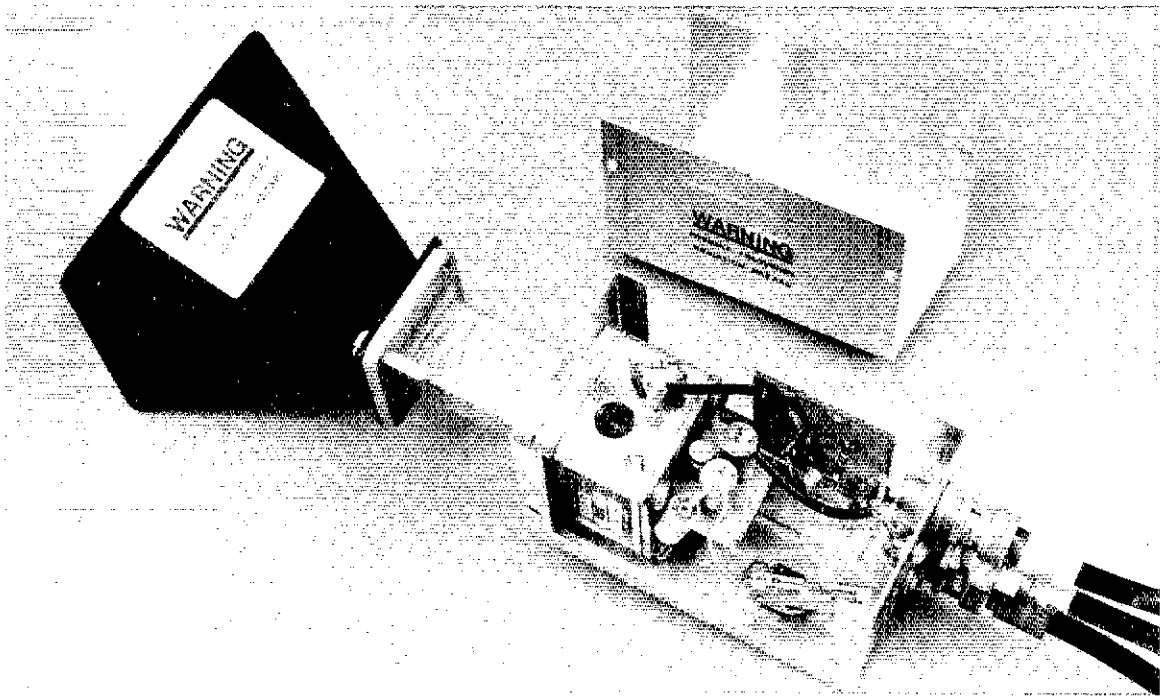
The Care and Feeding of Gunnplexers



Microwaves too difficult? Not so! We'll show you just how easy 10-GHz fm can be.

By Daniel N. Petersen,* WA6OIL

Do you have an adventurous spirit? Do visions of dish antennas pop into your head when you look at your portable barbecue? If so, you should consider "playing microwaves" with a Gunnplexer.[1] The Gunnplexer is a simple, effective way to jump on the 10-GHz bandwagon. In this article, I'll point out some of the pleasures and pitfalls of Gunnplexer operation.

What Is It?

The Gunnplexer, manufactured by Microwave Associates, is a solid-state microwave transmitter and receive converter. It consists of three sections: A Gunn source, a circulator/mixer and an antenna. The Gunn source contains the heart of the system — a Gunn diode. This diode, when placed in a waveguide cavity and subjected to a forward bias, will oscillate at a frequency dictated by the dimensions of the waveguide cavity and by the diode parameters. To put it simply, you apply 10 V dc to the Gunn diode and about 15 mW of 10-GHz "goo" will come out of that rectangular hole at the other end, see?

Also contained in the Gunn source section is a varactor diode. It is used to electrically change the frequency and to frequency-modulate the Gunn source. There is also a mechanical tuning slug that can be used for coarse frequency changes. I do not recommend "fiddling" with that control unless you have had some experience with microwave gear.

The center section is the circulator/mixer. It contains a ferrite circulator and a Schottky mixer diode. The circulator diverts a small portion of the transmit energy to the mixer diode, thus providing a local-oscillator signal for the mixer. A received signal mixes with the local oscillator and appears at the output port, which extends above the circulator/mixer section. The antenna is a 17-dB horn. This type of antenna provides a good amount of gain in a small package. Other types of antennas can be substituted, but for most experimentation the horn is more than adequate.

How Do You Use It?

The Gunnplexer requires very little in terms of operating voltages. A 10-V, 150- to 200-mA dc supply is required for the Gunn diode. This voltage goes directly to the diode with no series resistor. The diode provides the necessary current limiting. Gunn sources are not pillars of efficiency, usually being less than one percent efficient at these power levels. The important thing is that they work well without requiring special support equipment. The varactor tuning diode requires from 1 to 20 V for proper operation. Being reverse biased, the varactor draws virtually no current. You can use a potentiometer as a voltage divider, with a dial on the shaft calibrated in frequency. You can also use a dc voltmeter to indicate your frequency.

[1]Notes appear on page 18.

*Rte. 1, Box 11AA, La Center, WA 98629

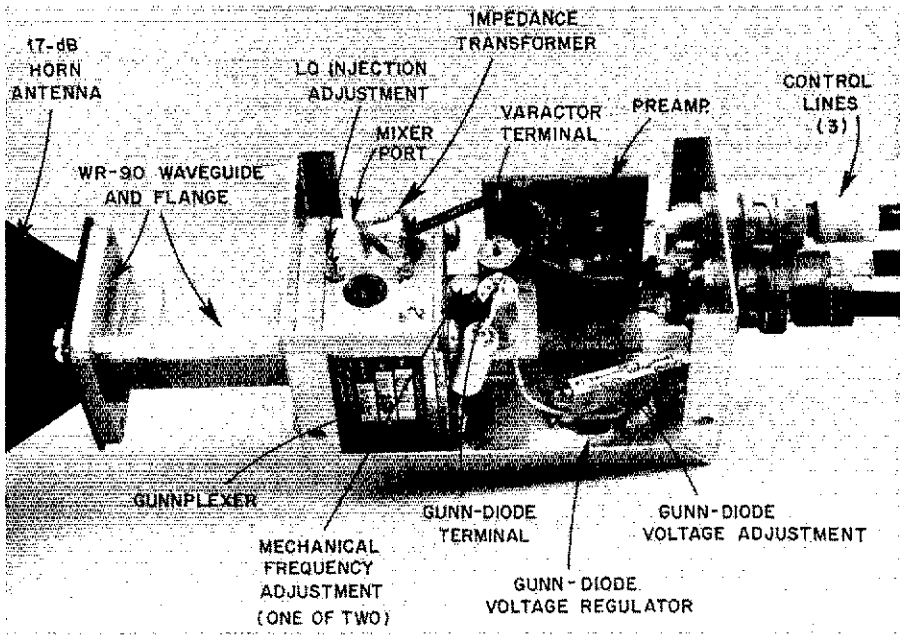


Fig. 1 — This Gunnplexer is housed in a small Minibox. Coaxial cables connect the unit to the i-f receiver and the control circuits. If you mount the horn antenna directly to the Gunnplexer enclosure, the waveguide section can be eliminated.

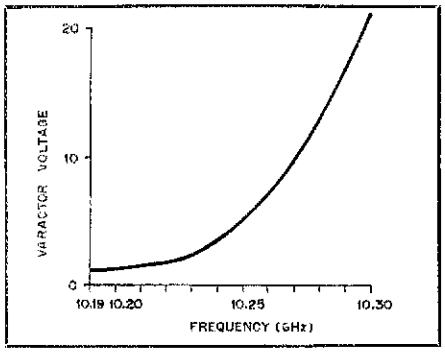


Fig. 2 — Gunnplexer frequency versus varactor-diode voltage. This graph is for a Gunnplexer that is factory tuned to 10.250 GHz at a varactor potential of 5 V.

Table 1

Mixer Port Impedances

Freq. (MHz)	*Z (ohms)*
10	355 – j 102 = 370 Ω
20	286 – j 165 = 330 Ω
30	214 – j 180 = 280 Ω
40	147 – j 164 = 220 Ω
50	123 – j 176 = 215 Ω
60	98 – j 157 = 185 Ω
70	75 – j 141 = 160 Ω
80	61 – j 126 = 140 Ω
90	56 – j 106 = 120 Ω
100	43 – j 106 = 115 Ω

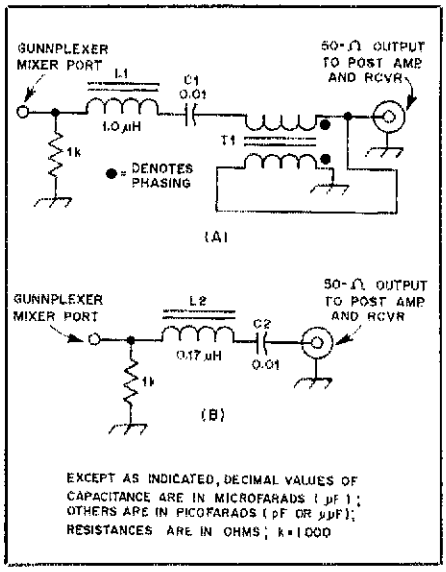


Fig. 3 — Gunnplexer i-f port matching circuits. The circuit at A is used to match the i-f port to 50 Ω at 30 MHz. Circuit B can be used to provide a 50-Ω output impedance in the 90-MHz range. T1 consists of 7 bifilar turns wound on an Amidon FT23-75 core.

I have been speaking "pleasure" so far, so here are some precautions. Treat that mixer port with a great deal of respect! The mixer diode is subject to damage from static electricity. Walk across a carpeted floor and touch the mixer port, and you could have a dead diode. Microwave Associates places a protection diode on the mixer port before shipment. Since this diode is removed before the Gunnplexer is placed in operation, you can't be too careful about avoiding static discharge. A good plan is to attach a clip lead to the mixer port and the Gunnplexer body while it is not being used, or when you are soldering to the mixer port.

Watch the Gunn- and varactor-diode power-supply polarities. I have inadvertently connected the Gunn diode backwards with no apparent damage to the diode (I hope), but I would not recommend doing it. Not only does it give you gray hair when you notice it's hooked up backwards, but having the Gunn diode changed is not cheap! As long as you have positive voltages on the Gunn and varactor ports, you'll be okay.

Mechanical Mounting

For better utilization, the Gunnplexer should be mounted in an enclosure. A 2-1/4 × 2-1/4 × 4-inch Minibox makes an ideal housing (Fig. 1). It provides plenty of room for the Gunnplexer, the Gunn-diode voltage regulator, an i-f preamplifier and connectors for signal and control lines. Because of the small size, the unit can be mounted on a tripod or at the focus of a parabolic dish, with cables going to the i-f and control circuits.

Another reason for mounting the Gunnplexer in a separate housing is that Gunnplexers tend to be somewhat microphonic. I discovered this while on an outing. I was making some adjustments in the Gunnplexer housing and as usual, I was talking to myself. My friend, at the receiving end, told me he could hear me just fine, even though the modulator was turned off. Tapping the case produced a healthy "bonging" noise at the receiving end. I would be interested to know if others observe this phenomenon.

Just When You Thought It Was Safe

Now that the preliminaries are out of the way, things get a bit more complex. As I said before, the varactor requires from 1 to 20-V dc. Before the Gunnplexer is shipped from the factory, a frequency is stamped on the body. This is the transmit frequency at a varactor voltage of 5 V. A change in this voltage produces a nonlinear change in frequency. The shift is much greater at low varactor voltages than it is at high voltages (Fig. 2). The output power also fluctuates with changes in frequency. I have measured a maximum variation of 0.6 dB. This variation should not cause a great deal of concern.

The next subject to be dealt with is the mixer port. Microwave Associates implies that it has an impedance of approximately 200 Ω. Since this declaration is somewhat vague, I connected the mixer port to an impedance analyzer. I found that the complex impedance varies quite a bit with frequency and that the mixer port is capacitive (Table 1). At 30 MHz, which is pretty much a standard Gunnplexer i-f, the transformation to 50 Ω is fairly simple. A matching network is shown in Fig. 3A: L1 cancels the capacitive reactance at the mixer port and dc blocking is provided by C1. T1 produces the required 4 to 1 impedance transformation. I tested the network with a Gunnplexer and came up with the results shown in Table 2. This network appears to work well with both of my Gunnplexers.

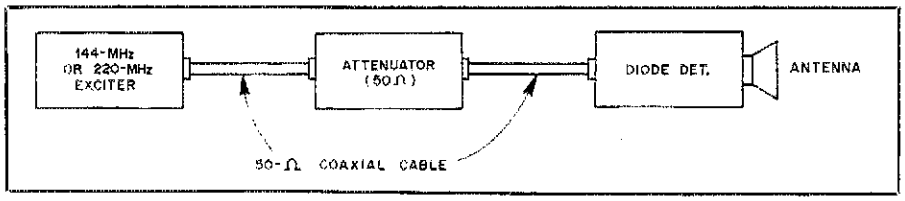


Fig. 4 — Frequency calibration setup. The attenuator should reduce the power applied to the detector diode to approximately 250 mW or less.

Table 2

Fig. 3A Matching Circuit Output Impedances

Freq. (MHz)	*Z (ohms)*
20	69.1 − j 11.0 = 70 Ω
25	60.7 − j 6.4 = 61 Ω
30	54.0 − j 0.94 = 54 Ω
35	48.4 + j 7.7 = 49 Ω
40	42.7 + j 17.2 = 46 Ω

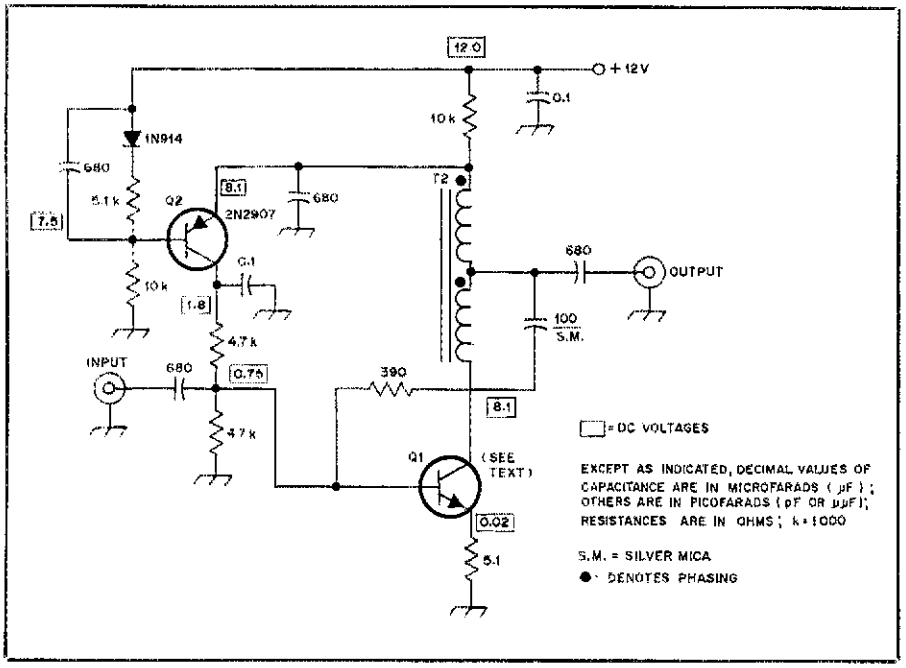


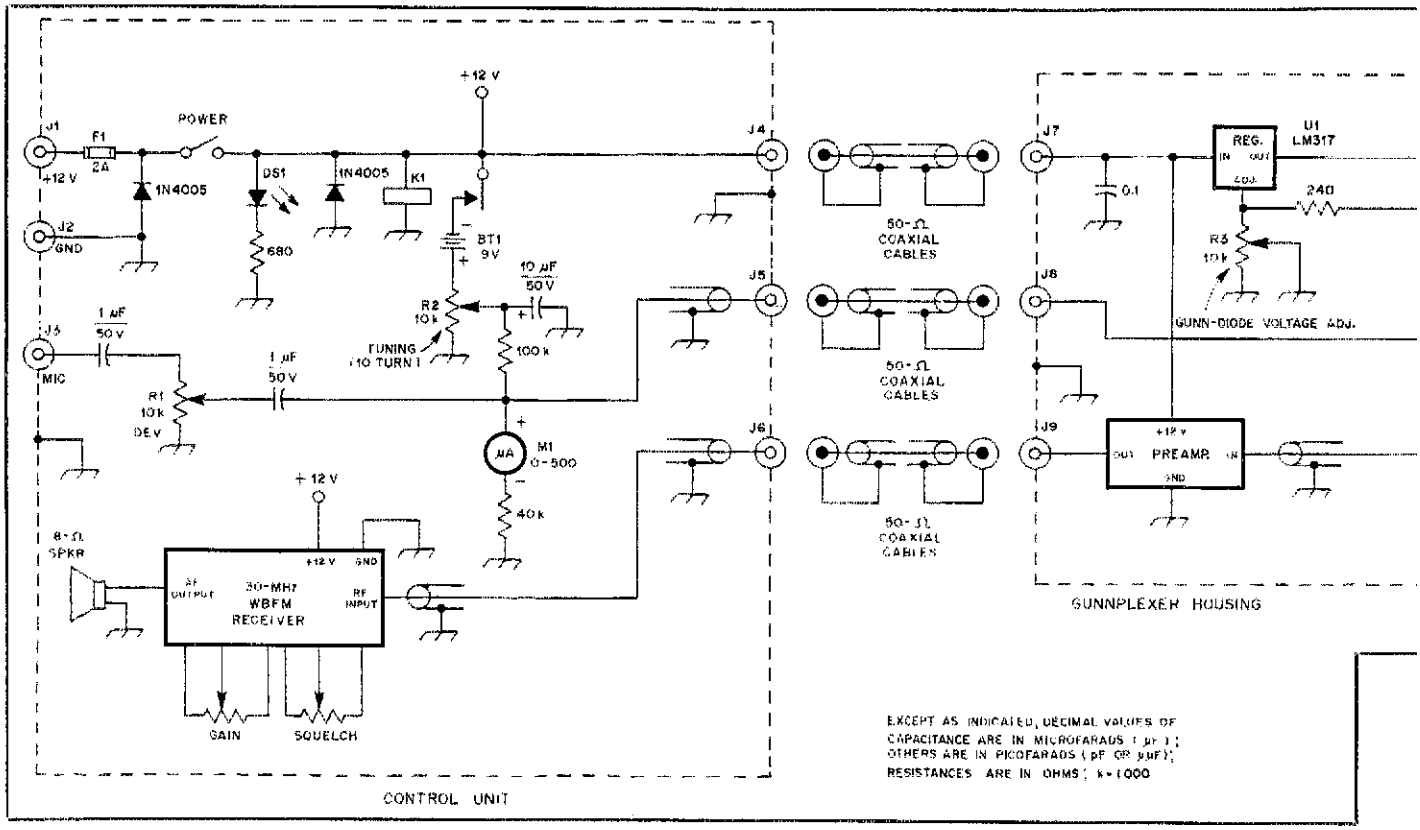
Fig. 5 — I-f preamplifier. All resistors are 5%, 1/4-W carbon types. Unless indicated otherwise, capacitors are disc ceramics. T2 consists of 7 bifilar turns wound on an Amidon FT23-75 core.

Tuning Considerations

The amateur X-band allocation is 10.0 to 10.5 GHz. Any modulation mode, with the exception of pulse modulation, is allowed. Gunnplexers can be ordered for operation anywhere in the band, but most hams prefer operating near 10.25 GHz. There are two reasons for this. First, sitting at the center of the band gives you lots of room to roam before you run into a band edge. The second reason is that calibrators, used to help you find your receive frequency, are simple to make for frequencies near 10.25 GHz.

So Where Are You?

The simplest calibrator is a waveguide type of diode detector (Fig. 4).[2] If you apply enough rf power to the diode, causing it to conduct, it will act as a multiplier. With a careful choice of frequencies you can place a harmonic at a favorable spot in the 10.25 GHz area. For example, the 70th harmonic of 146.52 MHz falls at 10.2564 GHz. A 220-MHz source can also



be used for harmonic generation. The 46th harmonic of 223.5 MHz provides a calibration signal at 10.281 GHz. I have used both a 144- and a 220-MHz rig for calibration sources. A word of caution, however: Please pad your excitation source. The idea is to turn the diode on and off with a volt or so of rf potential. Applying 10 W to a microwave detector diode will launch the diode into the "Twilight Zone" in a cloud of gaseous silicon. You should be able to detect the calibrator signal at a distance of several feet.

I-F Receivers

It has been generally accepted that a 30-MHz i-f is the standard for amateur 10-GHz work. If it is just you and someone else who are "X-banding," however, you can bend convention a bit. For your first experiments you can use a standard fm-broadcast receiver. Since Gunnplexers are easily modulated to produce wide-band fm, it seems only natural to use an fm broadcast set as a ready-made i-f receiver. The circuit shown in Fig. 3B can be used to approximately match the Gunnplexer mixer port to a 50-Ω line at frequencies within the fm broadcast band.

Commercial i-f receivers are available or you can "roll your own" receiver by designing it from scratch (a pain) or by P and M engineering (P and M, by the way, stands for Plagiarism and Modification). The ARRL *Handbook* contains an fm receiver circuit that can be modified for 30-MHz wide-band operation.

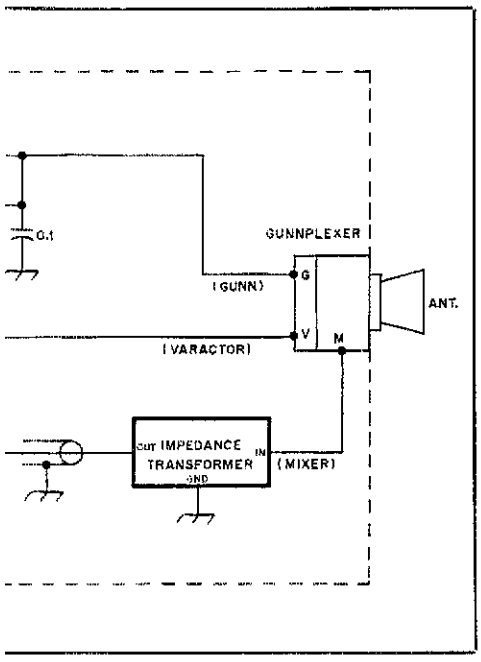


Fig. 6 — Gunnplexer control circuit. An interior view of the Gunnplexer housing unit is shown in Fig. 1. Any wide-band 30-MHz fm receiver can be used as the i-f receiver (see text). The remainder of the control-unit circuit supplies the varactor tuning voltage, Gunn-diode voltage and the modulation audio to the Gunnplexer.

The primary concern is the 10.7-MHz filter. For this mode, the filter has to be wide — in excess of 100 kHz or more is ideal. As luck would have it, Radio Shack has in their parts trove a 10.7-MHz ceramic filter that has a 280-kHz bandwidth for a low price. Why use such a wide filter? For tuning considerations mostly. If you had a narrow-bandwidth receiver, say 5 kHz, and were trying to tune in a modulated oscillator that drifts a bit, all you would hear is an occasional "pop" as you tuned across it or it drifted past your frequency. Also, you'll be impressed by the fidelity of wide-band fm. Your partner will sound exactly like your partner and not Donald Duck at the bottom of a well. [Later editions of the ARRL *Handbook* contain a 30-MHz wide-band fm receiver circuit designed specifically for use with Gunnplexers. — Ed.[3]]

Frequency Stability, or Do You Catch My Drift?

In the last section, I made mention of the Gunnplexer being "a modulated oscillator that likes to drift a bit." This can be construed as an understatement, for the Gunnplexer is an unstabilized oscillator. For example, the VFO in an hf rig should maintain a stability of one part in a million, resulting in a drift of 7 Hz in the 40-m band. The Gunnplexer, on the other hand, has a stability of one part in ten thousand (or 100 parts per million). This results in a drift of 1 MHz at 10,000 MHz. It may not sound like much, but an hf VFO with the same drift at 40-m would move 700 Hz, and that would be unacceptable. Don't despair, for we are not trying to receive cw or ssb with the unit — just wide-band fm.

Some people think that a Gunnplexer cannot be used without automatic frequency control (afc). It is my contention that, for experimentation over short distances, afc is not required. If you and your "partner" want to go hilltopping you should have no problem finding and tracking one another's signals without afc. I agree that for long-term reliability, afc or some sort of phase-lock system should be used.

The Gunnplexer drifts, but don't get the idea that it goes helter-skelter all over the band. When first fired up the Gunnplexer will drift at a terrific rate, slowing down after a minute or two. After five minutes of operation it will have settled down to a very slow drift, caused mostly by temperature changes. If both units are turned on at the same time they will both drift in the same direction at about the same rate. This will minimize the need to chase one another's signals. Some useful advice when operating without afc: Only one of you should tune. It's like hide and seek. One operator "hides" in one spot while the other one "seeks." The "hunter" shouldn't have any trouble finding his "prey." If you are only a few miles apart, tuning in your partner's signal will be as easy as tuning in a commercial fm broadcast station. It's easier, in fact, because there's only one station on the band.

Add an Afterburner

In this section we deal with an i-f preamplifier for your Gunnplexer. The circuit (Fig. 5) is essentially foolproof. It's easy to build and contains fairly common components. Q1 is the amplifier transistor while Q2 is part of the dc biasing circuit. A feedback network, extending from the base of Q1 to the output coupling capacitor, keeps the amplifier gain constant from below 10 MHz to over 90 MHz. The input and output impedances are near 50 Ω.

This circuit can be used in many applications. I find it to be unconditionally stable. If a low-noise transistor is used for Q1, the circuit should work very well. My preamplifiers, using N.E.C. (Nippon Electric) devices, have noise figures (NF) of about 3.5 dB.[4] That isn't great, but, with the Gunnplexer noise figure at about 12 dB or so, a 3.5-dB NF preamplifier will surely aid the system noise figure.

Controlling Your Gunnplexer

The Gunnplexer is simple to control. Fig. 6 contains a schematic diagram of the control system I use on my Gunnplexers. It's in two boxes: the control/receiver unit and the Gunnplexer housing. The control/receiver unit includes the main power control, varactor tuning circuit, modulator and receiver.

When the main switch is turned on, power is supplied to the Gunn diode, the modulator and the receiver. K1 is also energized, enabling the tuning circuit. The 9-V battery "rides" on top of the 12-V line to provide 21 V for varactor tuning. The modulator is a crystal microphone and gain control, with the output connected to the varactor control line. This impresses a small audio-modulation voltage on the varactor. I set the audio level by listening to the signal, adjusting R2 until over-deviation occurs. I then back off the setting of R2. It doesn't take much audio to *really* fm the Gunnplexer. [Some crystal microphones will require the use of an amplifier as shown in note 3 — Ed.]

I have left the receiver question open. You may use a bona fide 30-MHz receiver or a commercial fm-broadcast receiver. I have been using a homemade 30-MHz receiver that is still in the development stage. I hope to treat this receiver in a future article.

The second unit is the Gunnplexer housing. It contains the Gunnplexer, a regulator for the Gunn-diode voltage and an impedance-matching/preamplifier circuit. I have used an LM317 as the Gunn-

diode voltage regulator with good success. It provides precise control of the diode voltage — an important parameter for good oscillator stability. Another reason for a local regulator is that it allows you to operate the preamplifier at 12 V. The preamplifier, although not necessary, is an advantage. I would not compromise the impedance-matching circuit. Without it, you would see, at 30 MHz anyway, a 4 to 1 mismatch to your 50-Ω system. The varactor line simply conveys the varactor dc and modulator audio to the varactor diode. In my units I use BNC connectors and coaxial cable for all three connecting lines. You should use coax for the i-f line, but shielded cable can be used for the dc lines. In fact, Fig. 6 is meant only as a guide. It is one ham's attempt to "ride herd" on the Gunnplexer.

Where are They Sold?

A few phone calls to the New England area revealed the following information: Microwave Associates does not sell Gunnplexers directly or disseminate technical information about them. They sell the Gunnplexer through a single distributor, Advanced Receiver Research.[5] The 10-mW unit is type MA 87141-1 and is in the $250 per pair price class. Advanced Receiver Research also sells support equipment for the Gunnplexer.

If you have trouble locating parts to build this project (or others), you might give the folks at Circuit Specialists, Inc. and Jameco Electronics a try.[6,7] I have done business with Circuit Specialists for years. They have been prompt in replying and are usually well stocked. Jameco Electronics has a complete catalog with a wide variety of parts.

I have found that local Radio Shack stores have some surprising items. For instance, they sell 10.7-MHz wide-band filters (200 kHz wide) that can be used in wide-band fm receivers. Two filters cost $1.99. Consulting the various Amateur Radio publications will net you some other sources, but those I've mentioned are my favorites.

I have found the Gunnplexer to be very satisfying to experiment with. The system and information presented here is meant to stimulate interest in Gunnplexer operation. Don't worry about afc or phase locking yet; get on the air first! Once you have the ship launched and your feet wet, you can add the bells and whistles. Happy Gunnplexing! QST

An FM Pocket Radio I-F Receiver

For casual Gunnplexer experimentation, a low-cost fm-broadcast receiver can be modified easily for use as an i-f unit. One such receiver is the Realistic Model 12-714 sold by Radio Shack.

The first step in converting this broadcast set into an i-f receiver is to provide for a 50-Ω input. This will allow the i-f receiver to be connected to the Gunnplexer mixer through 50-Ω coaxial cable. Shown in the accompanying diagram is the input circuit of the Model 12-714. The fm antenna is connected to the input tuned circuit (C2 and L1) through a 10-pF capacitor. All you need to do to modify this circuit for use with 50-Ω cable is to remove the wire going to the fm antenna and replace the 10-pF capacitor with an 18-pF unit. The 50-Ω cable can then be attached to the two terminal lugs at the lower right-hand corner of the receiver circuit board. After the receiver has been attached to the Gunnplexer, this circuit can be adjusted for maximum sensitivity by spreading or compressing the turns of L1. The tuning is broad and the adjustment is not critical.

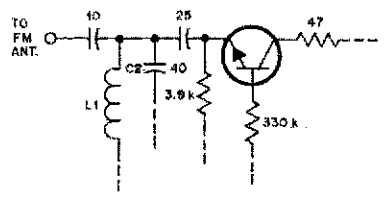
To reduce i-f feedthrough, the receiver should be enclosed in a metal box and all leads entering the enclosure should be filtered. A ferrite bead (Amidon FB101-43) and a 0.001-μF disc-ceramic capacitor on each lead will provide the needed filtering.

Note that this receiver is designed for use with a positive ground. That is, the positive battery terminal is the common circuit point. Because of this, it is difficult to power the receiver from the 12-V supply used to power the Gunnplexer. Using a separate battery (with the positive terminal connected to ground) to power the receiver avoids this problem.

To complete the Gunnplexer transceiver, an audio stage, to modulate the varactor voltage, is required. The simple circuit shown in note 3 will serve this purpose well.

Those wishing to experiment with afc will find a suitable voltage at the junction of C27 and R28 (refer to the schematic diagram that accompanies the Model 12-714). The afc voltage at this point swings approximately 0.4 V either side of the +9-V receiver reference level (the *transceiver* ground point). A simple op-amp circuit, powered from the Gunnplexer supply ($+V_{CC}$) and the receiver battery ($-V_{CC}$), can be used to provide the required amplification and level shifting.

Remember that while the exact i-f used is not critical, it is necessary that the transmitting and receiving units use the *same* i-f. The i-f receiver should be set to an agreed-upon frequency and the varactor-voltage control used for tuning. While the use of 30 MHz as the i-f is highly recommended for general Gunnplexer operation, this simple broadcast set modification will provide experimenters with a low-cost way to "try their hand" on the 10-GHz band. — *KC1V*



Notes

[1]Gunnplexer is a registered trademark of Microwave Associates, Inc., Burlington, MA 01803.

[2]S. J. Noll, "X-band Calibrator," *Ham Radio*, April 1981, pp. 44-50. [This article gives construction details for a waveguide-type calibrator using a 1N23 diode — Ed.]

[3]G. Woodward, ed., *The Radio Amateur's Handbook*, 60th ed. (Newington, CT: ARRL, Inc., 1983), pp. 14-24 to 14-26.

[4][An NE41632E-2 or a similar device is suitable — Ed.]

[5]Advanced Receiver Research, Box 1242, Burlington, CT 06013, tel. 203-582-9409.

[6]Circuit Specialists, Inc., Box 3047, Scottsdale, AZ 85257.

[7]Jameco Electronics, 1355 Shoreway Rd., Belmont, CA 94002.

Strays

Terry A. Ketron, WA4RJN, of Boone, North Carolina, used a crude but effective means to dispose of a CB linear amplifier he tried to sell at the Shelby Hamfest. The Norfolk, Virginia, FCC office sent WA4RJN a citation warning him of the penalties and prohibitions regarding the sale of such devices, and ordered him to show proof the equipment was destroyed. This photo served as part of the proof. *(photo courtesy FCC)*

Next Month in QST

Those who read May *QST* will learn about

- Vic Clark, W4KFC, and Dave Sumner, K1ZZ, who speak out on a wide range of issues facing the Amateur Radio Service and ARRL.
- digital logic, and how it relates to electronics — a timely Beginner's Bench article.
- the weather conditions that can cause a routine 2-meter contact to make the pages of "The World Above 50 MHz" in *QST* and 10 new states.
- the rules governing Field Day 1983.