RING ARRAY TT&C ANTENNA

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Introduction. Omnidirectional coverage is the most desirable pattern feature for antennas performing TT&C functions for spacecraft or missiles whose optimum coverage directions cannot be defined due to the motion of the vehicles in relation to ground stations. This paper presents techniques by which antennas can be designed to provide such coverage. Examination of the problem indicates that most spin-stabilized vehicles' physical geometries can be represented by a cylindrical body. For this reason, ways to achieve near-spherical coverage for a metal cylinder of an arbitrary diameter are investigated. The designs presented fall into three categories: (1) traveling wave ring-shaped radiators excited uniformly by an equal power division power divider, (2) parallel plates or biconical horn radiators excited by one or more probes, and (3) circumferential arrays excited by a corporate feed network. The design complexity varies from antenna to antenna. Some designs inherently provide circular polarization. Some are extremely simple to implement but must be located externally. Design details are presented for eight configurations.

General Design Considerations. To obtain an omnidirectional pattern around a large-diameter vehicle with an array antenna, a large number of array elements must be used. The number of elements required depends on the coverage uniformity desired. As a general rule, the required number of elements must be greater than the number of circumferential wavelengths. For example, a 56-inch-diameter vehicle in an S-band frequency requires 40 antenna elements to provide a pattern of 2.0 dB fluctuation in coverage; approximately 44 elements are required for 0.5 dB.

Antennas located around cylindrical structures have been extensively treated in the literature. For example, Carter [1] has investigated antenna systems composed of a finite number of radiators placed around a conducting cylinder. Ring arrays, comprising a large number of antenna elements, have been studied in detail by Page [2]. TELSTAR satellite antenna is a good example of belly-band ring arrays operating at 4 and 6 GHz [3].

It is desirable to minimize the number of array elements because of the inherent feed network complexity and cost. Consideration must also be given to the method of excitation of the antenna since this has an important bearing on antenna performance as well as production cost. Small antenna arrays, consisting of relatively few antenna elements, can be implemented readily to provide uniform excitation from a simple power divider network. However, this becomes rather difficult when the number of array elements, hence the number of power divisions, is large. Various configurations for obtaining omnidirectional coverage for a 56-inch-diameter vehicle are given below. The major differences between the designs are the methods of excitation.

Antenna Candidates. Figure 1 is a design which provides omnidirectional coverage from a simply shaped long-wire antenna. The pattern coverage of the antenna is essentially that of a closely spaced axial-dipole array around the cylinder. Simplicity is a major design feature of the antenna. The use of a long-wire antenna element greatly simplifies the feed network design. The Figure 1 antenna utilizes only eight input ports to obtain good uniform current around the entire antenna ring. The antenna conductor is bent alternately in quarter-wavelength intervals. The current on the conductor reverses its phase at intervals every half wavelength, which produces an in-phase current on the vertical sections of the antenna. This is indicated by arrows in Figure 1.

The horizontal segments perform the function of phase shifters and contribute little to the far-field radiation pattern. Consequently, the antenna behaves as an axial-dipole array with linear polarization along the axis of the vehicle. The shape of the antenna is such that it easily can be adapted to existing vehicle designs. The long wire should be located approximately one-quarter wavelength away from the vehicle body. The antenna can be fabricated on wires or etched on a copper-clad board and can be supported by feed lines and mounting pads on the vehicle body. This design concept has been verified experimentally.

Figure 2 presents a flush-mounted design of stripline construction. A continuous circumferential slot is excited by a feed line consisting of quarter-wavelength bends similar to the radiating structure of Figure 1. This design also makes use of the traveling wave excitation to reduce the number of feed points for the radiating slot. The radiation coverage is nearly spherical. The inherent linear polarization can be changed to circular by means of a transmission polarizer over the antenna aperture.

Figure 3 is a variation of the long-wire design. The antenna is composed of half-wave dipoles spaced equally along a transposed feeder. The antenna behaves as a coplanar array with two bands of dipoles. The elevation pattern of this antenna is narrower than the quarter-wavelength-bend long-wire antenna. The gain of the antenna is estimated to be between 2 and 3 dBi, a value approximately 3 dB higher than the quarter-wavelength-bend long-wire antenna.

Other versions of traveling wave excitation ring array antennas are shown in Figures 4 and 5 [4]. Both antennas are linearly polarized in a plane transverse to the vehicle. The performance characteristics of the two antennas are similar — a direct comparison between dipole and slot radiators. Compared with the long-wire designs, the waveguide-fed designs of Figures 3 and 4 are less desirable in terms of weight and complexity.

Figure 6 is another design which provides omnidirectional coverage. This design completely eliminates the need for a complex corporate feed network. The antenna consists of wedge-shaped posts placed about the periphery of a tapered radial waveguide. The coaxial feed in the radial waveguide excites these posts uniformly; the posts then radiate as a circular array. This design has been extensively investigated by Croswell and Cockrell [5] for a spherically shaped spacecraft. Good symmetrical patterns and impedance properties were obtained for a frequency band from 8.4 to 10.0 GHz. The most undesirable feature of the design is the antenna geometry. The antenna bisects the vehicle into two half sections, making it difficult to adapt to existing designs of vehicles.

A biconical horn antenna design is shown in Figure 7. This antenna is excited by a ring array. An array of probes are fed by a stripline divider. The central region is made hollow for clearance of electronics such as a despun mechanism. This design approach is used for directly mounting the antenna on the top of the vehicle. The aperture of the antenna should be sized to provide a directional pattern with minimum radiation toward the vehicle body. To keep antenna weight low, the transmission polarizer should be made of lightweight materials. Significant weight savings could be accomplished if a thin Kevlar material were used for the construction of the polarizer.

Figure 8 presents two corporate feed designs featuring approximately equal performance characteristics. Both antennas provide circularly polarized omnidirectional coverage. The antenna in Figure 8a consists of two linearly polarized orthogonal arrays (dipoles and slots) which are fed in phase quadrature to obtain circular polarization. The design in Figure 8b features an array of slot-dipole elements. Implementation of these designs are straightforward. In each case, an adequate number of elements must be used to ensure that the pattern ripple is within specified limits. Weight and complexity are the undesirable features associated with these design approaches.

Conclusions. There appears to be a number of antenna designs that could be utilized to provide an omnidirectional pattern for a cylindrical vehicle. Traveling wave long-wire antenna designs offer simplicity and are readily adaptable to existing structures. Ring array antennas of stripline design can be readily implemented for spacecraft or missile systems. An experimental program for evaluating the performance characteristics of these promising designs is recommended.

References

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[2] H. Page, "Ring-Aerial Systems — Minimum Number of Radiators Required," *Wireless Engineer*, Volume 25, pp. 308-315, 1948.

[3] J. T. Bangert et al., "The Spacecraft Antennas," *Bell Sys. Tech. J.*, Vol. 43, pp. 869-897, July 1963.

[4] S. Silver (ed.), *Microwave Antenna Theory and Design*, New York: Dover Publications, 1965, p. 322.

[5] Croswell and Cockrell, "An Omnidirectional Microwave Antenna for Use on Spacecraft," *IEEE Transactions on Antennas and Propagation*, Vol. AP-17, pp. 459-466, July 1969.

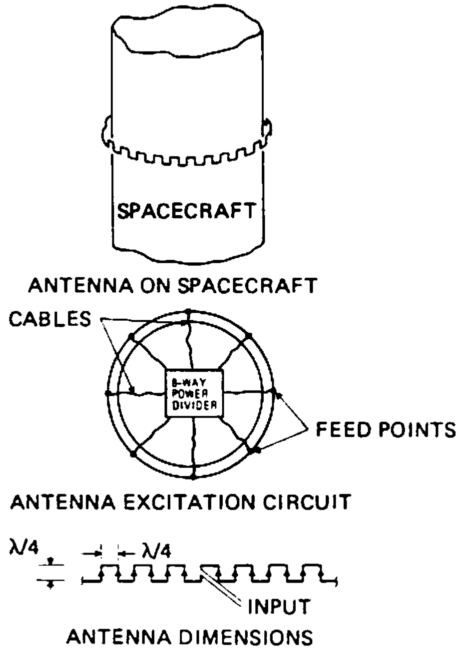

Figure 1. λ/4 Bend Long-Wire Ring Array Antenna

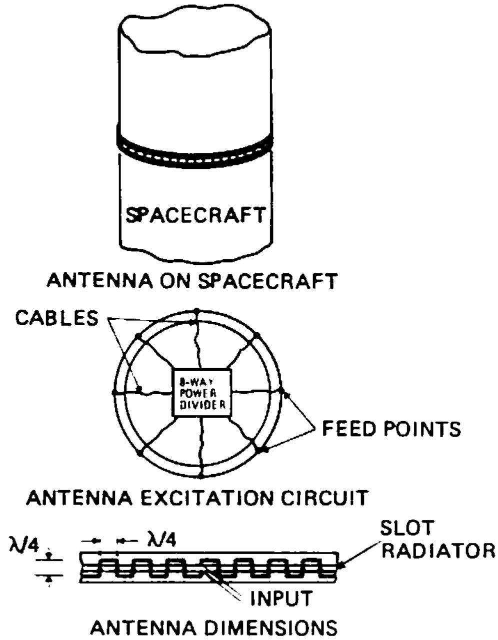

Figure 2. Long-Wire-Fed Ring Array Slot Antenna

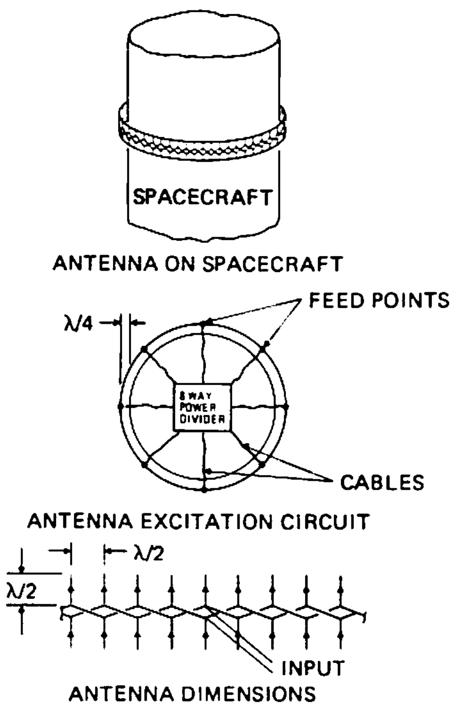

Figure 3. λ/2 Long-Wire Ring Array Antenna

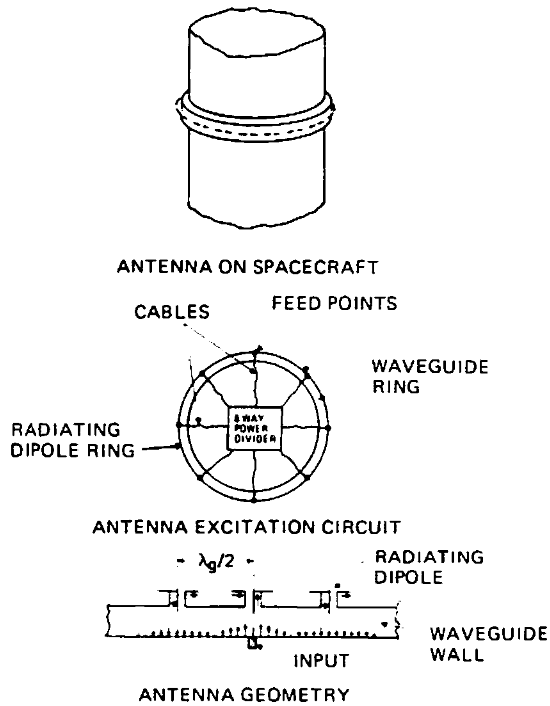

Figure 4. Waveguide-Fed Dipole Ring Array Antenna

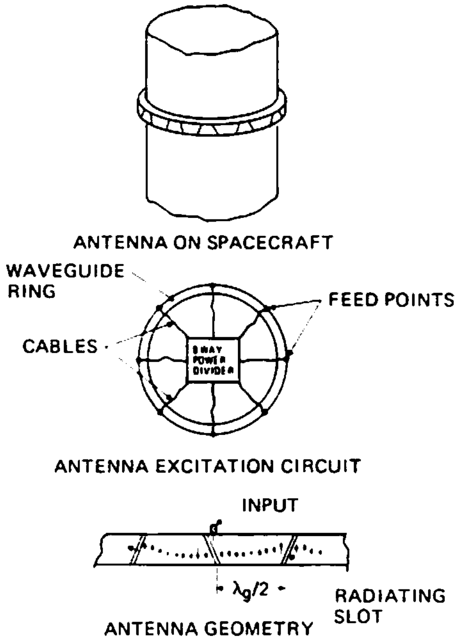

Figure 5. Waveguide-Fed Slot Ring Array Antenna

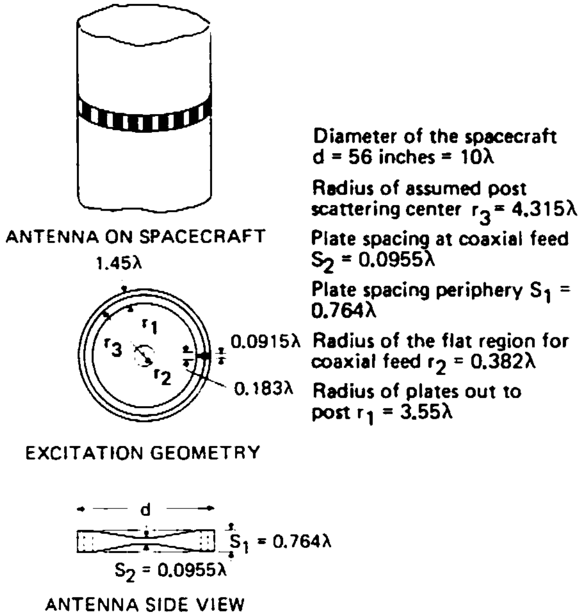

Figure 6. Tapered Radial Waveguide-Fed Ring Array Antenna

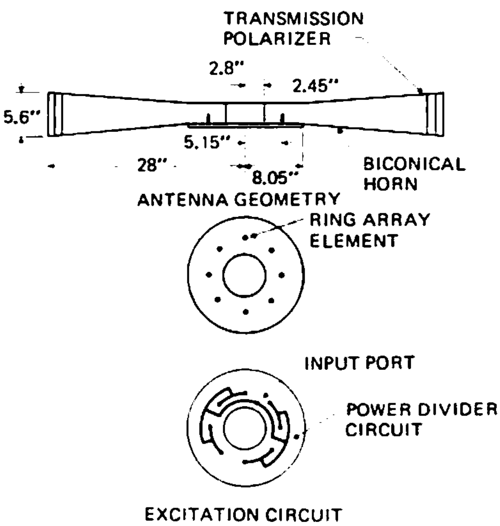

Figure 7. Circularly Polarized Biconical Horn Antenna

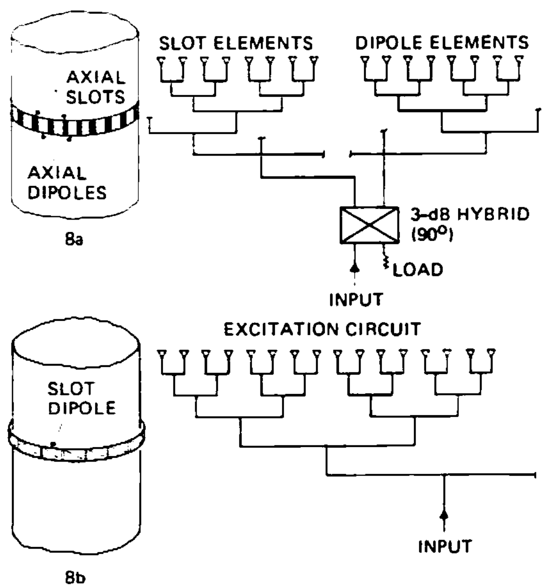

Figure 8. Corporate-Fed Ring Array Antenna