The Lenkurt® Demodulator

NEWS FROM LENKURT ELECTRIC

VOL. 6, NO. 4 APRIL, 1957

WAVEGUIDES

For Microwave Systems

Over the years, the transmission frequencies of telephone message channels have gone higher and higher. Starting with the early open-wire line systems operating below 30-kc, transmitting frequencies have climbed steadily through the ranges suitable for multi-pair cable, coaxial cable and, most recently, microwave. Each increase in frequency has brought about new techniques and components for frequency generation, filtering and transmission.

The newest techniques are those associated with microwave transmission at frequencies above 1000 mc. This article discusses an important component of such systems—the waveguide.

Every radio system needs a method of conveying energy from the transmitter to the transmitting antenna and from the receiving antenna to the receiver. At the low radio-frequencies, a two-wire transmission line may be used. At frequencies above a few hundred megacycles, the losses of a two-wire line become too high and a coaxial cable is used. Above 1000 mc, even the losses of coaxial cable become too high. At these higher frequencies, a waveguide provides the most efficient path for electrical energy.

In a broad sense, any device which confines electrical energy to a specific path in space is a waveguide. Thus, two-wire lines and coaxial cables are forms of waveguides. But in a strict sense, a waveguide is a hollow tube. It receives energy at one end and delivers it to the other end.

Waveguide Operation

Radio waves in space tend to propagate outward in all directions. But if they are set up within a hollow tube of conducting material as shown in Fig. 1, they can be confined within the tube. What is more, if the tube has the proper dimensions with regard to the wavelength of the r-f energy, the waves will travel down the length of the tube with little loss. Such a tube is a waveguide. It may be rectangular, square or circular in cross-section. By far the most commonly used form is the rectangular-shaped cross-section.

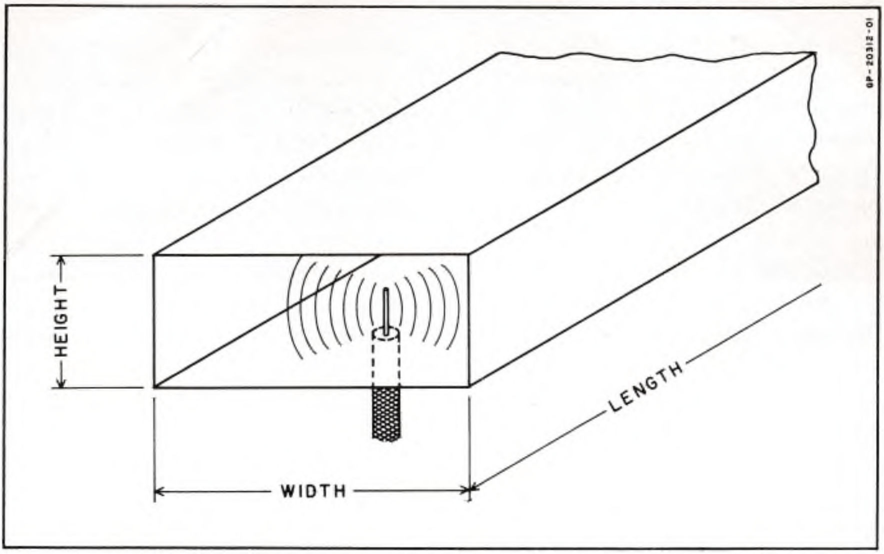

Fig. 1. Vertical probe radiating energy inside a rectangular waveguide. All sides of the guide are conductors.

Radio waves propagate within a waveguide by reflecting off the sidewalls of the guide. These reflections occur in a way that makes the electric and magnetic fields of the waves set up a definite pattern within the guide. The particular pattern depends on the wavelength of the exciting energy and the dimensions of the guide. Each such pattern is called a *mode*.

In addition, every mode has a *cutoff frequency*. This is the lowest frequency that a guide will transmit while operating in a particular mode. Energy at frequencies below this frequency will be attenuated instead of transmitted down the length of the guide. Above this frequency, energy will be transmitted with very little attenuation.

For a particular guide, the mode having the lowest cutoff frequency is called the *dominant mode*. This is the mode most often used in practice. For a rectangular waveguide operating in the dominant mode, the cutoff frequency is the frequency which has a wavelength equal to twice the width of the guide. At frequencies above the cutoff frequency, the electric and magnetic fields arrange themselves so that the energy follows a zigzag path through the guide. As the frequency is lowered, the energy rearranges itself so that the zigzag path is more compressed.

The energy paths of three different frequencies through the same waveguide are shown in Fig. 2. When the frequency reaches the cutoff frequency, the energy simply bounces back and forth between the sidewalls of the guide and has no forward motion through the guide. Thus energy at frequencies below the cutoff frequency will not appear at the receiving end of the guide.

Energy is usually fed into the guide by means of a probe which acts like a small antenna. Often the probe is simply the inner conductor of a coaxial cable as shown in Fig. 1. It is inserted through the bottom of the guide midway between the two sidewalls. At a distance of a quarter-wavelength back from the antenna, a conducting plate blocks off the end of the guide. The end plate acts as a reflector for the r-f energy and this reflected energy is in the proper phase to reinforce the original energy from the probe. The other end of the guide is open. It may feed to a resonant cavity or to another waveguide.

The construction of waveguides for use at the receiving end of a microwave system is the same, but the operation is reversed. The r-f energy enters the guide at its open end and travels through the guide to a probe which picks up the energy and feeds it to the receiver.

Application

Many modes other than the dominant mode can exist in a waveguide. But the common practice is to design the guide to propagate the dominant mode and suppress all other modes. The usual rectangular guide has a width greater than one-half wavelength but less than one wavelength of the desired operating frequency. The height is then made about one-half the width. These dimensions give a cutoff frequency below the operating frequency and a cross-sectional area too small to allow higher modes to form.

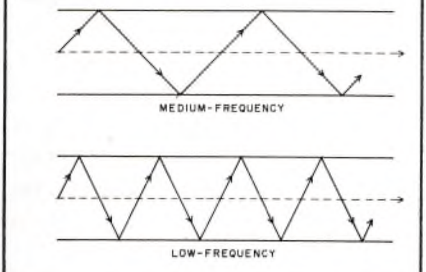

Fig. 2. Energy paths for three different frequencies in the same waveguide. Dotted line shows net direction of energy transmission.

The dominant mode is more commonly used because it gives the lowest cutoff frequency for a particular guide. In addition, it gives the simplest field pattern and is not as susceptible to impedance mismatches and reflections as the more complex modes.

The common conducting materials used in waveguides are brass, aluminum, gold, silver and copper. At the high operating frequencies of waveguides, the currents do not penetrate very deeply into the guide surface. Therefore, for short lengths, a thin inner plating of a high-conductivity material (gold, silver, aluminum) on a cheaper metal often provides a practical waveguide. Where weight is important, a guide may be constructed entirely of aluminum.

A new low-loss material coming into use is oxygen-free, high-conductivity (OFHC) copper. A typical attenuation-frequency curve for an OFHC copper guide for use with Lenkurt's new Type 74A microwave system is shown in Fig. 3.

When connecting two-wire transmission lines or coaxial cables, impedances have to be matched carefully to avoid reflections and losses. This is also true in waveguides. When two guides are connected together, there will be an impedance mismatch unless both have the same dimensions. If they differ, the losses can be reduced by using a tapered waveguide section to connect the two. By this means, the change in guide characteristics comes about gradually and reflection is kept to a minimum.

The physical path that a waveguide must take cannot always be a straight line. The over-all guide must be constructed to follow the curves of the physical path. Therefore, the guide path is usually made up of a combination of straight and curved sections of guide. The curved sections have the same cross-sectional dimensions as the straight sections. Two typical 90° curved sections are shown in Fig. 4.

Curved sections also tend to introduce reflections and power loss. These can be kept small by avoiding abrupt changes in direction. A common rule of thumb is to keep the radius of the curved section never less than two wavelengths of the signal to be transmitted.

A waveguide may also be used as an antenna. In this case, the open end of the guide is flared to make a gradual transition from the impedance of the guide to the impedance of space. Such an antenna is called an electromagnetic horn. It has characteristics similar to those of a directional antenna.

Horns may be shaped by flaring either the top and bottom of the guide or by flaring the sidewalls. To achieve maximum gain from a given length of horn, the top, bottom, and both sides are flared.

Waveguides offer many advantages at microwave frequencies. To begin with, they are of simpler construction than other means of transmission. But what is more important, they have very low losses. The conducting surface provides complete shielding to eliminate losses from radiation, and the losses in

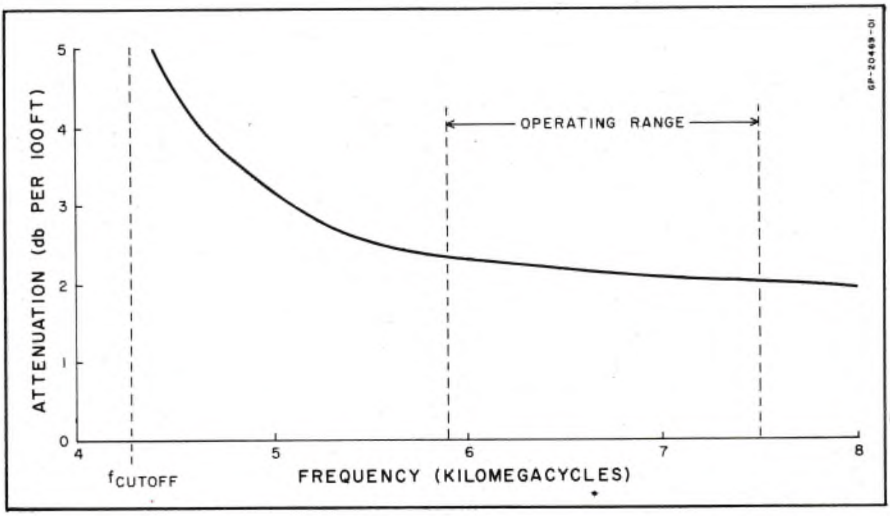

Fig. 3. Attenuation-frequency curve for typical waveguide used in Lenkurt Type 74A system. Operating range and cutoff frequency are shown by dotted lines.

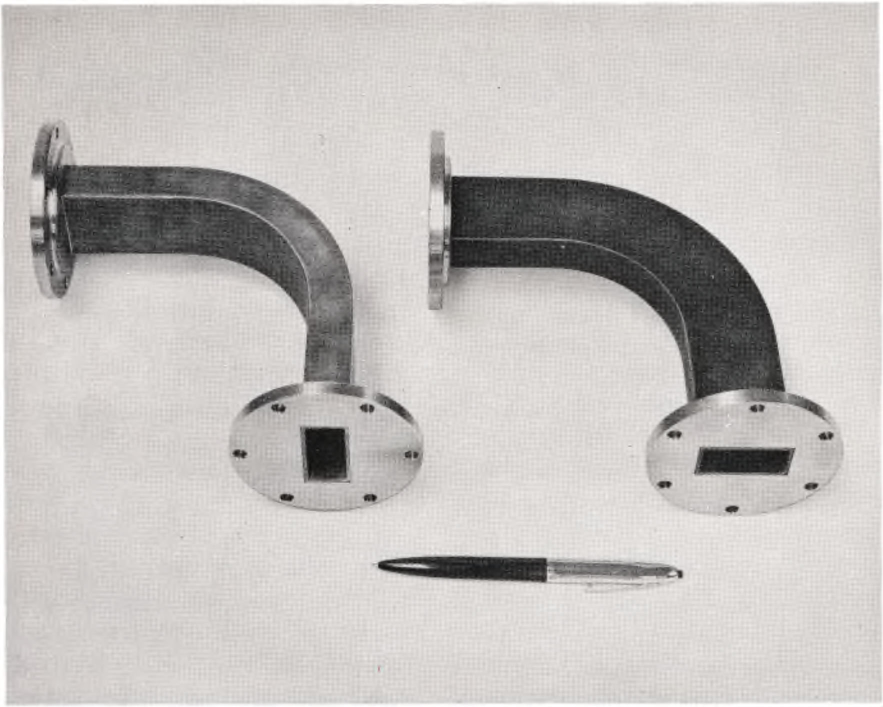

Fig. 4. Two forms of 90° bends for rectangular waveguides.

the conducting surface itself are small. In addition, a waveguide has more power-handling ability.

The main disadvantage of a waveguide lies in the limitation of its use to only the microwave frequencies. At lower frequencies, the guide dimensions become too large to be practical. Also, the installation of waveguides is more delicate than that of other methods. Solder beads, dents and bends will all tend to increase the attenuation and standing waves within the guide.

Circular waveguides are also used occasionally, especially where the guide must feed through a rotating joint. Their analysis differs from that of rectangular waveguides in several respects and, in general, is more complicated. They are seldom used unless the mechanical needs of the system call for them.

Conclusion

A waveguide is a device which isolates a specific path in space for the transmission of high-frequency energy. The energy, in the form of electromagnetic field patterns, travels along the guide from or to a probe enclosed in the guide. The size of a waveguide is inversely proportional to the lowest frequency it must handle. Therefore, the large size required at low frequencies makes them impractical at frequencies below the u-h-f bands. But at frequencies above 1000 mc, waveguides are the most efficient means of transmission and are used almost exclusively.

Increasing Microwave Reliability By

DIVERSITY AND STANDBY MEASURES

One of the important advantages of microwave systems is the ability to carry many message channels over the same route. Because it may often carry many times the number of channels of an open-wire or cable system, its reliability is many times as important.

Any factors which cause transmission to fall below a specified quality affect reliability. As far as the radio system itself is concerned, there are two important factors. One is fading of signal strength over the free-space transmission path. The other is improper operation of the transmitter or receiver.

Fading is a complex phenomenon which results from changes in atmospheric conditions. But, in general, it differs with the free-space path and the signal frequency. Fortunately, these differences can be used to advantage to increase the reliability of microwave systems.

One method of counteracting fading is *space diversity reception.* This method is based on the fact that the received signal strength may differ widely between two closely located points. At one point, fading may have reduced the signal level to a very low value. At another point, located just a few wavelengths away, the signal may come in at, or even above, its normal strength.

Space diversity takes advantage of this by receiving the signal over two antennas which are separated in space. Figure 1 shows the situation for one direction of transmission. Each antenna is connected to a separate receiver and both receivers go to a common output through a transfer panel. Here a sensing circuit monitors the received signal strengths and automatically keeps the output switched to the receiver with the stronger signal.

Only rarely will conditions exist which reduce the signal strength at both antennas below a suitable level. At all

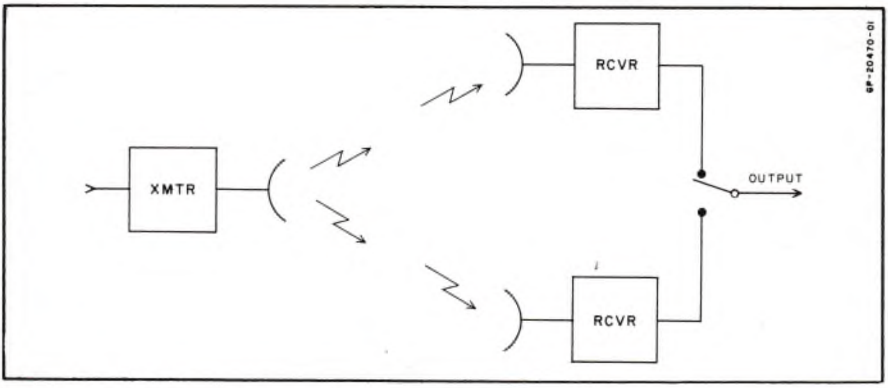

Fig. 1. Diagram showing principle of space diversity reception. The two receiving antennas may often be mounted on the same tower.

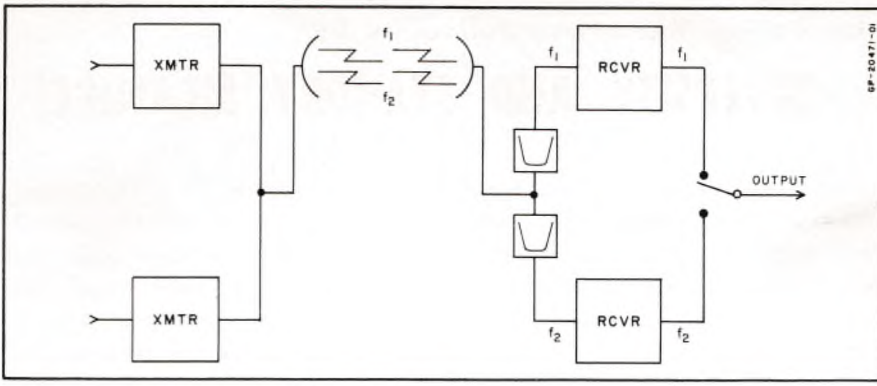

Fig. 2. Diagram showing principle of frequency diversity reception.

other times, the transfer panel is constantly delivering a high-level signal.

Another method of counteracting fading is *frequency diversity reception.* This method is based on the fact that the conditions which cause fading at one frequency will rarely cause simultaneous fading at another frequency. Figure 2 shows a scheme for frequency diversity for one direction of transmission.

In this method, the same intelligence is transmitted at two different frequencies. The same antenna receives both frequencies and feeds to two different receivers. Each receiver is tuned to accept one or the other of the two transmitted frequencies, but both go to a common output through a transfer panel. Here the outputs of both receivers are monitored and the common output is always kept switched to the receiver with the stronger signal. Thus, except for the rare conditions which cause the signal to fade at both frequencies, the system always delivers a high-level signal.

Both space and frequency diversity provide insurance against loss of signal in the free-space path. In addition, both provide a limited form of standby operation in case of failure in the radio equipment itself. For example, failure of a transmitter or receiver in the frequency diversity scheme of Fig. 2 would not put the system out of service, but the protection against fading would be lost. A similar condition would exist if one of the receivers of the space diversity scheme of Fig. 1 should fail.

To guard against possible equipment failure, additional standby equipment may be provided to take over the function of the primary equipment. In some cases, one standby unit may be maintained for each primary unit. In other cases, one standby unit may be maintained ready to replace any one of several units. Standby equipment can be arranged to switch over automatically, manually, or by remote control.

The degree of reliability required for a microwave system usually depends on the particular application of the system. Each case requires its own study and evaluation. But on a per-channel basis, the cost of diversity or standby arrangements is usually a small price to pay for system reliability .

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A Recently Issued Publication

A new publication, **Engineering Considerations, Type 45BN1 Carrier Telephone System,** provides useful information for laying out cable carrier systems using **Type 45BN** equipment. The new bulletin discusses route selection, equipment location and other factors affecting performance. The information applies to new routes as well as to applications of 45BN equipment on existing routes already equipped with 45BN or Western Electric Type N systems.

The new bulletin is designated **Form 45BN1-ENG.** Copies are available from Lenkurt plants and distributors.

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