and an outer shield. This type of transmission line is covered in detail in Chapter 3). Similarly, measuring with an ohmmeter from the conductor of a microstrip transmission to its ground plane would yield the same result. (A microstrip transmission line is a printed line on one side of a printed circuit board with a complete ground on the other. This type of transmission line also is covered in Chapter 3). This should reinforce the idea that a characteristic impedance is not a *direct-current* (dc) parameter but one that "characterizes" the system or transmission line at the frequencies with which it is designed to work.

We have mentioned earlier that the characteristic impedance most often used in high-frequency applications is 50Ω. The question that comes about is: Where does this 50-Ω figure come from? To understand how this value was reached, you need to look at Figure 1.3. It can be seen from this chart that

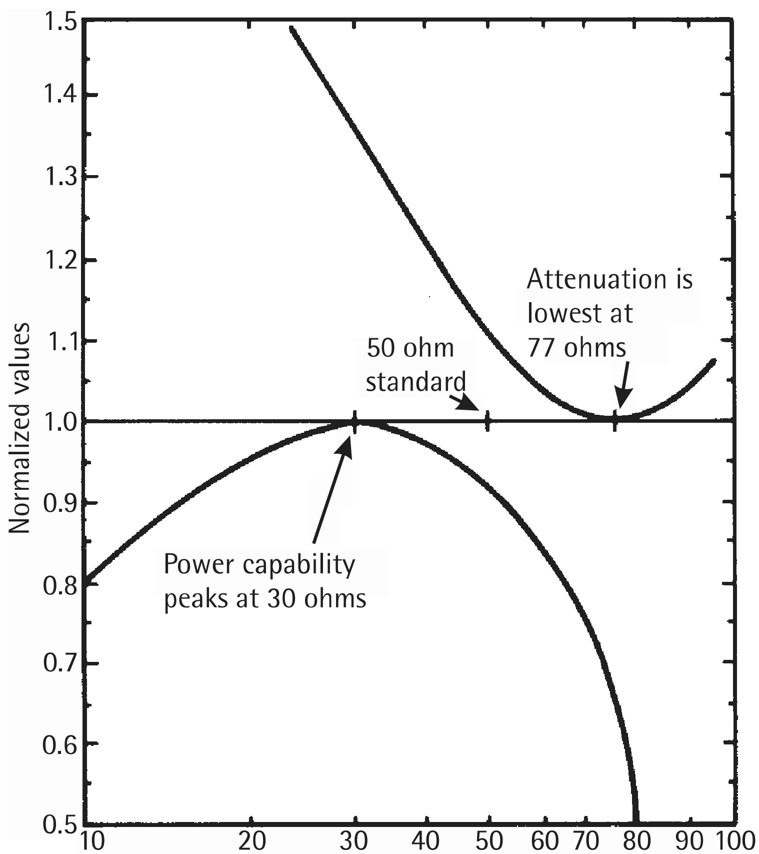

Figure 1.3 Attenuation and power capability. (From: [1]. © 1988 Artech House, Inc. Reprinted with permission.)

the maximum power handling capability of a particular transmission line or system is 30Ω, while the lowest attenuation for a transmission line or system is 77Ω. The ideal characteristic impedance, therefore, is a compromise between these two values, or 50Ω. Thus, you can see that this is not an arbitrary number, but one that has some semblance of order to it.

Another point to be brought out for this parameter is that the value of characteristic impedance is the same at the input of a transmission line or device as it is 30 cm away, 1m away, or 1 km away. It is a constant that can be relied on to produce predictable results in your system.

The term *voltage standing wave ratio* (VSWR) is used to characterize many areas of microwaves. It is a number between 1.0 and infinity. The best value you can get for the VSWR is 1:1 (notice that it is expressed as a ratio), which is termed a *matched condition*. (A matched condition is one in which systems have the same impedance, so no signals are reflected back to the source of energy.) To understand the concept of a standing wave, consider a rope tied to a post. If you hold the rope in your hand and flip your wrist up and down, you see a wave going down the rope to the post. If the post and the rope were matched to each other, the wave going down the rope would be completely absorbed into the post and you would not see it again. In reality, however, the post and the rope are not matched to each other and the wave comes right back to your hand. If you could move the rope at a high enough rate, you would have one wave going down the rope and one coming back at the same time. That would result in the waves adding at some points and subtracting at others. There would be a wave on the line that was "standing still," which is where the term *standing wave* comes about.

The amplitude of a standing wave depends on how well the output is matched to the input. In high-frequency microwave applications, the standing wave ratio depends on the value of the impedance at the output of a transmission line compared to the characteristic impedance of the transmission line. It also can be shown that the standing wave ratio is a comparison of the impedance at the input of a device compared to the impedance at the output of the device that is driving it. A perfect match is indicated by no standing waves. A drastic mismatch like an open circuit or a short circuit shows a large amplitude standing wave on the transmission line or device. That would indicate a very large mismatch between devices or between the transmission line and the load that was at its output. Remember that the larger the