The Lenkurt

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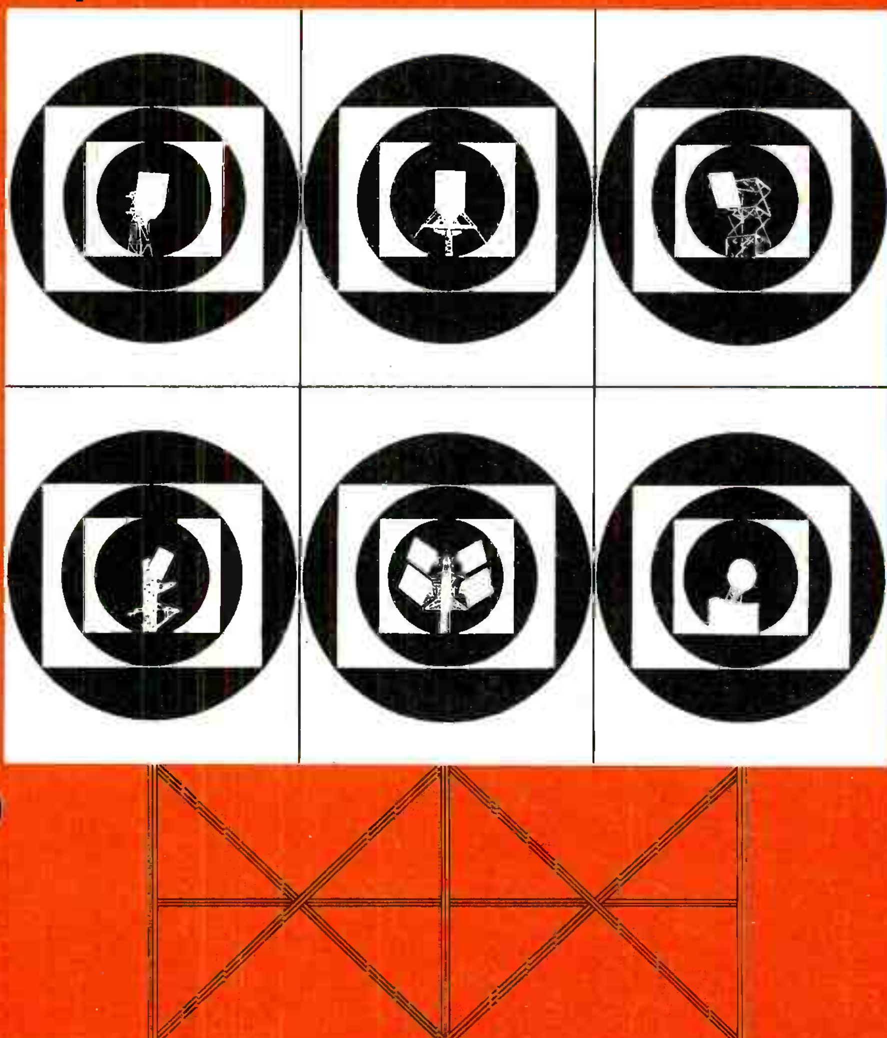
DEMODULATOR

Reflectors & Repeaters



Radio-reflective surfaces offer design engineers an efficient and relatively inexpensive alternative to some path redirection problems.

Because radio waves bounce off reflective surfaces in much the same way light is reflected by a mirror, radio reflectors can be thought of as radio mirrors.

In actual practice, the use of radio mirrors is dictated essentially by topographical conditions where the ruggedness of intervening terrain either makes a direct path impossible or requires that the antenna towers be extremely high.

Generally, speaking, radio mirrors fall into two categories – reflectors and passive repeaters. Those used in periscope antenna applications – rectangles, ellipticals, or "flyswatters" (Figure 1) are referred to as reflectors. The large "billboards", usually found on isolated hilltops, and certain "back-to-back" parabolic reflector arrangements are both classified as passive repeaters. (Figure 2).

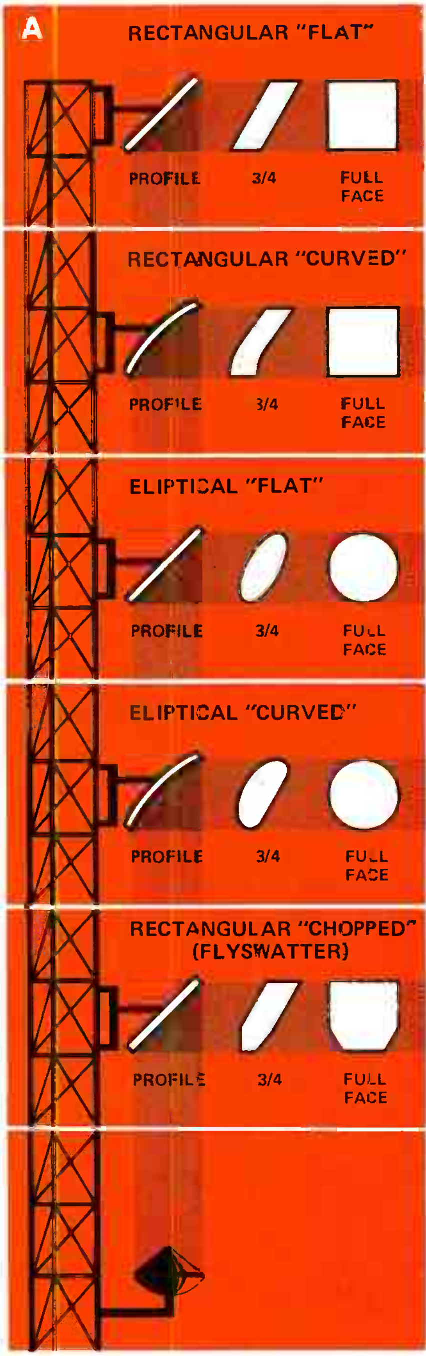
In order to determine the relative advantages of one antenna reflector arrangement over another it is convenient to refer to some standard of measurement. In the case of microwave antennas, performance is measured in gain and expressed in decibels (dB). Using the isotropic antenna as a standard point of reference it is common practice to speak of an antenna's performance as the gain improvement (in dB) over what could be expected of an isotropic antenna.

An isotropic antenna would theoretically radiate or receive energy equally in all directions. (Figure 3). (A completely spherical radiation pattern is not really possible.) If an antenna could focus all its radiant energy into one-half a sphere, its gain (over isotropic) would be defined as 3 dB, since all the radiated energy would be concentrated in half the sphere and twice as much would appear on any given area of the half-sphere. Therefore, gain is 10 log 2 = 3 dB. Common beams run as small as 1 to 2 degrees and provide gains in the area of 40 dB.

The primary function of a good microwave antenna is to focus its radiant energy into the most concentrated and efficient beam possible.

Reflectors

All periscope antenna systems require a reflector of some kind to redirect the transmitted beam from



B

Figure 1. Various shapes of tower reflectors used in periscope application are represented in (A). Actual appearance of eliptical reflector (B) has circular shape when viewed from waveguide path.

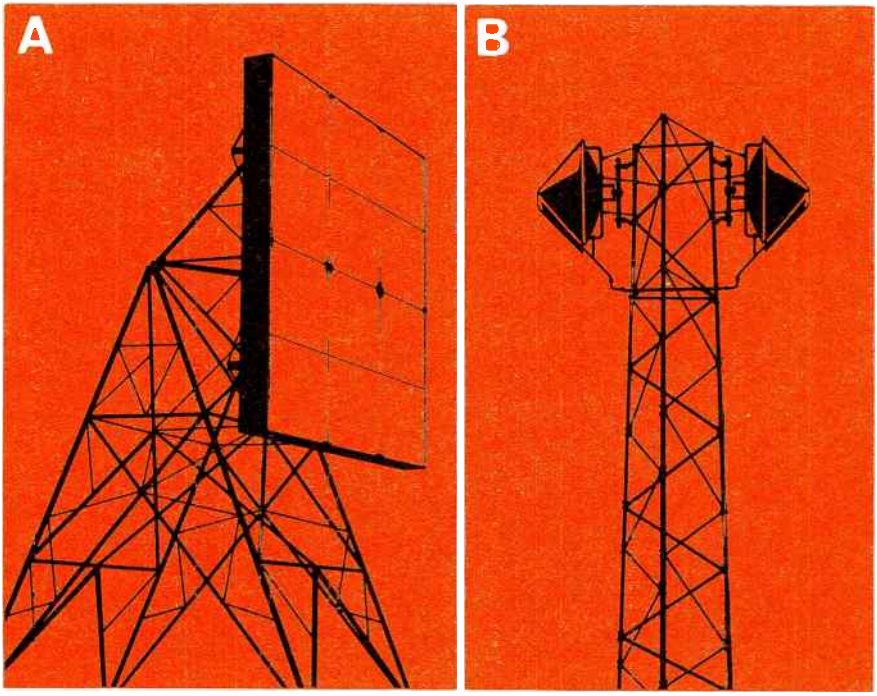


Figure 2. Passive repeaters are of two basic types: the "billboard" (A), so labelled because of its appearance, and the parabolic "back-to-back" passive (B) which uses two standard antenna dishes directly joined by a short length of waveguide.

the parabolic antenna to some distance receiver.

In most cases these reflectors are in close proximity to the transmitter-tower complex. There are some exceptions and because there is no absolute dividing line between what constitutes a periscope reflector and a passive repeater it is generally held that any system in which there is more than a few hundred feet of horizontal separation between reflector and illuminating dish is a passive repeater – not a periscope reflector.

The decision to use a periscope antenna arrangement is dependent on several considerations. Economic studies reveal that when the waveguide run to the parabolic antenna approaches distances of 150 feet and beyond, it is usually less expensive to use the periscope arrangement and beam the signal from the ground to the reflector atop the tower.

Tower height is not, however, the only consideration. Periscope antenna systems typically have somewhat higher side lobes and somewhat poorer

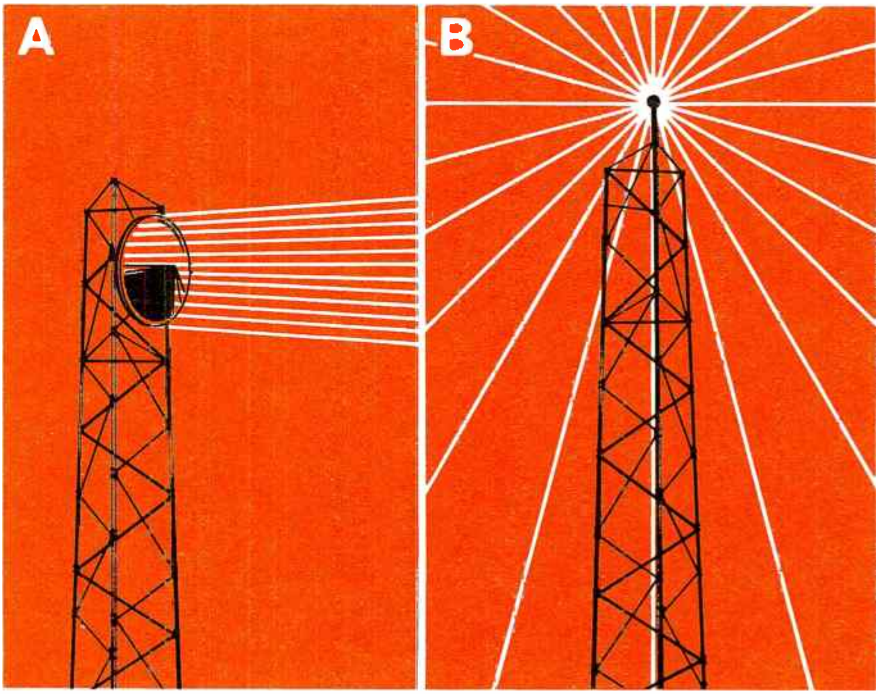


Figure 3. Energy radiation is theoretically assumed to radiate isotropically in all directions (B). Parabolic antennas are used to focus radiant energy into a directional beam (A) which has an obviously high amplitude gain over the hypothetical isotropic antenna.

discrimination patterns for radiation or reception at angles off the main beam than do direct-radiating antennas with comparable gains. They thus have a greater likelihood of creating interference to or receiving interference from other microwave systems operating in the same geographical area. This characteristic is probably the most negative aspect of periscope antennas. In areas of heavy microwave congestion it may be sufficiently important to preclude the use of periscope antenna systems, even though they might be advantageous from other points of view.

Another problem with the periscope setup is the "sneaking" of the signal from the illuminating dish to the distant receiver. (Figure 4). This bypassing of the reflector can occur when the direct path is not effectively blocked and allows a certain amount of the signal to reach the receiver ahead of the reflected main beam. This "sneaking" can produce troublesome noise levels requiring corrective engineering. In some instances, it has been

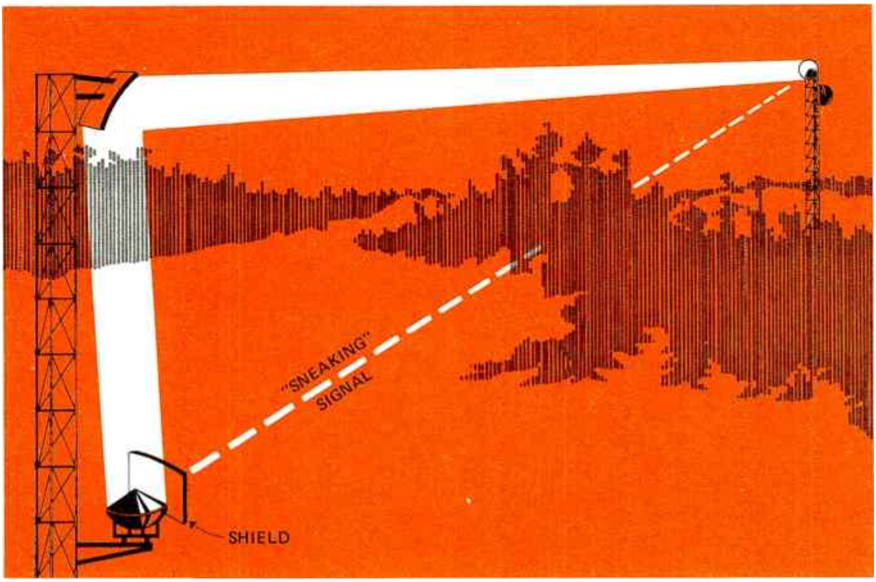


Figure 4. In situations where the path is not effectively obstructed, the signal may sneak from the illuminating dish, directly to the distant receiver. This bypassing of the reflector causes noise at the receiver. Shielding is used to control this problem.

necessary to place metal shields on the path sides of the illuminating dish in much the same manner blinders are used on race horses.

The periscope system has wide usage. Although the efficiency does not change with different frequencies, periscope application can nevertheless be more expensive at the lower frequencies (2 and 4 GHz) because the required dish sizes for these wave lengths are much larger.

One unique advantage of a properly laid-out periscope arrangement is the possible gain improvement over what can be expected from the parabolic antenna alone. This complex matter was clearly described in the July 1963 issue of the DEMODULATOR. By way of recapping, it is sufficient to say that the reflector's size, shape and its distance from the parabolic antenna can make it possible to reflect only first zone energy (Figure 6). When only first zone energy is reflected, the possibility of phase cancellation (caused by simultaneous reflection of the out-of-phase second zone energy) is almost completely eliminated. This arrangement produces sharper beams at distant points while giving net gains of from 2 to 3 dB for reflectors with flat faces.

Additional gain can be achieved by curving the face of the reflector to the approximate shape of a section of a paraboloid with the illuminating dish at its focus. (Figure 5) Actual practice has provided substantial evidence that a properly curved reflector can produce as much as 4 to 6 dB more gain than a flat uncurved reflector in the same application. This gain improvement results from the fact that the phase relationships of the various portions of a reflected beam are determined by the relative points at which the wavefront is intercepted by the reflective surface. It can be shown that because of this curving some of the second zone (out-of-phase) energy can be converted to in-phase energy thereby actually boosting the gain beyond anything possible with a flat reflector.

Passive Repeaters

Erecting an active radio relay station where inaccessibility and severe weather changes can inflate construction and maintenance costs beyond desirable limits is a situation every engineer tries to avoid. This is precisely the kind of problem the engineer can resolve by using a passive repeater.

The two general types of passive repeaters in common use are shown in Figure 2. One consists of two parabolic antennas connected back-to-back through a short length of waveguide. Because the size requirements and the associated cost, this type of passive is rarely used except for very short paths where small dishes are sufficient. The efficiency of this arrangement is approximately 30% compared to a 98% efficiency rating for the "billboard".

"Billboard" passives range in size from 4' x 6' single panels to 40' x 60' connected panels. The reflective surfaces are generally made of aluminum

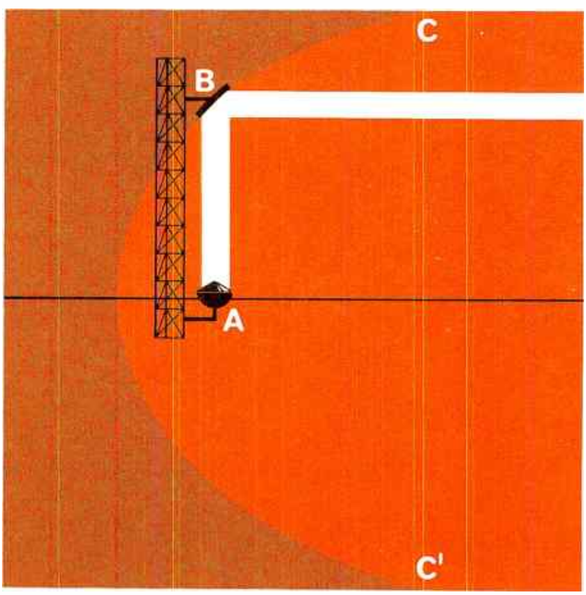


Figure 5. To calculate the curve of a periscope reflector (B), it is convenient to consider the illuminating dish (A) as the focal point of the parabola represented by CC^1. The reflector (B) may simply be considered a solid segment of the imaginary parabolic shell.

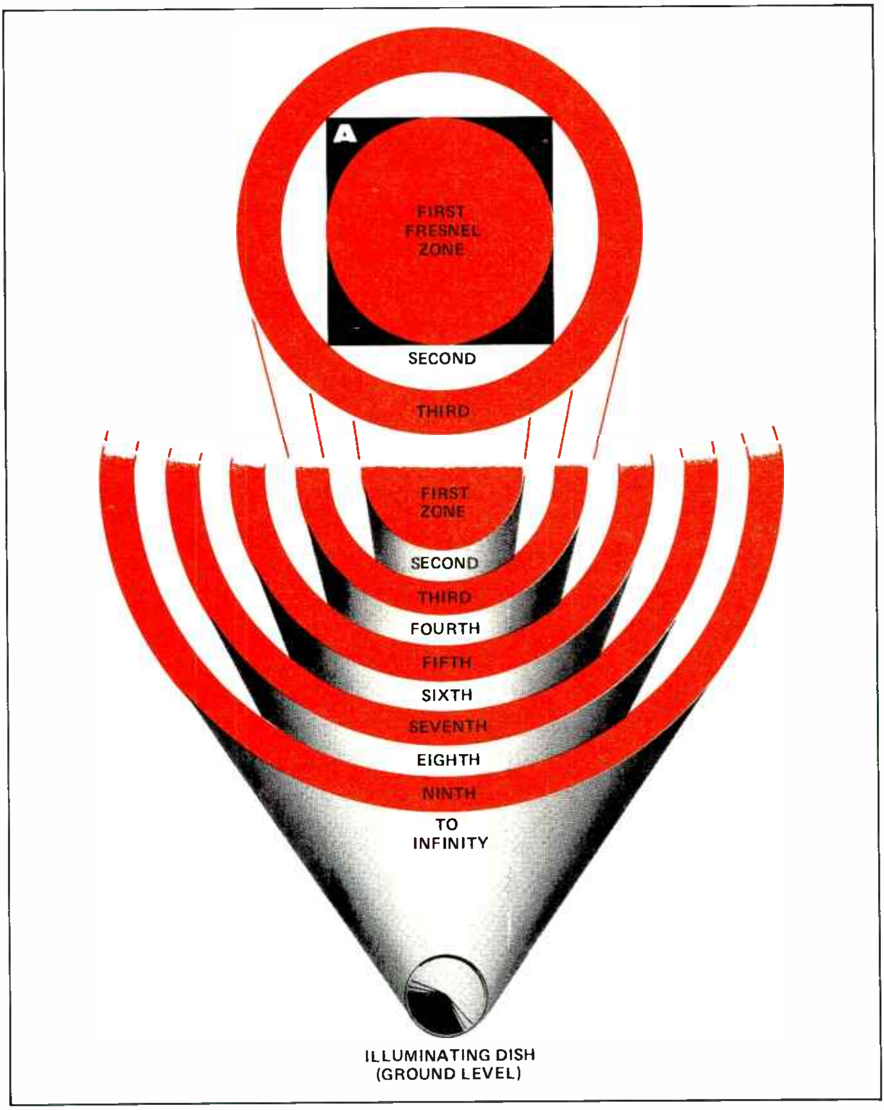


Figure 6. Microwave signals are transmitted in concentric bands of energy (fresnel zones). Each zone is 180° out-of-phase with its adjacent zone. All even numbered zones are in phase with each other and out-of-phase with all odd numbered zones. The 2nd zone energy which is picked up by a flat reflector (A) will tend to cancel it equivalent in first zone energy. By using a curved periscope reflector which extends into the 2nd energy zone it is possible to actually convert the out-of-phase 2nd zone energy to an in-phase relationship with the first zone improving the overall gain.

which has been treated to prevent corrosion. As a rule of thumb, face flatness should be within 1/8 the transmitted wavelength. It has been determined that the reflective surface of the passive must be flat to within 1/8" for 11-GHz transmissions, 1/4" for 6 GHz, and 3/4" for 2 GHz.

Once the existence of an obstruction makes it fairly certain that a passive must be used, it is then necessary to calculate the most efficient site available. The efficiency of any microwave path arrangement using a passive repeater has an inverse relationship to the product of the path distances.

Because of this it is obvious that any arrangement which reduces this product will improve the overall signal strength. It logically follows that those arrangements which place the passive nearest either of the path ends are therefore the most desirable. An additional benefit to this kind of site locating is the fact that the required surface area of the passive decreases as the distance to the path-end is shortened.

Some mention should be made of the fact that while certain topographical conditions appear to be well suited for passive repeater sites they may actually not be desirable at all. This has sometimes proved to be the case in heavily timbered areas immediately surrounding sites of small passive repeaters. Depending on their relationship to the passive and the signal beam, trees can produce serious interpath noise problems. This is also the situation which is occasionally created by unwittingly placing a small passive in front of a rock wall or bluff. For these reasons it is advisable to determine passive sites only after acquiring a thorough awareness of the particular terrain involved. Once the most realistic sites have been selected it is then possible to estimate their relative efficiencies.

Fields — Near and Far

One practical approach to determining antenna-reflector efficiency involves the calculated value of 1/K:

$$1/K = \frac{\pi \lambda}{4 a^2} d^1$$

Where:

λ = *the wavelength in feet*

d^1 = *the path length in feet*

a = *the effective area of the passive repeater*

When the value of 1/K is 2.5 or less, a near field condition exists. Once having determined a near-field condition it is then possible to decide the proper method to use in calculating the gain or loss of the proposed path arrangement.

If the passive is found to be in the far field, its gains and those of the end antennas are independent and the two-way gain of the passive repeater can be calculated by the following formula:

$$\text{Gain in dB} = 20 \log \frac{4 \pi A}{\lambda^2} \cos \alpha$$

Where:

α = *1/2 the horizontal included angle*

λ = *wavelength in feet*

A = *area in square feet*

To find the net loss between the two end points, it is only necessary to calculate the two path attenuations, add them together, then subtract from the result the two-way gain of the passive and the gains of the end antennas.

However, if the passive is found to be in the near field of either antenna then antenna and reflector gains are no longer independent but react with each other in such a way that the net gain would be reduced. In this case the above methods cannot be used, since they give overly optimistic results.

One way to evaluate gain where the passive is in the near-field is to consider the antenna and the nearby passive as a periscope antenna system. In this case a correction factor is calculated and applied to the gain of the antenna to obtain the net gain of the periscope combination. In these situations, the "path" is only taken to be the distance from the periscope reflector (passive in this case) to the far end – the distance between the antenna and reflector within this periscope arrangement is disregarded.

Double Passive Repeaters

If the passive repeater location is behind or off to one side of the near end path, so that the included angle between the two paths at the repeater does not exceed about 120°, a single billboard reflector is most efficient. One reason the angle of the passive to the path should not exceed 120° is that the surface dimension requirements increase unrealistically beyond this angle. If, however, the passive location is more or less along the line between the two end points, it is possible to use a double passive installation. (Figure 7).

Such an arrangement, in which two closely spaced billboards are so situa-

Figure 7. Double passive used to beam signal over a ridge.

Figure 8. An example of a "billboard" passive living up to its name.

ted, can provide the desired beam displacement with only slightly less gain than a single reflector – it is also true that twice as much billboard surface is required.

Reflections

The basic fact that microwave radio transmission is line-of-sight has imposed rather restrictive limitations on the methods microwave engineers can use in getting signals from one place to another. These limitations, like so many others, only serve to stimulate deeper investigations and more imaginative solutions to the problems which arise.

Although the use of radio mirrors in microwave path engineering is not a new development, it is indeed an excellent example of how imagination has provided a simple solution to a complex problem – both in terms of cost and performance. When viewed as simple components, these radio reflectors may be considered the only tool at the engineer's disposal whose efficiency approaches 100%.

It is important to point out that there is a wide distinction between reflective efficiency and overall path efficiency. Without exception, the reflective efficiency of periscope reflectors and passive repeaters is very close to 100%. Path efficiency is, however, a rather complex matter to determine and requires calculating whether or not a passive is in the near field or the far field. Additional figuring is then required to weigh the two-way antenna and passive repeater gains against the total path attenuation. To complicate matters further, in the case of periscope arrangements, it is customary to think of the reflector as simply an extension of the parabolic antenna and not a reflector as such.

These various approaches which experience has shown to be quite reliable, make it somewhat difficult to assess with a blanket statement the path efficiency of reflectors and passive repeaters, because it varies considerably with each application. It can be said without reservation, that the development of reflectors and passive repeaters has greatly increased the number of path engineering alternatives while measurably reducing installation and maintenance costs.

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