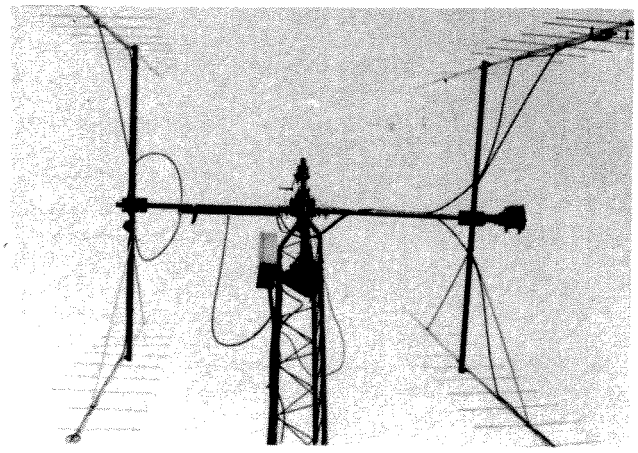
A Basic Approach to Moonbounce

QST July 1985, pp. 18-21

A Basic Approach to Moonbounce



Is moonbounce an esoteric mode beyond the reach of most amateurs? No! Recent advances in amateur equipment have brought EME even closer to the mainstream of Amateur Radio.

By Jim D. Stewart,* WA4MVI

A simple but effective earth-moon-earth (EME or moonbounce) station is now within the reach of most amateur experimenters. With the advent of very sensitive GaAsFET receiving preamplifiers and commercially available high-gain Yagis, many VHF operators are enjoying successful EME QSOs with commercial equipment and relatively small antenna arrays. VHF DX via other modes, such as meteor scatter, sporadic E, troposcatter or ducting, is usually limited to around 1600 miles, and you must wait for Mother Nature to provide a band opening. Worldwide DX contacts via moonbounce, still affected by certain conditions of nature, are limited only by mutual moon visibility.

I'm not going to present an exhaustive "how-to" article on building your own station. Rather, I want to whet your appetite and show you, in general, what is involved. There's more to getting on EME than putting an antenna on your roof and calling "CQ Moonbounce," but I hope to remove some of the mystery that shrouds this mode. Specific information may be found in the reference material listed at the end of this article. I'll also tell you how to get in touch with active EME operators. Contact them for advice. You'll find that most are anxious to attract new blood into the facet of Amateur Radio that they enjoy so much, and will be exceptionally generous in sharing their experiences with you.

What Kind of Equipment Do I Need?

A block diagram of an EME station is presented in Fig. 1. There are as many different arrangements as there are operators, but most follow the format shown. The station can be as simple or as elaborate as you wish. A lot depends on your technical ability and on how much time and money you're willing to invest. I believe that 2 meters is the best band for a beginner to try, so this article is slanted in that direction. Much of the information, however, applies to any band.

The basic station might consist of a VHF multimode rig or an HF transceiver with transmit and receive converters (transverters). Both methods have been used successfully. A good-quality HF receiver with passband tuning, several IF CW filters and an audio filter are desirable. Many EME operators prefer the HF transceiver/transverter route to take advantage of these features. Multimode transceivers are available from the major manufacturers, such as Yaesu, Kenwood and ICOM. Sources of commercial VHF transverters and converters are listed in Table 1. Construction articles detailing transmitting and receiving converters are listed in the references at the end of this article.

A high-power amplifier is necessary for EME operation. Although the legal limit of 1500-W output is desirable, many QSOs

Table 1
Suppliers of Equipment of Interest to EME Operators

Receive and Transmit Converters

Advanced Receiver Research, Box 1242, Burlington, CT 06013.
Microwave Modules, imported by Hans Peters, VE3CRU, Box 6826, Station A, Toronto, ON M5W 1P3, Canada.
Spectrum International, P.O. Box 1084, Concord, MA 01742
The VHF Shop, 16 S. Mountain Blvd., Rte. 309, Mountaintop, PA 18707.
SSB Electronics, imported by The VHF Shop.

High-Power Amplifiers

Henry Radio, 2050 S. Bundy Dr., Los Angeles, CA 90025.
Fred Merry, W2GN, 35 Highland Dr., East Greenbush, NY 12061.

Mast-Mounted Preamps and TR Sequencers

Advanced Receiver Research.
Angle Linear, P.O. Box 35, Lomita, CA 90717.
Landwehr, imported by Henry Radio.
Mutek Ltd., imported by The VHF Shop.
SSB Electronics, imported by The VHF Shop.

Note: This is a partial list. The ARRL and *QST* do not endorse specific products.

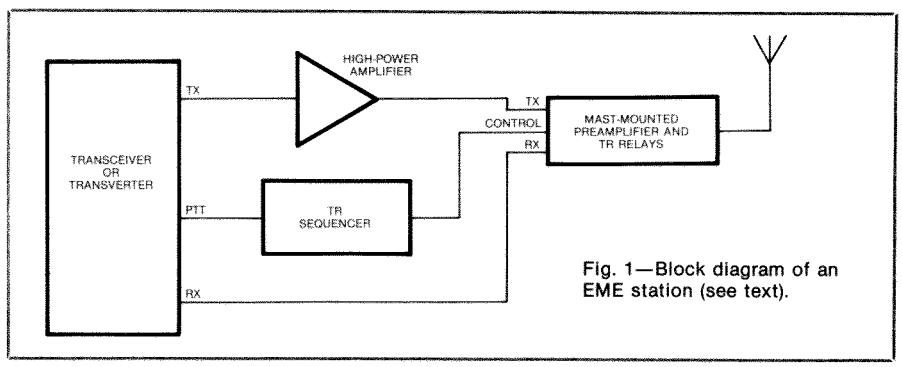


Fig. 1—Block diagram of an EME station (see text).

*20 Country Club Dr., Greer, SC 29651

have been made with amplifiers operating in the 500- to 1000-W range. There are few high-power amplifiers available commercially or surplus (see Table 1), so many operators "roll their own."

Good transmission lines are a must at VHF and above. EME signals are extremely weak, and every watt of RF delivered to the antenna really counts. Most operators locate their EME arrays on short towers, as close to the shack as practical, to minimize line loss (more on antennas later). Hardline, preferably with a corrugated jacket for improved flexibility, is desirable for the transmit line, especially above 2 meters. Surplus ¾-inch, 75-Ω CATV Hardline has excellent characteristics and can be used. Thoroughly check surplus transmission lines before use. Type-N connectors are recommended for use on 144 MHz and up. Leave the "UHF" connectors on your low-band gear.

You'll need at least one high-power RF relay to switch your antenna from transmit to receive. A suitable relay will have Type-N connectors and will be rated for at least the output of your power amplifier. Beware: Relays are usually de-rated as frequency increases. A relay rated for 1 kW at 30 MHz may be rated for only half that power at 144 MHz. These relays may prove difficult to find. Surplus relays with Type-N fittings are often available at flea markets, in ham ads, or from other amateurs interested in VHF/UHF work. It pays to get to know other amateurs interested in EME; they often know where to find hard-to-get station components. Transco, Amphenol and Dow Key are three popular manufacturers of high-power VHF relays.

Received EME signals are extremely weak, so a tower-mounted preamplifier is recommended to reduce the system noise figure to a minimum. Many EME operators find it convenient to mount the preamplifier and antenna relays in a weatherproof box near the top of the tower. The basic arrangement is shown in Fig. 2. Full construction details may be found in the references, and some manufacturers listed in Table 1 can provide ready-to-go remote preamplifier/switching boxes.

Most authorities recommend that two transmission lines be run to the antenna—separate lines for transmit and receive. The transmit line should be Hardline, as discussed before, but the receive line may be RG-8 coaxial cable, or Belden 9913. The relays should be arranged so that they must be energized to receive. This method provides good isolation between the preamplifier and the transmitter, makes it impossible to transmit into the preamplifier if a relay or control line fails and offers some assurance that the final amplifier will transmit into a load if a relay or control line fails.

The remote preamplifier that we have been discussing should be a low-noise GaAsFET type. Generally, the lowest noise figure available will mean the best sensitivity, but in practice, a noise figure of 1 to 1.5 dB is good on the 2-meter band.

GaAsFETs are susceptible to damage from RF and stray pulses, so care must be taken to protect them. The 12-V dc line powering the preamp can be made from RG-58 or other shielded cable to prevent unwanted voltages from entering on the power input line. A separate power supply should be used to power the relays to prevent transient spikes from reaching the GaAsFET line. Many multimode transceivers transmit briefly when they are first turned on, so you must be sure that you can never, however briefly, transmit into your preamp and receiver.

TR switching must be accomplished in the proper order to avoid equipment failures. The station switching control box should be set up so the antenna relays are switched before transmitter power is applied to avoid "hot switching" the relays or transmitting into no load. Similarly, RF should be removed before the relays return to the receive position.

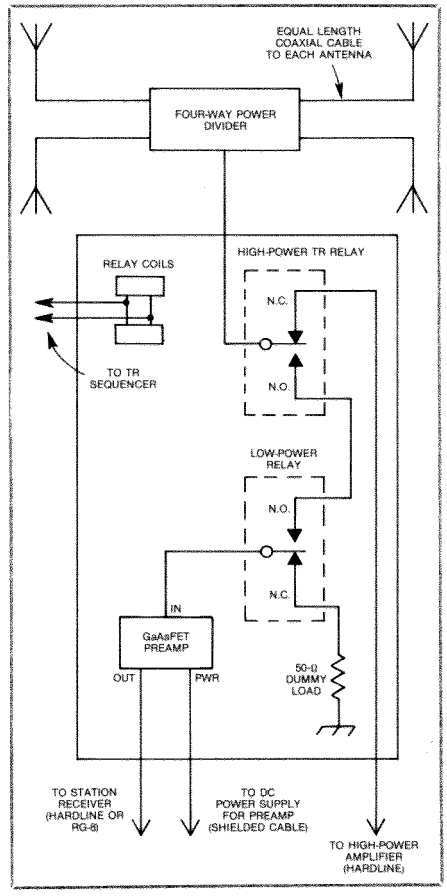


Fig. 2—A weatherproof tower-mounted preamplifier is important in EME work. Usually, the station TR switching is also mounted at the tower.

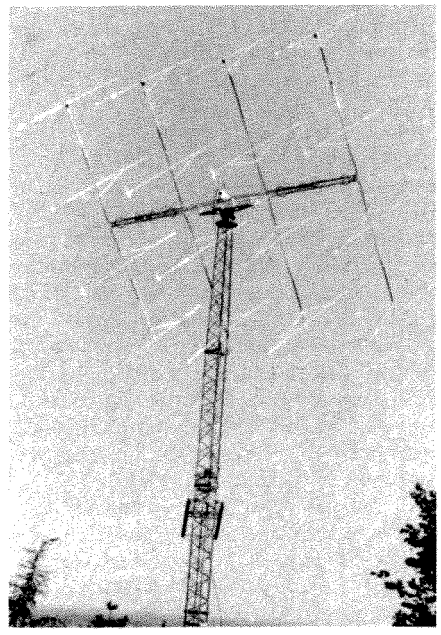


Fig. 3—This 2-meter EME array at I2ODI is built from 16 long-boom Yagis. Arrays like this are great to have, but smaller antennas can work, too.

What Kind of Antenna Will Work?

A simple array of four Yagis, aimed visually at the moon, is a good way to begin. If you keep the array on a short tower near the operating position, you will be able to aim the antenna visually. You can even use an "arm-strong" method for pointing.

Antenna arrays can be as simple or as elaborate as the builder desires. The dish antennas often associated with EME work are generally used at 432 MHz and above; a dish of adequate gain would be 35 to 40 feet in diameter at 144 MHz. Yagis are the most popular antennas at 144 MHz, but quads, collinear arrays and quagis are also used. Fig. 3 shows a 2-meter EME array carried to extremes, but many successful contacts have been made with antennas like that shown in Fig. 4.

Fig. 5 shows the details of a simple but effective EME antenna system. The minimum recommended antenna array gain for 144-MHz EME work is about 20 dB. You may use commercial antennas such as the long-boom, high-performance Yagis manufactured by Cushcraft and KLM, or you may build your own. You will probably save yourself some disap-

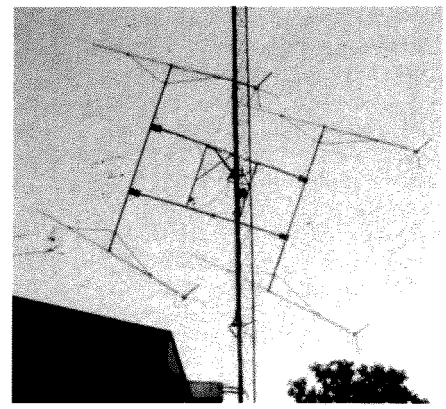


Fig. 4—K7KOT has incorporated his EME array into his existing antenna system by side mounting it on a tower.

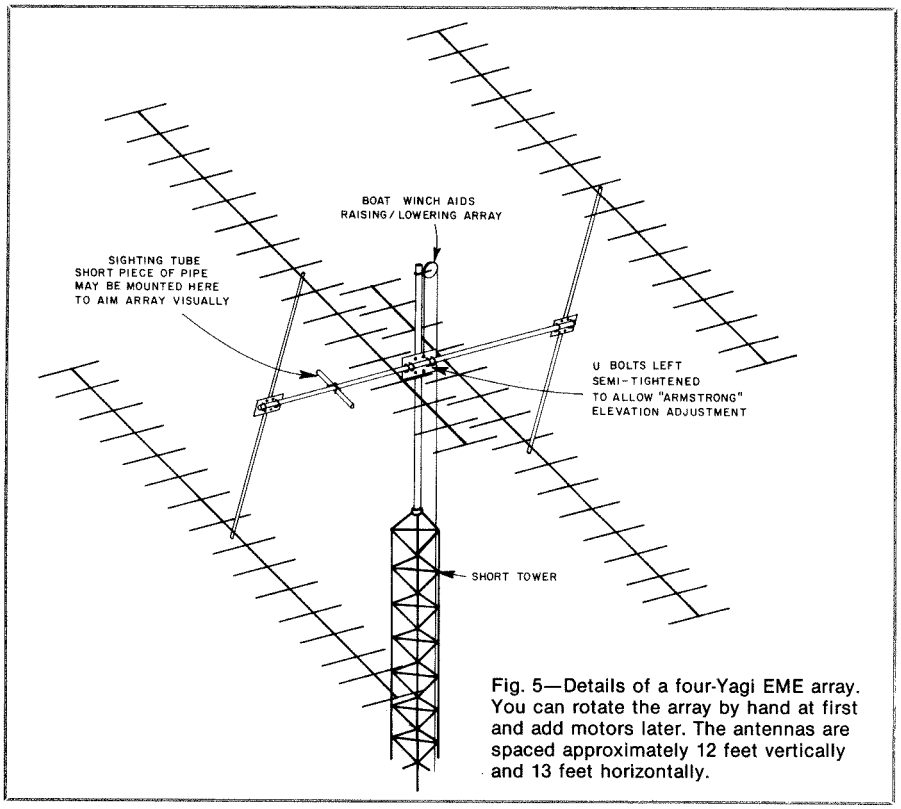


Fig. 5—Details of a four-Yagi EME array. You can rotate the array by hand at first and add motors later. The antennas are spaced approximately 12 feet vertically and 13 feet horizontally.

it closest to the earth. At this time, path loss is lowest and you may hear your signal echo off the moon about 2.5 seconds after releasing your key. It is not necessary to hear your own echoes to have a QSO. Often the suggested antenna gain of about 20 dB will not be quite enough to hear your own echoes, although many stations with larger arrays can copy you. You should be able to hear many of the larger stations with an array of four Yagis with about 20 dB of gain. Listen for activity, especially on those days listed in Table 2. If you can hear stations, chances are good that your system is working.

Operating Techniques

Almost all EME work is done on CW. Like most of the specialized areas in Amateur Radio, EME has its unique problems, so a unique operating style has been established to enhance communications. I'll present the basics here. EME is an extremely weak-signal mode, so experience first with meteor scatter and SSB/CW DX modes on VHF is very helpful. Patience is required above all; such factors as Faraday rotation can cause signals to return out of polarization and nothing will be received for long periods.

pointment if you ask knowledgeable EMEers for antenna recommendations before you begin. The antenna array is often the most difficult part of the system to assemble, so take advantage of other amateurs' experiences and do the job right the first time.

How Do I Find the Moon?

Antenna-aiming accuracy is essential for successful QSOs with a small system. With a multiple-antenna array, beamwidth is narrow, and you need to know exactly where your antenna is pointed if you are to work anybody. This isn't like using a three-element tribander on 20 meters, where you can point anywhere between north and south and still hear a station to the east.

For starters, you can visually sight the moon and point your array by hand; motors for azimuth and elevation can be added later. As you become more sophisticated, you can use a home computer to track the moon or learn how to use *The Nautical Almanac* to predict its location.[1] This is necessary during periods when the moon is hidden by clouds, or when the sun and moon are close enough together that the sunlight obscures the moon.

The array can be tested and calibrated and the complete receive system "tweaked" by aiming first at the sun. (Caution: Never look directly at the sun!) The sun radiates radio noise, which can be readily received and used for testing. This noise varies from time to time, but the level usually stays constant for short periods.

Aim the completed EME array at the sun. With the receiver AGC off, rock the array from side to side and up and down until the signal peaks on the S meter or on a VOM connected across the speaker output terminals. The main electrical lobe of the antenna isn't always the same as the mechanical center of the array, so peaking the antenna on sun noise will help you to determine where your antenna is actually pointed.

Once this is done, the position of the sun can be noted with respect to one of the antenna booms, or you can use a 2-inch-OD pipe, about 2 feet long, for a "boresight tube" to line up the array (just like a telescopic sight on a rifle). With the array peaked for maximum sun noise, hold a piece of paper near the rear end of the tube and move the boresight around until the sun casts a symmetrical spot of light on this paper. When the spot is symmetrical, the boresight is aligned with the main antenna lobe. Never look at the sun through the boresight tube!

If you can see the moon through the boresight, then your array is zeroed-in. The moon will appear to move very quickly because of the earth's rotation, and reaiming will probably be needed every 15 to 20 minutes, depending on the array beamwidth.

For several days each month, the moon is at perigee, the part of its orbit that places

[1] *The Nautical Almanac for the Year 1985*, available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Price: $10.

Table 2
Suggested Times for EME Operations for July-Dec., 1985

Date		Time (UTC)	Date		Time (UTC)
July	13	1200	Nov.	2	0700
	14	1300		3	0800
	20	1800		9	1300
	21	1900		10	1400
Aug.	10	1100		23	0100
	11	1100		24	0100
	17	1700		25	0100
	18	1800		30	0600
Sept.	1	0600	Dec.	1	0700
	7	1000		7	1200
	8	1100		20	2300
	28	0400		21	2400
	29	0400		22	0000
Oct.	5	0800		23	0100
	6	0900		28	0500
	12	1400		29	0600
	13	1500			
	26	0200			
	27	0200			

Good Times for Echo Testing (Moon near Perigee)

Date		Time (UTC)
June	29	0200
July	27	0000
Aug.	18	1900
Sept.	19	2100
Oct.	16	1900
Dec.	14	2000

Several days either side of date given should also be good.
These periods were selected to provide windows of mutual visibility between stations in the U.S. and Europe, low noise and when activity will probably be highest. Times are beginning times, and activity should continue for 4 to 5 hours after time shown.
Suggested frequencies: 144.000-144.020 MHz and 432.000-432.020 MHz.

Table 3

Signal Reports Used on 144 MHz

T—Signal just detectable.
M—Portions of call copied.
O—Complete call set has been received.
R—Both "O" report and call sets have been received.
SK—End of contact.

Table 4

144-MHz Procedure—2-Minute Sequence

Period	*1½ Minutes*	*30 Seconds*
1	Calls (W6XXX DE W1XXX)	
2	W1XXX DE W6XXX	M M M M
3	W6XXX DE W1XXX	O O O O
4	RO RO RO RO	DE W1XXX K
5	R R R R R	DE W6XXX K
6	QRZ? EME	DE W1XXX K

Getting In Touch

EME enthusiasts have a well-developed system of exchanging information, and you can tap into this network to get in touch with active operators who can help you get started.

Nets

Every Saturday and Sunday, EME operators gather on 14.345 MHz to exchange information and arrange schedules to work each other. The 432-MHz-and-above EME Net meets at 1600 UTC each day, while the 144-MHz group meets at 1700 UTC.

The Central States VHF Society conducts a net each Sunday evening on 3.818 MHz at 9:30 P.M. CST (0330 UTC). Although this net is a general-interest VHF net, many active EMEers attend. In addition, active VHFers gather informally on 3.818 most nights of the week.

Newsletters

Several monthly newsletters cater to the EME operator. You can find a lot of good information in these newsletters, and it would be worth your while to subscribe if you are interested in EME. They are

2-Meter EME Bulletin, c/o Gene Shea, KB7Q, 417 Stadhauer, Bozeman, MT 59715.
VHF/UHF And Above Information Exchange, c/o Rusty Landes, KAØHPK, P.O. Box 270, West Terre Haute, IN 47885.
KCØW's VHF + Update, P.O. Box 11023, Reno, NV 89510-1023.

Terms Commonly Used by EME Operators

apogee—that point in the moon's orbit where it is farthest from the earth.
az-el mount—an antenna mount that allows adjustment of both azimuth and elevation.
declination—refers to the moon's position, north or south of the earth's equator. Northern declinations occur for several weeks each month and are usually good periods to operate because of reduced background noise radiation from sources in space. These sources often mask the low-level signals returning from the moon.
Faraday rotation—a rotation of the polarization plane of radio waves when the waves travel through the ionosphere. Echoes will often return out of polarization with the receiving array. The polarization of a returning signal slowly rotates and will line up with the receiving array after some period.
perigee—that point in the moon's orbit where it is closest to the earth.
polar mount—a type of antenna mount whereby the axis of rotation is aligned with the North Star. Used by some operators, primarily those with dish antennas.
sked weekend—when most operators tend to operate each month because conditions are favorable (see Table 4).
sun noise—radio noise from the sun, which varies with solar activity. This noise can be used to test EME systems, but it can also mask echoes from the moon when the sun is close enough to the moon to be in the main lobe of your antenna.
universal window—a common aiming point in the sky, where stations can see the moon at the same time.

Faraday rotation usually changes, so some reception will be possible during a one-hour test on 2 meters.

When you have checked your system and completed some receiving tests, it's time to contact an experienced EME operator and attempt a QSO. You can usually find someone who will attempt a QSO if you check into the EME net (see sidebar). If you can't operate HF, look in The World Above 50 MHz column in *QST,* check the results of the ARRL EME Contest, or obtain a copy of one of the EME newsletters for an idea of who is active with a big signal, and write a letter asking for a schedule. These sources are explained elsewhere in this article.

Operating times and procedure must be agreed upon in advance and a frequency selected. The usual procedure on 144 MHz is for each station to transmit for two minutes and listen for the next two minutes; the easternmost station begins by transmitting the first two minutes of the hour. This sequence continues for one hour or until the QSO is completed. Clocks must be calibrated carefully with WWV or at least with each other.

Two-meter EME QSOs follow a set procedure. See Tables 3 and 4. Call signs of the stations are repeated during the first minute and a half of each two-minute sequence. Once an operator hears his call sign, he will send a signal report during the last half minute. If he hears nothing, then nothing is sent during the last half minute.

If complete call signs are copied, an O is sent as the report; if portions of calls are heard, an M is sent. Experienced operators sometimes use the RST system if signals are very strong. Once you hear your report from the other station, discontinue sending call signs (except as required by FCC for identification) and begin filling the first 1½ minutes of your 2-minute transmit periods with RO RO RO RO. This indicates "Roger my report. Your report is O." Send O until you hear an RRR from the other station. Many finish a QSO by sending 73 73 73 SK SK SK. Discussion with the other operator prior to beginning the test should help clarify QSO procedure.

That's the end of our overview of EME operation. If you think you would enjoy putting together a station, read the referenced articles and books for more information. Most important, contact active EME operators and ask for help. Don't be bashful! Most would jump at the chance to help you get on the air "off the moon." With some work, you can join that exclusive club of operators who have QSOed via the ultimate long path!

Bibliography

General Reference Books

The ARRL Antenna Book, 14th ed. Newington: ARRL, 1982.
The 1985 ARRL Handbook for the Radio Amateur. Newington: ARRL, 1984.
Jessop, G. R., *VHF/UHF Manual,* 4th ed. Hertfordshire, England: Radio Society of Great Britain, 1983. Available from ARRL.
Orr, W. I., *Radio Handbook,* 22nd ed. Indianapolis: Howard W. Sams & Co., 1981.

Magazine Articles

Barber, A. L., Jr., "A Simplified Procedure for Locating and Tracking the Moon." *QST,* Jan. 1982.
Powlishen, S., "Stacking Yagis is a Science." *Ham Radio,* May 1985.
Reisert, J., "Requirements and Recommendations for 70-cm EME," *Ham Radio,* June 1982.
Reisert, "VHF/UHF World: Stacking Yagis." *Ham Radio,* April and May 1985.
Reisert, "VHF/UHF World: VHF/UHF Exciters." *Ham Radio,* April 1984.
Reisert, "VHF/UHF World: VHF/UHF Receivers." *Ham Radio,* March 1984.
Reisert, "VHF/UHF World: 220-MHz EME Requirements." *Ham Radio,* Sept. 1984.
Shuch, H. P., "Quiet! Preamp at Work." *Ham Radio,* Nov. 1984.
Tynan, W., "A VHF/UHF Primer—EME." *QST,* Nov. and Dec. 1981, and Jan. and Feb. 1982.

Jim Stewart, WA4MVI, an Extra Class amateur, was first licensed in 1962. He holds a BS in chemistry and is currently employed by FAA. Jim holds 50- and 144-MHz WAS, as well as 50, 144 and 432-MHz WAC awards. He is an ARRL Technical Advisor, specializing in propagation and EME.