1.4.3 Radiating RF

Let's digress a moment to talk about towers and antennas. A *tower* is a narrow platform usually made of steel. An *antenna* is a device to radiate RF energy. Confusion exists on the difference between a transmit antenna and a transmit tower. In AM radio the antenna and tower are the same. Due to the low frequencies used with AM (centered at 1 MHz) it is important to create a strong ground-wave signal. Ground-wave signals can go a long way and easily travel over the horizon. So AM antennas are near the ground. The height of these towers is usually related to the wavelength of the transmitted carrier. Thus, AM stations with lower frequencies tend to have taller towers than ones at higher frequencies. To minimize the height for a low-frequency AM broadcaster's tower, a station at 540 kHz might use a one-quarter wavelength height tower, while one at 1540 kHz might use a one-half wavelength height tower. It is important for efficiency that the tower be some fraction of the transmitted carrier's wavelength. Since these towers are also the antennas, the RF power is applied directly to the whole tower. The base of the tower is isolated from the ground, and these towers are fenced off because if you walked up and touched one, it would ruin your day, and maybe your life. Often you see multiple antennas near one another at the AM transmit site. These antennas are called an *array.* They are driven by the AM transmitter such that they amplify the RF transmitted in some directions and minimize it in others to protect other AM stations in other markets. Thus, these antennas are often called *directional arrays.* AM ground waves are best created in wet, highly conductive soil so AM towers are usually in low-lying areas, often near water or swamps.

In contrast, FM and television antennas and towers are separate entities. At high frequencies very little, if any, ground wave is created. The radiated signal is said to travel only in a line of sight. The RF signal can be thought of as being like a street light. To cover the widest area with that light, you want lots of height and a lot of light or power. Therefore, the tower is used as a platform to get the antenna as high as possible. That is why television and FM antennas often sit on top of mountains or tall buildings. If neither is available, towers that are often 1000 ft high are erected, although towers as tall as 2000 ft are not uncommon (Fig. 1.13).

Now let's go back to UHF difficulties. The transmitter at the base of the tower produces RF power, although generally less efficiently for UHF than for VHF frequencies. That power must be sent up to the top of the tower to the antenna. Half the power can be lost in the trip up the tower (Fig. 1.14).

To maximize what is left, television (FM also) transmit antennas don't radiate straight up into space or straight down the tower. They are generally designed to radiate only toward the horizon. If it were possible to see the RF energy being emitted from the antenna, the pattern would look like anything from a fat donut to a thin phonographic record (today the reference should probably be to a CD). Donut patterns are good for close-in coverage, while thin or flat patterns are used to push the signal out toward the horizon. With thin patterns, viewers close in to the transmit antenna might have far worse recep-

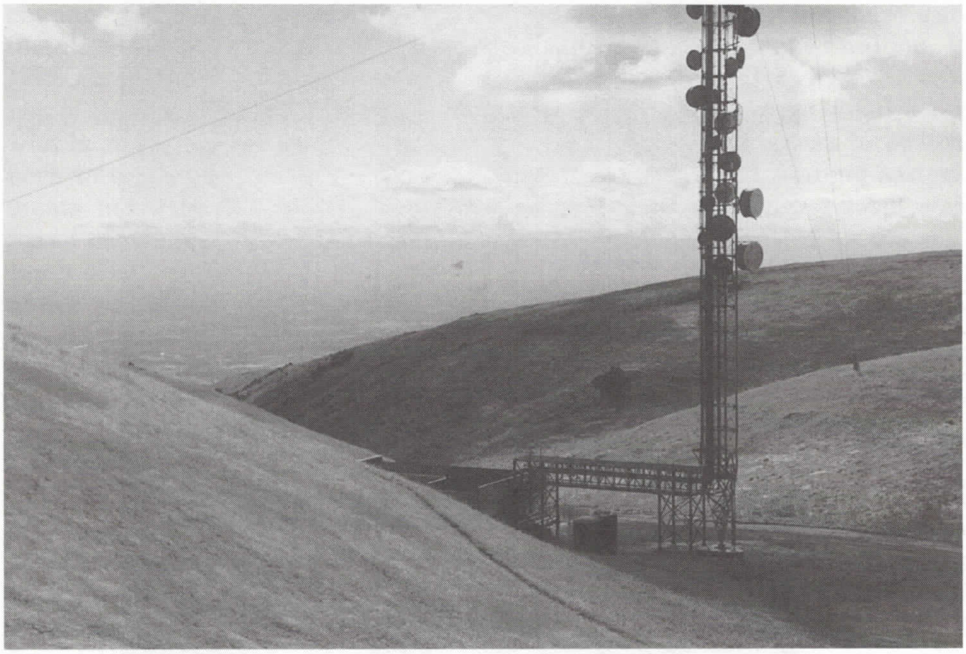

Figure 1.13 Bridge carrying RF power (through a transmission line; see Chap. 13) from the transmitter building to the base of the tower, and then up the tower.

tion than viewers much farther out. Fat donut patterns cover near-in viewers well but limit the far reaches of the station's coverage.

VHF signals can reach to the optical horizon and then some. It is said that the radio horizon for VHF is greater than the optical horizon. For UHF the radio horizon is often less than the optical horizon. To make up for the UHF propagation shortfall, the FCC lets some UHF stations effectively radiate power toward the horizon that is 50 times greater than their low-band VHF counterparts. In contrast, high-band VHF broadcasts are only allowed to be a maximum of just over 3 times "hotter" than the VHF low bands. However, in order to generate all this power, UHF stations tend to have much greater power bills than VHF—6 to 10 times is a fairly common disparity. In addition to more power, the UHF station can build higher towers and find higher mountains and buildings on which to place their antennas. Height turns out to be very important in maximizing UHF coverage.

1.4.4 DTV channel assignments

Now with DTV the FCC has assigned a second DTV channel to every TV station. In most markets there isn't any room for additional VHF channels because their saturation prompted the original UHF allocations. It should be noted that, in several markets, the FCC experimented with handing out only UHF and no VHF licenses. During the 1960s, the FCC toyed with the idea of

Figure 1.14 RF transmission line, which appears to the layperson as water pipes, carries the RF energy from the UHF transmitter up to the antenna on top of the tower.

moving all broadcasters to UHF and reclaiming the VHF band. Now the plan is to have all television broadcasters end up on channels between 2 and 51 when NTSC broadcasts go dark. These are referred to as the "core" channels. Many VHF stations have UHF assignments for DTV. When NTSC goes dark, they must hand one channel back to the FCC. It doesn't matter which one; it can be either the UHF or the VHF, with the following exception. If a station has an initial DTV channel assignment above channel 51, that station must move back to the current NTSC channel to continue DTV broadcasts when NTSC ends.

Now it would seem that it is a "no brainer" as to what the VHF NTSC broadcaster with a DTV UHF assignment will do when it is time to choose, but it is not that simple. Many components in a television transmitter are frequency or channel dependent, as is the transmit antenna. The cost to purchase and install the DTV transmitter and antenna can easily be above $3 million. If NTSC is discontinued earlier, say around 2006, then later it might make economic sense to keep the UHF frequency. However, the VHF NTSC broadcaster who is now on a UHF DTV channel will have major incentives to switch back to the original channel. The FCC not only handed out channel assignments but also the maximum allowed power levels. The power level was based on what it would take to duplicate the coverage provided by the station's NTSC signal with the station's DTV signal. A tremendous increase in power would be necessary for VHF coverage to be duplicated by UHF. So in a simple effort to save money on power, a VHF to UHF to VHF movement for such a station might prove advantageous no matter how early the initial DTV equipment might have to be scrapped. The downside is that DTV coverage is sort of like the Oklahoma land rush. The first stations up on a channel will have more protection from interference than later arrivals.

There is a saving grace with DTV modulation. The modulation process and error recovery ability of DTV receivers are such that a DTV signal 20 times weaker than a NTSC signal will provide comparable coverage. This is creating an interesting situation for the few broadcasters that have NTSC and DTV assignments that are both in the VHF band and the few broadcasters going from UHF to VHF assignments. In both cases these broadcasters are receiving power assignments that are extremely low. Whereas an NTSC UHF broadcaster might have had an effective radiated power (ERP) of well over 1 MW, now the ERP for that DTV channel might well be under 10 kW. Low-band VHF DTV power assignments as low as 1 kW have been handed out. Typical maximum low-band VHF ERPs for NTSC have been 100 times that amount. In some markets assigned power levels for DTV stations have differed by a ratio of 500:1. This has happened where NTSC VHF stations have been given DTV UHF assignments while NTSC UHF stations in the same market have been given DTV VHF assignments.

1.4.5 Television transmitters

The fact that some stations will have much lower power bills than their competition creates other fallout. As was already mentioned, UHF transmitters tend to be more inefficient than their VHF counterparts. Less efficiency means that more heat is generated, which means larger air conditioning units, requiring more space. Greater transmission power also means larger transmitters and more RF plumbing to accommodate a larger, more complex system (Fig. 1.15).

Additionally, UHF transmitters must cope with two opposing laws of physics. To handle more power, the mass and size of many components must be made larger to dissipate heat; conversely, higher frequencies require that components be made smaller as wavelength decreases. This is why devices that create high-power UHF RF signals tend to be much less efficient. However, they also require more support systems. Whereas VHF transmitters

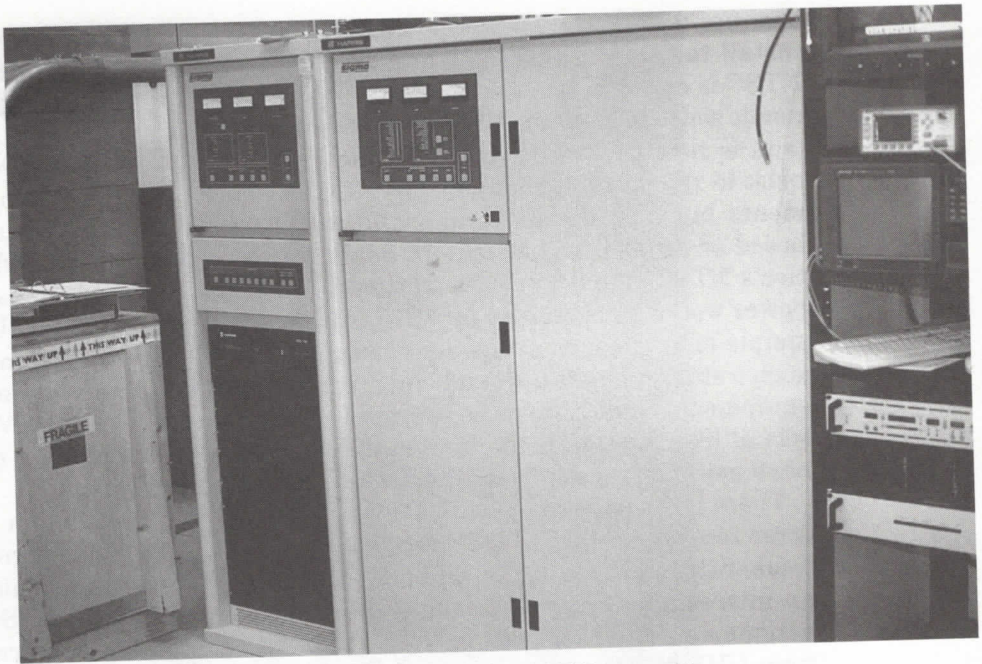

Figure 1.15 Newly installed DTV (IOT; see Chap. 13) UHF transmitter.

of all power levels have always tended to be air cooled, high-power UHF transmitters tend to be water cooled as water is a better medium to carry heat away quickly. This leads to complex plumbing systems, with their tendency to leak, and large heat-exchanger systems (Fig. 1.16).

High-power UHF transmitters use technology that tends to work at higher voltages. All transmitters can be extremely dangerous systems. Most who have worked around these systems have first- or second-hand accounts of people being blown across rooms, out of shoes, or worse by coming in contact with, or just even being near, these potentials. The high voltages found in VHF transmitters tend to be under 10 kV, with 7 to 8 kV common. Historically, UHF transmitters tend to run at triple that voltage, around 25 kV. Now new technology for more efficient high-power UHF amplifiers is running as high as 35 kV (Fig. 1.17). High voltage doesn't like dust, water leaks, or things that change in conductivity. Additionally, the inductive and corresponding current spikes that occur on power-up or shutdown tend to produce fail-ures. Because of the voltage potential, these failures can be spectacular.

Since VHF transmitters generally run at low power levels, solid-state technology has found wide acceptance. Although all VHF and UHF transmitters have been solid-state, except for the final few amplifying stages since the early 1960s, now triodes and tetrodes (vacuum tubes) used in VHF final amplification stages are being replaced with solid-state modules. These modules work

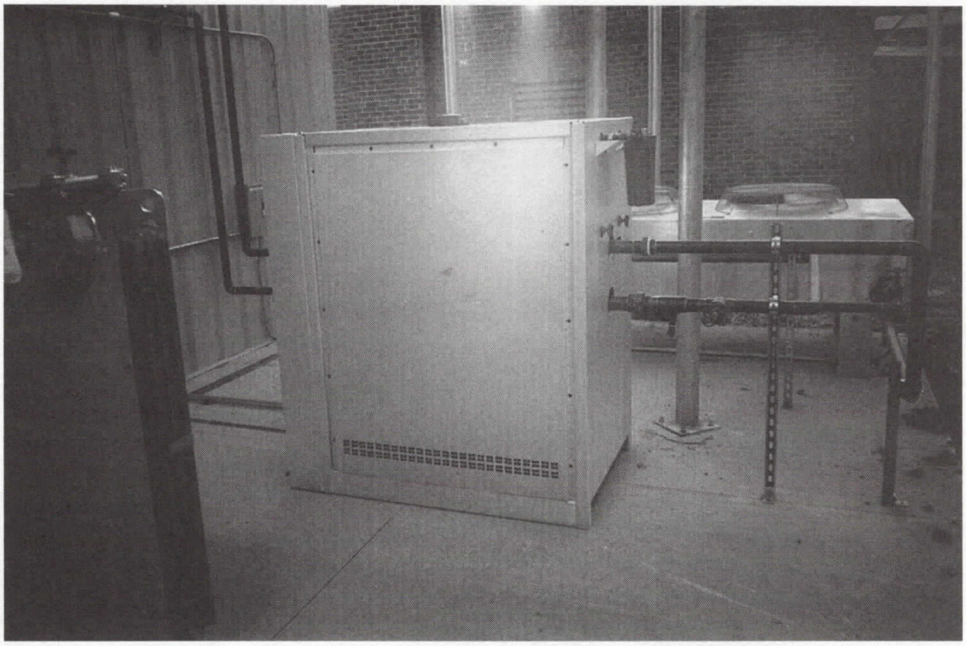

Figure 1.16 Heat exchanger used by a UHF transmitter. Water is used to carry heat away from the final amplifier stage. The heat exchanger cools the water for a return trip to the transmitter. If more than one final amp is used, additional heat exchangers may be required.

at fairly low voltages, with 45 V common, but handle a fair amount of current. Lots of arcing potential (high voltage, low current) has been replaced with lots of welding potential (low voltage, high current). Whereas a tube would slowly burn up its filament, and consume its cathode, the solid-state devices do neither. As the tubes age, adjustments have to be performed periodically. Solid-state devices generally require no such tweaking. It is claimed that the most important maintenance procedure for solid-state transmitters is the timely replacement of air filters.

Today even some UHF transmitters are solid-state. The architecture of the solid-state transmitter is the limiting factor in the amount of power a solid-state transmitter can efficiently produce. Each solid-state amplifier module handles only a few dozen watts so there are many of these amplifiers in parallel. It is the combining process of summing the power for the many parallel amplifiers that wastes power. At some point, the combining networks reach a size where their combined power loss from each individual combiner makes the overall transmitter too inefficient (Fig. 1.18).

The major advantage to this architecture is that if a module fails, the output power drops only by the amount that the failed amplifier was contributing. There is no single point of failure. The module can even be pulled “hot,” which means while power is still on, and replaced.

Figure 1.17 High-voltage supply (often called a beam supply) for a high-power UHF transmitter. This supply is filled with oil to minimize the chance of arcing.

1.4.6 DTV reception

A lot of DTV will be on UHF, at least initially. As we will see later in the book, it is not yet clear what the cable systems will do with the additional DTV channels. Many are betting that many early DTV viewers will have to use a set-top antenna or put up a roof-top antenna. Following the enactment of the Telecommunications Act of 1996 by Congress, the FCC instituted a rule known as 47 C.F.R. 1.4000, which preempts local ordinances and homeowner agreements from prohibiting the mounting of terrestrial television or satellite

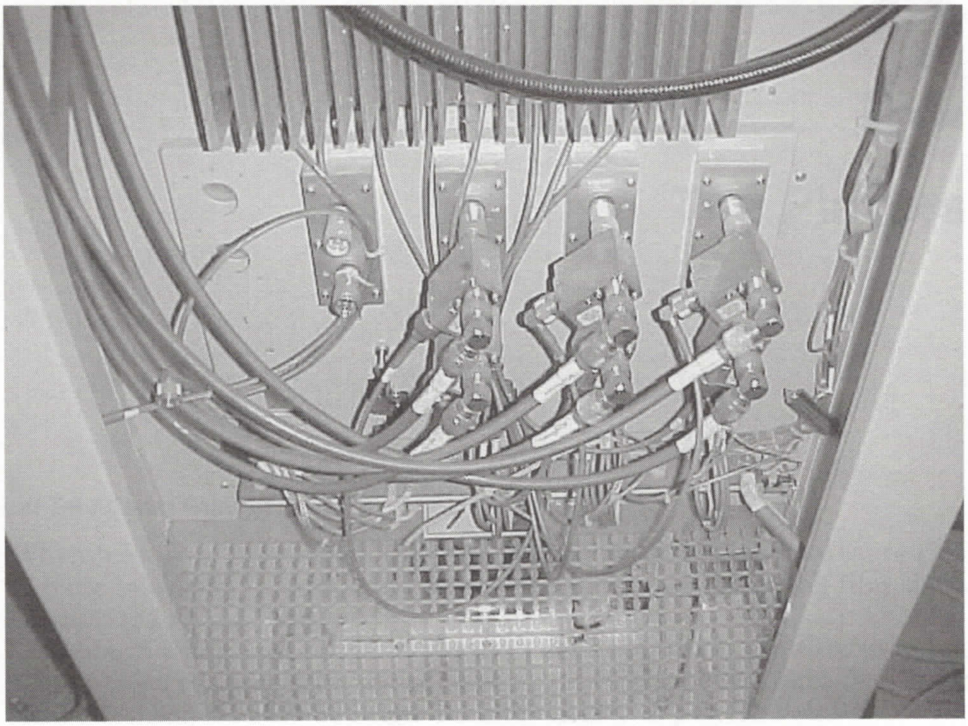

Figure 1.18 RF power combining in a small solid-state transmitter.

receive dishes on dwellings. This is surely a series of court fights waiting to happen. Just as UHF has greater losses and lower efficiencies at the transmit end, the same is true at the receive end. Poorly installed receive systems will hurt UHF channels much more than VHF channels—NTSC or DTV.

Common problems with NTSC reception are a noisy picture caused by low signal levels, "sparklies" caused by electrical noise (which actually affects VHF more than UHF), intermod (which was discussed earlier), and ghosting, which is caused by multipath. Multipath occurs when the signal bounces off natural and man-made objects on its path between the station's transmit antenna and your receive antenna. The received signal could consist of a signal that traveled directly to your receive antenna, along with one or more signals that bounced off buildings, hills, or airplanes to get to your antenna. Because the paths these bounced signals took is longer than the direct path between transmit and receive antennas, they arrive later in time. DTV signals can have the same problems, but you won't know that any exist until they are bad enough to swamp the error-correction circuitry in the DTV receiver.