmitter (30) and receiver (40) employing Meinzer's RSM technique. (The numerical representation of various circuit stages were used in the explanation of system operation found in Meinzer's patent.) An incoming digital data stream is passed through data input block 10 to a differential encoder 32 to provide coded data to a frequency modulator 34. Frequency modulator 34 creates an approximating Delta function using pulses 5 to 10 times shorter than the digital data bit duration and passes these pulses to a low-pass filter 26 having the desired response. The signal output by low-pass filter 26 is then mixed with a carrier frequency by a mixer 38 and broadcast.

Receiver 40 receives this spectrum,

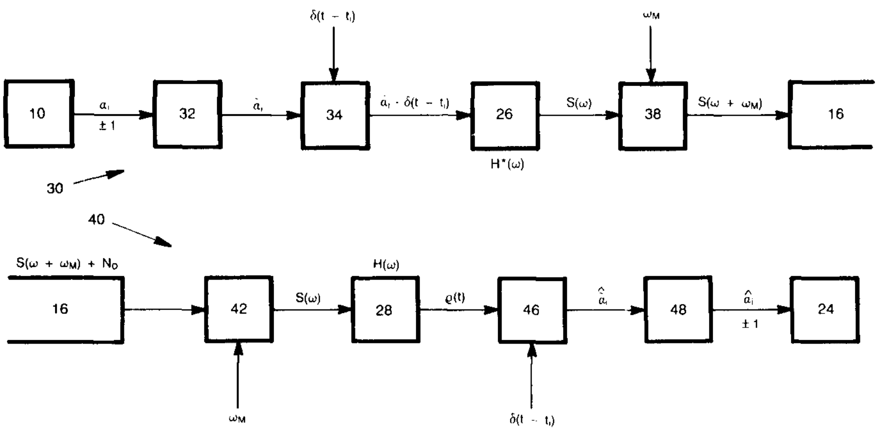

Fig 1—Block diagram of the transmitter (30) and receiver (40) that uses the Meinzer RSM technique. How each section manipulates incoming data is discussed in the text. The numbers assigned to the various circuit stages are those used by Meinzer in his patent application.

together with some white noise, and downconverts it in mixer 42 by subtracting out the carrier frequency. The resulting spectrum is fed into a receiver low-pass filter 28 having the desired response to create the auto-correlation function. The auto-correlation function is then provided to an interrogation gate 46 which is controlled by the Delta function. The demodulated symbols are then fed to differential decoder 48 to decode the symbols and make the recovered digital data available at data output block 24.

The spectrum of a representative RSM system is shown in Fig 2. Operating at a data rate of 10 kbits/s, the single sideband bandwidth is 5 kHz and is 70 dB down at 7.5 kHz. The spectrum of a corresponding QPSK signal is shown in Fig 3 for comparison.

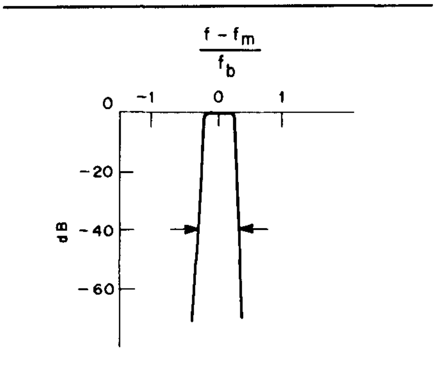

Fig 2—The spectrum of a representative RSM system. Operating at a data rate of 10 kbits/s, the SSB bandwidth is 5 kHz and is 70 dB down at 7.5 kHz.

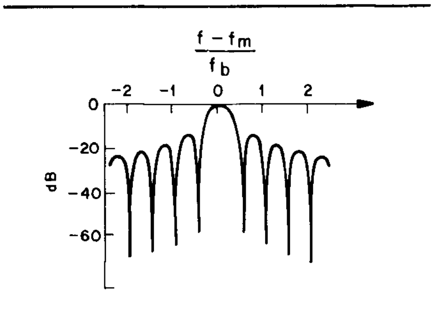

Fig 3—The spectrum of a corresponding QPSK signal.

Meinzer's system can be adapted to both frequency-shift and phase-shift keying. The modulated signal bandwidth can be reduced even further by use of two or four-phase modulation techniques.

Complete details on rectangular spectrum modulation can be found in Meinzer's US patent, number 4,646,323, available from The Commissioner of Patents, Washington DC 20231 for $1.50.

Information on this patented invention is provided here in accord with *QEX*'s stated purposes of (1) providing a medium for the exchange of ideas and information; (2) documenting advanced technical work in the Amateur Radio field; and (3) supporting efforts to advance the state of the Amateur Radio art. The Meinzer invention may not be used, except with the permission of the inventor, until February 24, 2004. Nonetheless, the publicity of this advance in the state of the art will broaden the perspective of amateur experimenters and will promote future technical advances within the amateur community.

Bits

Amateur Radio Operator's Satellite Tracker Accepted For NASA Teacher In Space Project

Congratulations to Roy Welch, W0SL, who has been acknowledged by Southwestern Bell Telephone for his development of a computer program that plots paths of communications satellites circling the earth. W0SL is a network design manager at Southwestern Bell Telephone Company, and his program, ORBITS II, recently gained the interest of NASA's Teacher In Space Project. It will be used in education centers so that teachers and students may predict visual sightings of satellites.

Interested Amateur Radio operators who also participate in satellite communications may purchase the color-graphics version of the ORBITS II program for $35 from AMSAT, PO Box 27, Washington, DC 20044 or from W0SL, 908 Dutch Mill Dr, Manchester, MO 63011. An enhanced color graphics version (ORBITS III) is also available for $45. Sales of the prediction programs are designed to obtain donations for AMSAT to support the construction and deployment of new satellites and promote interest in Amateur Radio.

Both programs operate on either an IBM® PC or IBM-compatible hardware equippped with color monitor and graphics capability. The user simply enters his or her latitude and longitude with the satellite orbital parameters and it's ready to go. The program can also forecast where the satellite will be days or months in advance. Besides tracking satellites, it will automatically move the antennas to follow the satellite's path.—*Tnx Southwestern Bell Telephone*

Feedback

Please make two corrections to my article, "Calculate 5- and 7-Element Filter Components," (May 1987 *QEX*). In the first paragraph of p 4, footnote references 1-8 should read 1-7. And, on p 6, Table 3 is data for a 5-element, 500-ohm low-pass filter.—*Ed Wetherhold, W3NQN, 102 Archwood Ave, Annapolis, MD 21401*

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Advanced Computer Controls, Inc: 20
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