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. 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.

*Notes appear on page 18.
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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.

![Graph showing frequency versus varactor-diode voltage.]

**Table 1**

<table>
<thead>
<tr>
<th>Mixer Port Impedances</th>
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<tbody>
<tr>
<td><strong>Freq. (MHz)</strong></td>
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<tr>
<td>-------------------</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>20</td>
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<tr>
<td>30</td>
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<td>40</td>
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<td>70</td>
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<td>80</td>
</tr>
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<td>90</td>
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<td>100</td>
</tr>
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</table>

**Mechanical Mounting**

For better utilization, the Gunnplexer should be mounted in an enclosure. A 2-1/4 x 2-1/4 x 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.

![Graph showing output impedance versus frequency.]

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,
Table 2
Fig. 3A Matching Circuit Output Impedances

<table>
<thead>
<tr>
<th>Freq. (MHz)</th>
<th>Z (ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>69.1 - 11.0 ≈ 70 Ω</td>
</tr>
<tr>
<td>25</td>
<td>60.7 - 6.4 ≈ 64 Ω</td>
</tr>
<tr>
<td>30</td>
<td>54.0 - 0.94 ≈ 54 Ω</td>
</tr>
<tr>
<td>35</td>
<td>48.4 + 7.7 ≈ 49 Ω</td>
</tr>
<tr>
<td>40</td>
<td>42.7 + 17.2 ≈ 46 Ω</td>
</tr>
</tbody>
</table>

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). 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.

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 channel that drifts a bit, you would hear an occasional "pop" as you tuned across it or if 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.]

**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. 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. 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. 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!

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Notes

1Gunnplexer is a registered trademark of Microwave Associates, Inc., Burlington, MA 01803.
2J. E. Noll, "X-band Calibrator," Ham Radio, April 1981, pp. 44-50. [This article gives construction details for a waveguide-type calibrator using a (N33 diode — Ed.]
4An NE4193E-2 or a similar device is suitable — Ed.
5Advanced Receiver Research, Box 1242, Burlington, CT 06013, tel. 203-582-9409.
6Circuit Specialists, Inc., Box 3047, Scottsdale, AZ 85257.
7Jameco Electronics, 1355 Shoreway Rd., Belmont, CA 94002.

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- 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.