# Give Me Power

Signals on the microwave bands come from stations that run considerably lower power than is common on HF and VHF. In general, this is sufficient because with the relatively short distances and high gain antennas that microwavers use, not much power is needed.

Experienced microwavers have mastered the art of low noise receivers and are using as large an antenna as practical (and believe me, there are many impractically large ones out there). For them, the next step in station improvement is to increase transmitted power. When trying to make a difficult contact with imprecise frequency control and direction information, having "lots of smoke" at one end of an attempt helps to get the weaker station to optimize its antenna and frequency before transmitting.

There are several sources for power on the microwave bands. Much of the development has been spurred by the military requirements for radar transmitters; some by telephone and video circuits carried by microwaves, satellite links, and more recently, mass marketed cellular and digital commercial applications.

The operation of a Magnetron is not described here. They are not generally useful as amplifiers, but rather are oscillators, and so see very little use in Amateur Radio. Microwave ovens and marine radars most often use Magnetrons as their RF source.

In 1937 the brothers Sigurd and Russell Varian invented the Klystron. These tubes can deliver power in the hundreds of kilowatts at UHF through 10 GHz, and special versions have been developed up to 240 GHz! Klystrons are very expensive and rarely found in amateur applications, and so I won't use space to describe the internal operation. Their narrow operating frequency range, and very high efficiency make them ideal for UHF TV transmitters, tropospheric communications links and some types of radar.

In the early 1940s Pierce and Shepherd of Bell Labs invented the reflex Klystron, a low-power device often used as a local oscillator in radar receivers. Some amateurs used these for bands from 10 GHz through 47 GHz prior to the advent of the Gunn.

### The Traveling Wave Tube

In1944 Kompfner invented the TWT (Traveling Wave Tube). Continuous wave TWT amplifiers can be constructed for power levels from 1 W to hundreds or even thousands of watts. They range in frequency from 1 GHz to over 40 GHz.

Because TWTs are available surplus, and because they are true amplifiers, giving lots of gain and at useful power levels, amateurs often employ them as amplifiers in home stations. Their weight, high power consumption and exceedingly high internal high voltages make them impractical for hill-topping expeditions.

### How does the TWT Work?

As shown in Figure 1, an electron beam in the TWT is focused and injected into the "slow-wave" circuit where it interacts with the propagation RF wave. This wave is presented to the beam through a helical winding. The helix slows the phase-velocity of the RF wave such that its velocity matches the electron beam's. The electron beam is velocity-modulated at the beginning of the helix. As it passes through the tube, the velocity modulation changes gradually to density modulation, and then induces an amplified RF wave at the output section of the helix. Usually an attenuator is placed around the center of the tube to prevent feedback. The efficiency is low but the TWT is inherently broad band, often having more than an octave, and in some designs over a decade of bandwidth. Gains can be as high as 40 dB. Example units that deliver tens to hundreds of watts are shown in Figure 2.

### Are Triodes used on Microwave Bands?

The planar triode tube has been developed for amplifier use in the 400 MHz to 1 GHz range. Amateurs have made many Q5 1296 QSOs over the years with the 7289/2C39 tube. It is common to produce over 100 W from an air-cooled pair (see Figure 3) and 250 W from a water-cooled pair of these tubes. There have also been successful designs that use up to six of these tubes to generate over 500 W. The same tube, in a single configuration has been used by some amateurs on 2304 MHz, with reports of between 15 and 40 W of output.

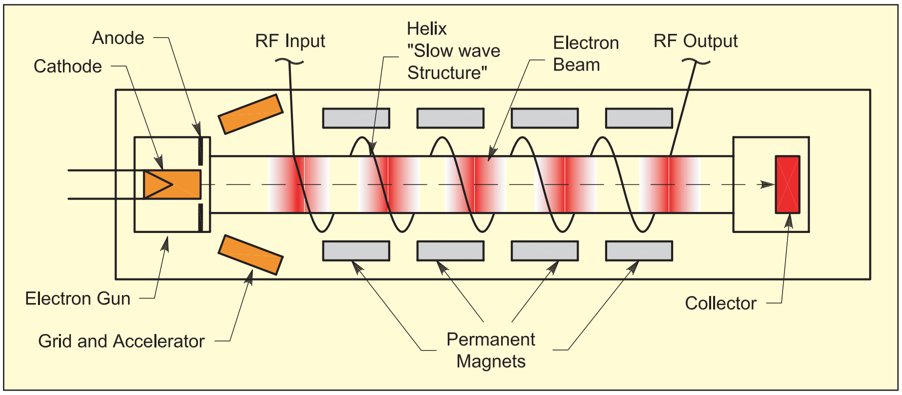


**Figure 1—Simplified schematic of a Traveling Wave Tube.**

**Figure 2—Here is Dick, K2RIW discussing two TWT amplifiers with the author.**

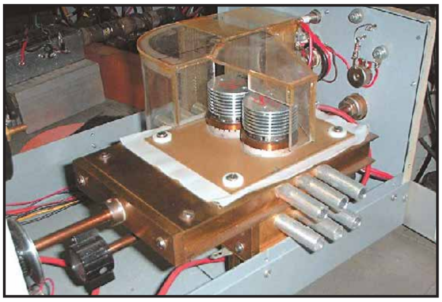

**Figure 3—A two tube 100 W, 1296 MHz amplifier. The air-cooling fins can be seen here with a plenum made from Plexiglas.**

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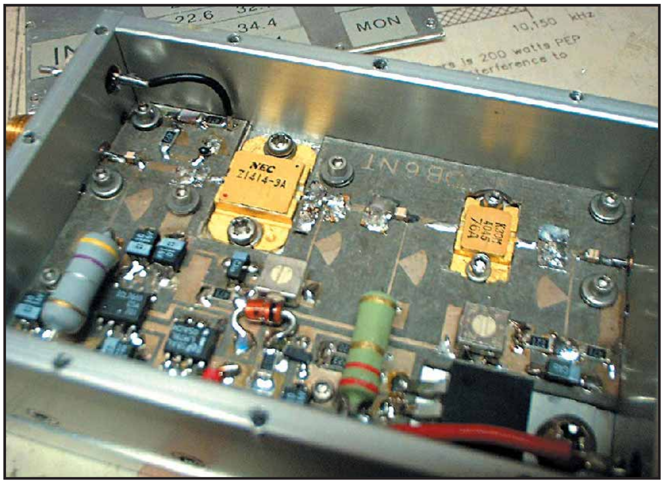

**Figure 4—A 3-W, 10 GHz amplifier using FETs. The author constructed this from a DB6NT board and FETs removed from surplus 14 GHz satellite uplink systems. It is usually easy to retune FETs to frequencies lower than their original design.**

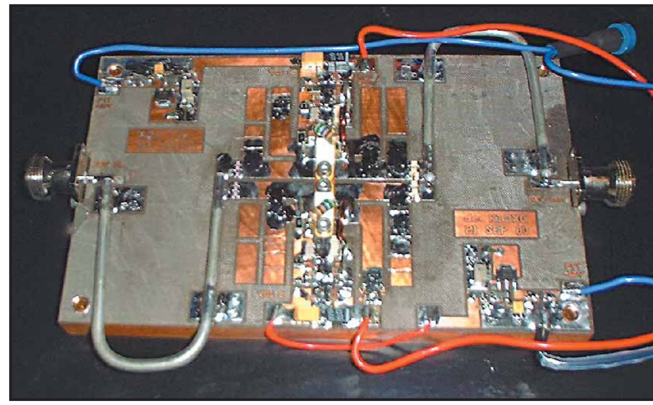

**Figure 5—An LDMOS 100 W, 1296 MHz power amplifier, designed and built by John, KB3XG (see *Microwave Update 2000*). The transistors are the white objects in the middle. Most of the rest is matching network.**

There have been several other, higher power tubes available (notably the Gs9b and Gi7b) at reasonable cost that can produce several hundreds of watts on 1296 MHz. EMEers have put these tubes into service with good results.

### Solid State

Solid-state amplifiers have the advantage of no warm-up, lower voltage than tubes, and generally smaller completed units. This has resulted in more power in portable stations, and the ability to place reasonable power level amplifiers on the mast to deliver most of the RF to the antenna.

### Gunns and IMPATTs

The Gunn diode is a device originally investigated by (and named after) John B. Gunn in the early 1960s. In a resonant circuit and dc biased it will oscillate and produce some RF power. Typical power levels are 5 or 10 mW, but there are 100-mW devices available.

Gunns and IMPATTs can be configured as amplifiers when connected to a circulator. If the device is biased carefully and matched properly to its cavity, it will oscillate at the frequency of incoming RF. Although not linear in its response, such amplifiers can operate over sufficient frequency and power range to be useful as amplifiers in some communications systems. Because these are quite difficult to tune and because there are alternatives with competitive cost, they are relegated by amateurs primarily to EHF bands (47 GHz and above).

### Bipolar Transistors

Bipolar transistors are useful as power amplifiers into the 2 GHz range, but at higher frequencies they become difficult to match and keep stable. Many affordable bipolars for the 1.2 GHz and 2.3 GHz bands are designed for class C operation. They can provide plenty of efficient power (100 W is not uncommon) for CW but have too much distortion for SSB communication. Fortunately, some can be biased into class AB operation, sufficiently linear for an undistorted SSB signal, but at about $^1/_3$ the class C power. This biasing requires two power supplies and a biasing network that is bulkier than most FET designs.

### FETs

Gallium Arsenide and Indium Phosphide Field Effect Transistors are useful up to and beyond 100 GHz. They can be effective power amplifiers as they are inherently linear devices and fairly easy to bias with two voltages. Although individual FET dice do not produce much power, many elements are often placed into one component along with internal matching. This allows easy development of circuits based on 50 Ω striplines. Figure 4 shows a 3 W 10,368 MHz amplifier using internally matched FETs. Single devices with ratings of over 20 W at 5 GHz and over 10 W at 10 GHz are available, but not cheap. FETs are often used in RF ICs called MMICs for Monolithic Microwave Integrated Circuit. There are units on the market that combine several stages of amplification to provide for both low noise and medium power at EHF bands. Examples include 1 W at 24 GHz, 300 mW at 47 GHz, and 50 mW at 80 GHz.

### LDMOS

Various formulations of enhancement mode power MOSFETs have been developed for cellular industry base stations that produce 100 to 200 W of linear power at the 900 MHz and 2 GHz bands. These are somewhat difficult to match, but once mastered, very effective solid-state amplifiers developing over 100 W on the 1296 MHz band can be constructed. Figure 5 shows a 1296 MHz 100 W power amplifier with these devices.

### How Can I Get a Solid-State Amplifier?

There are plenty of choices. Published designs, kits, boards and fully constructed packages are available from several vendors. There are many surplus amplifiers found at hamfests, for auction on the Web, and occasionally listed for sale in Amateur Radio newsletters. Some of the boards and kits require skill in surface-mount soldering and tuning striplines. Also, to properly tune up a home made amplifier you will need an RF source, controllable power supplies, a reliable power meter and a load appropriate for the band. If you don't have these items, get some help from someone in your club or group.

Don't forget—high power is not the first thing to concentrate on when assembling a station. Get good frequency control, a sensitive receiver and a good antenna before trying go QRO. Once you hear the weak ones you may want to get on another band rather than trying more power. But if you do want more power, talk to other hams and you may be surprised just how easy it can be.

### Resources

Links to appropriate information and vendors can be found at **www.wa1mba.org/interest.htm/**.

Visit **www.arrl.org** to find a variety of microwave books and *Proceedings of Microwave Update* that include designs for several of the amplifiers shown in this column.