# 1

# Introduction

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# Making the Most of the Microwaves

*By David Sumner, K1ZZ*

(Adapted from *QST*, May 1992)

If you go to a typical radio club meeting and ask for a show of hands from those who have operated above 450 MHz, there's a good chance you'll get *no* responses. Not one.

Yet, we radio amateurs pride ourselves on our interest in experimentation. We complain about bands being too crowded. We see red if anyone even *thinks* about introducing a new service in one of "our" bands, even if we couldn't put a signal there if our lives depended on it.

All of our bands between 902 MHz and 10.5 GHz are secondary allocations. That is, they're available to us on condition that we cause no harmful interference to the primary users (mostly military), and we can claim no protection from them. But that's no excuse. The 420-450 MHz band is the same way and it's our second most popular band above 30 MHz.

"It's too expensive" is commonly heard but, like many complaints, it isn't necessarily accurate. There are plenty of consumer electronics products that operate in this range and higher: TV satellite receivers, "wireless cable" systems (including those $69 gadgets to "broadcast" from your VCR to TV sets in the rest of the house), radar detectors, and so on. GPS radionavigation satellite receivers operating near 1.6 GHz are practically a consumer item. The lesson is obvious: If manufacturers believe a market exists, they can make products for this frequency range at reasonable prices.

The fact is, what's keeping us from making better use of our microwave bands is that all but a few of us have gotten into a comfortable rut. While the rest of the telecommunications world is poised to leap into the 21st Century, most amateurs are not. We can hardly afford such complacency.

Personal communications systems operating around 2 GHz are the hottest concept in telecommunications. To make room for them, the FCC will have to "bump" private fixed microwave links at a cost of somewhere between $750 million and $2.75 billion—in other words, between $3,400 and $12,500 per kilohertz. Exactly who will pay is unresolved, but the FCC seems to think this is a reasonable burden for society to bear in order to benefit from the new systems. How does the societal value of *our* access to microwave spectrum stack up?

By the time they get to junior high, some of the kids now in grammar school will be hounding their parents for a "satellite Walkman" so they can listen to pop music being broadcast in CD-quality, digital sound. In the commercial world, virtually every communications system now being designed or contemplated is a digital system. Will Amateur Radio help lead the way into the digital era? Will we even stay abreast?

These are tough questions, but the ARRL Board of Directors believes they need to be asked—and answered. At its January 1992 meeting, the Board tasked the Headquarters staff with encouraging amateur use of the bands at 902 and 1240 MHz. Not that the problem goes away above 1300 MHz: Our bands at 2.3, 3.3 and 5.65 GHz are also subject to pressure because the military—which generally has been an indulgent sharing partner for us—is being forced to relinquish considerable spectrum in this range to the private sector, for commercial use.

What are we doing with these bands? Not enough?

The amateur satellite bands that we won at WARC-79 and have protected at subsequent WARCs—including WARC-92—mostly have not been used. While we've barely made it to 2.4 GHz with our satellites, by contrast, other space services now operating near 2 GHz are looking above 20 GHz to meet their future needs. Amateurs were credited at WARC-92 for having pioneered the low-earth-orbit (LEO) satellite concept. We can't rest on those laurels.

Too many amateurs who feel constrained by crowding on lower frequencies still would "rather fight than switch."

There is a bright side. Homebrewing at these frequencies isn't difficult, as proved by many articles in this book. An investment in a good dish antenna can serve on several bands. While generating high power can be a problem, for most amateur applications a few milliwatts will do. If you want broadband, interference-free communications over short distances, or longer point-to-point paths, these bands are definitely the place to go.

Since the Board resolution in January 1992, we've heard from several members who have offered to help popularize our microwave bands. Let's hear from you. What would get *you* excited about the world above 902 MHz?

# Getting Started on the Microwave Bands

*By Rick Campbell, KK7B*

(from *QST*, February 1992)

Several pockets around the country contain much of the US amateur microwave activity. These pockets come into being when one amateur in a geographic location builds a station for the "next higher band," and then serves as a mentor to a small group of interested enthusiasts—often contesters who want to improve their scores. Recent advances in microwave technology have made access to the microwave bands easier than ever before. Building a complete microwave station in the 1990s is about as challenging as assembling a mobile rig in the 1950s—and just as much fun!

I intend this tutorial to help you get your feet wet in engineering, building and operating Amateur Radio stations on the microwave bands, with a focus on the 5.7-GHz band (which I'll sometimes refer to as "5760"). Although the focus of this article is weak-signal contest and "grid-expedition" style communication, the information provided here is useful to anyone interested in getting on any of the microwave bands. After a little introductory theory, I'll describe a basic 5760 station that you can use as-is for line-of-sight hilltopping, or that you can enhance in stages all the way to moonbounce (also known as earth-moon-earth, or EME) capability.

## Introduction

Commercial equipment is now available for narrowband, weak-signal work on all amateur bands from 1.8 MHz through 10 GHz. Until recently, the only gap in that coverage was the 5760-MHz band, a void that Down East Microwave filled with a no tune 5760-MHz transverter.[1] Amateurs who have operated on 2.3, 3.4 or 10 GHz will find no surprises at 5.7 GHz; those who haven't done so will find 5760 to be an interesting and surprisingly far-reaching band.

It's easy to find other hams interested in getting on 5760—their calls are published in the VHF and UHF contest scores in *QST*. Look for a nearby call with lots of letters after it, but no *h*.

A few of the developments responsible for the dramatic increase in amateur microwave activity are:

• Unconditionally stable MMIC amplifiers are now available at far less than the cost of the surplus amplifiers used by amateurs a few years ago. Destroying a component is now a three-dollar mistake instead of a total catastrophe!

• Printed-circuit no-tune bandpass filters, widely used in industry, have been designed for the amateur bands. These filters include the manufacturing and circuit-board tolerances in the design, and use many low-Q resonators in a flat-response bandpass filter, instead of a few high-Q, critically tuned resonators. It's now possible to obtain better performance with *no tuning at all* than was previously available with multiple interacting microwave tuning adjustments made by carefully tweaking a device while watching its output with a spectrum analyzer!

• You can build a complete microwave transverter system, using all new components, at a cost competitive with radio equipment for the lower frequencies. This makes the use of surplus components optional and removes the greatest barrier to amateur microwave operation: the lack of reasonable priced equipment.

• A pair of basic transverters can be used to test receive and transmit amplifiers, filters and antennas, *with essentially no other test equipment.*

### Propagation

Amateurs commonly use four propagation modes at 5.7 GHz: line-of-sight, obstructed paths, over-the-horizon tropospheric, and EME. Line-of-sight paths provide the strongest signals, and an excellent way for microwave experimenters to get their feet wet. The other modes are discussed in more detail in my article in the *Proceedings of the 1991 Central States VHF Conference.*[2]

### Free-Space Path Loss

The Friis path-loss formula, often quoted but seldom understood by communications-systems engineers (amateur or professional), states that: *The loss between a pair of isotropic antennas increases as the square of the distance and the square of the frequency.* The statement, "Path loss increases with frequency," taken out of the context of the Friis path-loss formula, has been repeated so many times in the literature that many amateurs and professionals believe it is a physical law. *It's not!*

Friis actually worked with *three* "path loss" formulas, the most basic of which states that the loss between an isotropic transmit antenna and a one-square-meter receiving antenna goes up as the square of the distance—independent of the frequency. This is called "geometric spreading," and it *is* a physical law.[3] The second formula is for the loss between a pair of isotropic antennas, and includes a correction factor for the effective size of an "isotropic receiver." The third formula states that the loss between two antennas of a given size goes up as the square of the distance, *and down as the square of the frequency.*[4,5,6]

Because antenna gain can be converted to effective area and vice versa, any of the three formulas can be used to obtain the correct path loss for any transmit and receive antennas. The only difference between the three formulas is in the correction factors needed for the different antenna combinations.

Most of us would rather remember a few simple rules of thumb than a bunch of formulas in a textbook. Let's convert the various "path loss" formulas into English:

1) For systems with antennas like dipoles and Yagis, where we specify antenna *gain*, the "path loss" goes up as the frequency goes up. A dipole is a fine receive antenna for 80 meters, but a 5760 dipole isn't very useful—it doesn't intercept much signal, and it's too small for a tie clip!

2) For systems with dishes and lenses, where we specify antenna *size*, "path loss" goes *down* as frequency goes up. If you use the same dish for 2304, 3456 and 5760, *and run the same power and noise figure on all three bands*, signals will be 8 dB stronger on 5760 than 2304.

*Reference Data for Radio Engineers* concludes its section on free-space path loss with this statement: "As frequency is increased, the transmit power or the antenna sizes can be reduced; it is clearly better to use the highest frequency for which generators and receivers are available."[7]

Remember: *Loss on a free-space path is independent of frequency*; the antenna gain-size correction factors are frequency dependent.

On line-of-sight paths with no ground reflections, path loss increases as 20 times the log of the path distance. In very useful terms, that works out to 6 dB every time you double the distance, or 20 dB if you multiply the distance by 10.

Let's put all this into practice. Suppose you set up two 5760-MHz systems 100 meters apart. Using a calibrated variable attenuator in the transmit feed line, you determine that the signal received on the 100-meter path is 46 dB above the noise. How far apart can these two stations be and still have a signal above the noise level? First, double the distance to 200 meters—this reduces the signal by 6 dB, to 40 dB above the noise. Next, multiply the distance by 10, to 2 km—this reduces the signal by 20 dB, to 20 dB above the noise. Multiplying the distance by 10 again, to 20 km, reduces the signal another 20 dB, down to the noise level.

Setting up portable (rover) systems on a known path and measuring the signal-to-noise ratio is an excellent way to both determine the maximum range of the system on line-of-sight paths and to verify system performance.

### Obstructed Paths, Trees and Tropospheric Scatter

When you're attempting to work over non-line-of-sight paths, many other variables become important. A few of these are frequency dependent, such as antenna height above ground. Most loss mechanisms are not very frequency dependent. In my experience, all of the microwave bands have very similar propagation on obstructed paths, *after all the bugs are worked out at both ends of the system.*

Over much of the country, even the best microwave paths have a few trees. How much attenuation do a few small trees have? If they are close to one end of an otherwise line-of-sight path, it's about 10 dB. If a few small trees occlude each end of an otherwise line-of-sight path, the tree attenuation will be about 20 dB. In other words, if the microwave system is capable of operating over a 100 mile line-of-sight path with no trees, it should be able to work over a 10-mile path with a few trees at each end.[8,9]

What about dense or big trees? Once the direct signal is attenuated by 20 dB or so, the signals bounced (or "scattered") from the treetops will be stronger than the signals coming directly through the trees. These scattered signals can be used to communicate when line-of-sight signals are attenuated by more than 20 dB. If one end of the path is in the clear and the other is inside a dense forest, expect 20 or 30 dB of additional path loss. If both ends of the path are forested, but with a clear line-of-sight path between the treetops near the receiver and transmitter, 40 to 60 dB of additional path loss may occur. The path from the forest floor to the nearby treetops near the receiver, and then down to the receiver is called a "scattered lateral wave."[10] A microwave system that can communicate 100 miles in free space may be able to communicate 1 mile in dense forest.

These numbers are speculative, but they represent a cur-

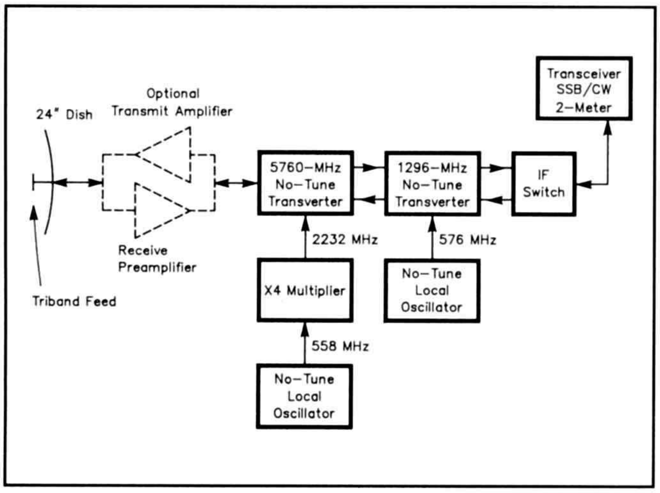


**Fig 1—Block diagram of a basic 5760-MHz transmit/receive system.**

### Approximate Gain, Size and Beamwidth of Dish Antennas

$$\text{gain} = \eta \frac{4\pi A}{\lambda^2} \cong 5D^2$$

$$\text{Gain (dB)} \cong 7 + 20 \log (D)$$

where
$\eta$ = efficiency, typically about 0.5
A = area of dish = $\pi r^2$
D = dish diameter in wavelengths

$$\text{3-dB beamwidth} \cong \frac{90}{D} \text{ degrees}$$

$A_e$ (effective receive aperture) = $\eta$ (area of dish) $\cong$ 0.4 (diam)$^2$

These formulas are generally accurate to within 10%, or less than 1 dB.—*KK7B*

rent consensus of experimental and anecdotal data by professional and Amateur Radio scientists. In any case, they are the best information currently available. This is an area in which amateurs can make a meaningful contribution to radio science.

*Tropospheric scatter* (also known as *troposcatter*) is a practical propagation mode on all of the amateur microwave bands. The US Army has operated long-range portable troposcatter links above 3 GHz for many years. Amateur experience indicates that a 5.7-GHz station equipped with a small TVRO dish, a GaAsFET preamp and a 10-watt amplifier is approximately equal to a 150-watt, single-Yagi 2-meter station—reliable for SSB communications out to about 250 miles and occasionally supporting CW work out to about 400 miles. During enhancements, much greater distances are possible.

## Antennas

Selecting an antenna for 5760,MHz is easy: Nothing matches the performance of a small dish. Approximate formulas relating the gain, diameter and beamwidth for dish antennas are given in the sidebar "Approximate Gain, Size and Beamwidth of Dish Antennas." For example, a 24-inch dish at 5.8 GHz has the following gain, beamwidth and effective aperture, according to the formulas given in the sidebar:

Dish diameter: 11.7 wavelengths
Gain: 28 dB
3-dB beamwidth: 7.7 degrees
Effective aperture = 0.15 m$^2$

The gain can be improved by up to about 2 dB by using an optimized dish feed. Several excellent articles have been published on such feeds. The recent one by Barry Malowanchuk, VE4MA, is particularly useful.[11]

Unlike the lower-frequency bands, it's fairly easy to develop *too much* antenna gain at 5.7 GHz. Recall that gain and beamwidth are inversely related. My 19-inch dish on a small camera tripod has a nice 10-degree beamwidth. It is ideal for loaning to high-school students running a grid expedition to a

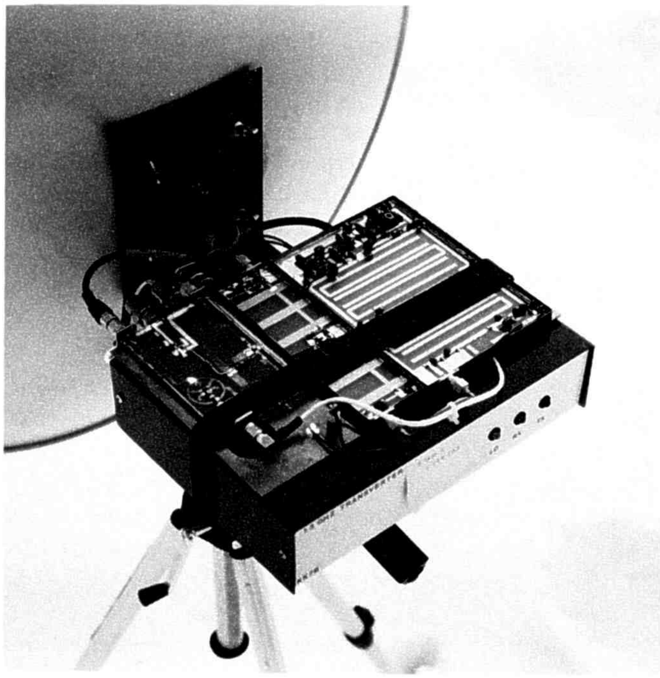

**Fig 2—A complete 5760-MHz station and 24-inch dish antenna, less IF transceiver and 12-V power supply, mounts on an inexpensive camera tripod and is ready to go anywhere!**

windy hilltop for the first taste of microwave Amateur Radio. Even a 10-degree beamwidth is awful narrow when you can't see the other station and aren't sure where to point the antenna. In addition to antenna aiming uncertainty, there's also frequency uncertainty. For the contact to occur, the antenna aiming and radio tuning must be correct at the same time. For beginning operators, or experienced operators on cold, wet hilltops with state troopers slowing down to ask questions, aiming a narrow-beamwidth antenna can be frustrating.

## Building a Basic Station for 5760 MHz

This section presents a basic 5.7-GHz station. You can improve this station by adding amplifiers, TR switching and a bigger dish. This is in contrast to another common microwave system concept, in which an operator builds a "simple" duplex station to make a few contacts with one other station, and then has to build a whole new station if he or she becomes interested in working someone else on the weak-signal calling frequency (5760.1 MHz).

The entry-level station I'll describe here is simple, almost foolproof, can be built at low cost using only new components, and can serve as the core of a moonbounce or troposcatter system. Of equal importance is that the entry-level station serves as test equipment for all of the antennas, feed lines and amplifiers as they're added to the system.

There are two attractive approaches to entry-level 5760 stations that can be easily enhanced up through the EME level (and beyond). The first approach, used by many hams already on the band, is to convert a Frequency West-type surplus phase-locked oscillator to 5760 plus or minus 144 MHz, use a surplus microwave mixer, and retune a surplus filter to pass 5760 mHz. The surplus route has some advantages—if you have access to the parts, expertise and test equipment needed to get it up and running:

- It can be very inexpensive
- Converting surplus is a long and honorable Amateur Radio tradition.
- There may be a psychological advantage—it seems easier to start with something that already works and modify it rather than to make something new from a little Teflon board and a teaspoonful of parts.
- Converting surplus is fun—and is the perfect excuse for buying and using a spectrum analyzer—which is even more fun, but negates the first advantage.

The second approach to an expandable entry-level 5760 station involves assembling a station from no-tune boards, as discussed in October 1990 *QST*.[12] This approach has numerous advantages, mostly because microwave technology has come a long way since those Frequency West local oscillators were built a quarter century ago. Some of the advantages of the no-tune approach are:

- You don't need microwave engineering talent to get the basic station on the air.
- It uses all new, inexpensive parts, and you can duplicate or repair it at low cost.
- You don't need any RF test equipment.
- It is very easy to assemble and very reliable.
- Most importantly, a station can be put on the air by anyone with basic soldering and construction skills—not just mystical guru spectrum-analyzer engineers.

## System Block Diagram

The block diagram of a 5760-MHz transverter system using no-tune boards is shown in Fig 1. (The block diagram of the entry-level system using surplus components is not shown—it depends on the available components, and if you're capable of assembling a microwave station from surplus components, you don't need my block diagram!) Note that a 1296-MHz IF is needed with the no-tune 5760 transverter board. Three options for a 1296-MHz IF are (1) a 1296-MHz multimode transceiver (expensive but increasingly popular); (2) an existing 1296 transverter with a multimode IF transceiver; and (3) a no-tune 1296 board with a multimode 2-meter IF radio.

**Where to Get the Pieces**

In addition to flea markets and VHF conferences, here are a few places where you can get the parts you'll need to get on any microwave ham band:

Down East Microwave, RR 1, Box 2310, Troy, ME 04987, tel 207-948-3741, fax 207-948-5157: no-tune transverters, antennas, triband dish feeds, components, etc; catalog available.

Microwave Components of Michigan, PO Box 1697, Taylor, MI 48180, evening tel 313-753-4581: components; price list available.

The Antenna Center, 505 Oak St, Calumet, MI 49913, tel 906-337-5062: spun-aluminum dishes; price list available.

Steve Kostro, N2CEI, RD 1 Box 341A, Frenchtown, NJ 08825, tel 201-834-1304 (9AM to 7 PM) and 201-996-3584 (after 9 PM): components; price list available.

### *2-Meter IF Transceiver*

Any 2-meter multimode radio can be used as a microwave IF. Older rigs are simple, inexpensive, and have poor sensitivity, which is fine, because the system noise figure is set by the 1296-MHz IF or 5760-MHz preamp. My favorite is the ICOM IC-202, a nearly ideal microwave IF rig in the $100 to $150 price range. These radios, unfortunately, are becoming quite hard to find. The original Yaesu FT-290R is my second choice, as it is small, has a few useful bells and whistles and low battery drain. The typical price range for these rigs is about $200 to $300, depending on condition and accessories. For those who prefer a "real" radio, the analog-tuned Kenwood and Yaesu radios from the TS-700 era are widely available in the $250 to $350 price class. I personally prefer digging for weak CW signals with an analog knob, rather than a 100-Hz click-step synthesizer knob.

### *Antennas*

As mentioned earlier, for an entry-level antenna, it's hard to beat a 24-inch dish (UPS shippable and currently about $70 from The Antenna Center [see the sidebar "Where to Get the Pieces"]). Use the triband feed designed by Tom Hill, WA3RMX[13] (available for $15 when this book was being prepared from Down East Microwave), mounted on an inexpensive tripod from K-Mart or another variety store. Feed efficiency can be improved later, but the 24-inch dish is just about optimum for both hilltopping and long-haul tropo work. For what other band can you buy the same antenna the big guns are using, brand new, for $70?

## Communication with Entry-Level Stations

As Table 1 shows, a pair of entry-level stations are capable of surprising DX from hilltop to hilltop—roughly the same as a pair of 10-GHz Gunnplexer stations with small dishes. A pair of operators willing to locate the appropriate set of grid squares and hilltops can easily work VUCC. Entry-

## Table 1
### Basic 5760-MHz Station Characteristics

Power output: –10 dBm (100 µW, or 0.1 mW)
Noise figure (NF): 10 dB
Bandwidth: 100 Hz or 2.5 kHz*
Antenna gain ($G_a$): 25 dB†
Effective aperture ($A_e$): 0.1 $m^2$†
Maximum communication distance: 8000 km (5000 miles)**
Routine SSB communication distance: 160 km (100 miles)††
SN100:*** 84 dB

*100 Hz is an approximation for the ear-brain bandwidth when copying weak CW through an SSB filter.

†$G_a$ and $A_e$ are for a 24-inch dish with 25% efficiency (includes illumination and feed-line losses).

**Represents a 0-dB signal-to-noise CW signal at the human hearing threshold.

††Represents "armchair copy" SSB (20 dB above the noise in a 2.5-kHz bandwidth).

***Expected signal-to-noise ratio in a 2.5-kHz bandwidth of two identical 5760-MHz systems aimed at each other over an unobstructed 100-mile path.

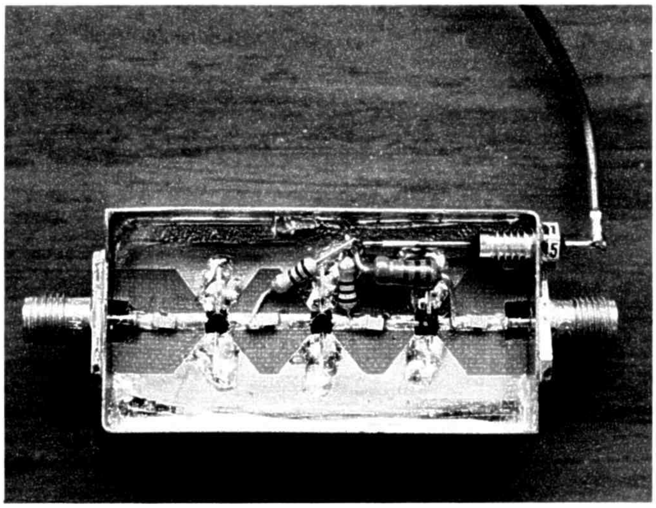

**Fig 3—This simple utility amplifier, suitable for 903, 1296, 2304, 3456 and 5760-MHz transmitting and receiving use, consists of three MMICs, three ordinary resistors and five chip capacitors.**

level stations are nearly ideal for contesting because they use no amplifiers that could oscillate or fail, no expensive microwave relays with their associated connectors and switching-voltage complications, and they can be mounted right at the dish to eliminate feed-line loss and all the other complications of using feed lines. The entry-level station is all many operators will ever need, and smart contesters experiment with entry-level stations before adding the complexity of amplifiers and relays. Fig 2 shows a complete entry-level system built entirely from Down East Microwave no-tune boards.

### Entry-Level Stations as Test Equipment

The nature of microwave hamming is such that you either own two complete systems for each microwave band or are within driving distance of another station. The ideal piece of test equipment for a 5760-MHz station is a second 5760 station. If each is an entry-level station made from no-tune boards, then the approximate power output, noise figure, antenna gain, and so forth, are known and, more importantly, stable.

One rule needs to be followed: The local oscillators (LOs) in the two transverters need to be on slightly different frequencies. Otherwise, it's impossible to separate the up- and down-converted microwave signals from IF-signal leakage (sometimes called *breakthrough*). Normally the natural offsets of fifth-overtone crystals are more than enough to provide the needed LO frequency offset, but if you're not sure whether the signal you're hearing is at 5760 MHz or IF breakthrough, wave your hand near the antenna and listen for Doppler fluctuations, or breathe on the LO crystal to change its temperature, which should provide enough frequency shift for you to hear easily.

A number of useful tests are possible by setting up two stations as described in Table 1 facing each other over a path of about 100 m.

- Place a 40-dB pad in the 1296-MHz IF line of each system. SSB signals should be just barely readable both ways. With pads in the IF lines and signals at the "just-barely readable" level, you can compare the effects of different dish feeds, feed lines and filters. By using CW, disabling receiver AGC and using an audio-output meter calibrated in decibels, you can make quantitative comparisons. If a standard-gain antenna is available, you can also make antenna-gain measurements.
- You can determine frequency offsets and study the effects of time and temperature on stability. I write the frequency offset (ie, "5760.100 MHz = 144.126 MHz") on each transverter with an indelible marker.
- On the bench, an entry-level system can serve as a low-level source for aligning filters and measuring amplifier gain, filter loss and transmission-line loss. In receive, the entry-level system provides a way to listen and compare signal levels in transmitters.

### Enhancing the Entry-Level Station

The entry-level transverter is the heart of a more elaborate station for working over obstructed paths, and via troposcatter and moonbounce. Moving up to the next level requires adding 5760-MHz gain to the transmit and receive signal paths. You need three things to do this: (1) a way to separate the transmit and receive signal paths; (2) a receive preamplifier; and (3) a transmit power amplifier.

The easiest way to split the transmit and receive paths is with a pair of microwave relays. These are expensive, but are often available surplus at hamfests and flea markets. Once the transmit and receive paths are separated, you can add amplifiers. A particularly useful amplifier for low-level transmit and receive use is shown in Figs 3 and 4. At 5760 MHz, the three-MMIC circuit has a gain of about 15 dB, a noise figure (NF) of about 7 dB and a few milliwatts output. Station enhancements are discussed in more detail in my article in the *Proceedings of the 1991 Central States VHF Conference*.[14]

### Grid-Hopping Operating Hints

Here are four suggestions that have been useful in the last

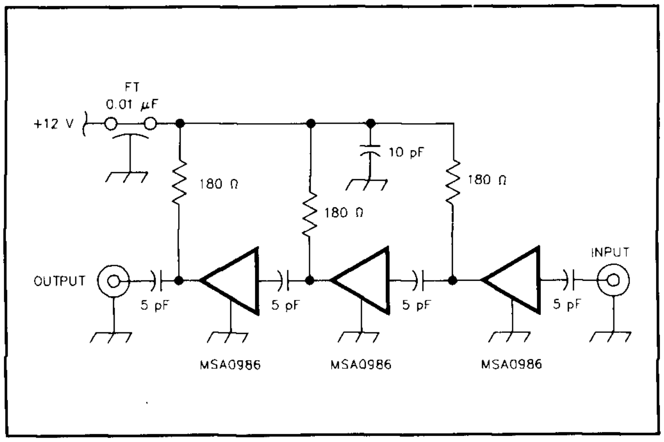


**Fig 4—Schematic of the utility amplifier. Chip capacitors and MMICs are available in small quantities from Down East Microwave, Microwave Components of Michigan, and other sources.**

ten years of microwave grid hopping at KK7B:

- Set up and test everything (both stations) the week before the contest or grid expedition. Fix any loose connectors, charge batteries and make sure everything is ready to go.
- Pick a reasonable liaison frequency. Two-meter FM handhelds are useless for all but the shortest microwave paths. Two-meter SSB radios with 5/8-wavelength whips are okay for medium-length paths, but remember that even the simplest pair of 5760 stations with 24-inch dishes is capable of operating SSB over a 100-mile path. With amplifiers, the 5760-MHz system will outperform 2-meter SSB stations with 150-watt "bricks" and Yagis! During the last few KK7B/8 multiband grid expeditions, I've used 5760 MHz as the liaison frequency for the lower bands!
- Work your own grid square first by setting up both stations a couple of hundred feet apart. This confirms that everything still works, permits a final check on operating frequencies, and gives you at least one contact on the band, in case the weather turns foul or something fails.
- Most "line-of-sight" microwave paths have a ground-reflected component. Ground-reflected signals may add or subtract with the direct signal. Sometimes aiming a dish a few degrees above the horizon improves signal strength by reducing the ground-reflected component.

## Conclusions

The 5760 stations described in this article are portable, lightweight, reliable and can be battery powered. They can be operated from home stations, but the *real* fun begins when you take the station to a hilltop or beach. You can earn a 5760-MHz VHF-UHF Century Club (VUCC) award by working just five grid squares on 5760. Obtaining VUCC from a portable location is not only practical, but is generally *easier* than working five grids from a home station. This is one of the few areas in ham radio where you can be a "big gun" while living in an apartment, dormitory, barracks or "controlled community"! Two-foot dishes fit nicely in the trunk or back seat of a car, and a backpack station is entirely feasible.

An operator who concentrates on 5760 and coordinates with other 5760 operators can stay happily busy for an entire contest weekend. And this is without even considering adding a couple more bands to your setup, which you can do easily using no-tune transverters and a multiband dish feed.[15] You don't even have to get permission in advance to set up a camera tripod and small dish at a scenic overlook.

Perhaps best of all, you get to drive around and enjoy the hilltops and beaches between contacts, instead of gritting your teeth in front of an overloaded 2-meter rig while your neighbor works the rare grids with his legal-limit amplifier!

## Notes

[1] R. Campbell, "A Single-Board Bilateral 5760-MHz Transverter," *QST*, Oct 1990, pp 27-31 (reprinted in Chapter 3 of this book).

[2] R. Campbell, "A 5760 MHz Primer," *Proceedings of the 1991 Central States VHF Conference* (Newington: ARRL, 1991), pp 7-24.

[3] A. Ishimaru, *Electromagnetic Wave Propagation, Radiation and Scattering* (Englewood Cliffs, NJ: Prentice-Hall, 1991), pp 123-127.

[4] *Reference Data for Radio Engineers*, 6th Ed. (Indianapolis: Howard W. Sams, 1975), pp 33-3, 33-7.

[5] R. Campbell, "Does Path Loss Increase with Frequency?" Technical Correspondence, *QST*, Jan 1991, p 38.

[6] A. Hambley, *An Introduction to Communications Systems* (New York: W. H. Freeman and Co, 1990) pp 168-169.

[7] See note 4.

[8] D. Hilliard and B. McCaa, "Preliminary Results of Foliage Attenuation Measurements at 902 MHz and 3456 MHz in the Boulder, Colorado Area," *Proceedings of Microwave Update '89* (Newington: ARRL, 1989), pp 133-147.

[9] W. Vogel and J. Goldhirsch, "Roadside Tree Attenuation Measurements at UHF for Land Mobile Satellite Systems," *IEEE Transactions on Antennas and Propagation.*

[10] R. Campbell and H. Wang, "A Theoretical and Experimental Study of Scattered Lateral Wave Propagation in Forest," *Digest of URSI North American Radio Science Meeting*, London, Ontario, Jun 1991.

[11] B. Malowanchuck, "Use of Small TVRO Dishes for EME," *Proceedings of the 21st Conference of the Central States VHF Society* (Newington: ARRL, 1987), pp 66-77.

[12] See note 1.

[13] T. Hill, "A Triband Microwave Dish Feed," *QST*, Aug 1990, pp 22-27 (reprinted in the Antennas chapter of this book).

[14] See note 2.

[15] See note 13.