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# Radial Microstrip Slotline Feed Network for Circular Mobile Communications Array

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# **RADIAL MICROSTRIP SLOTLINE FEED NETWORK FOR CIRCULAR MOBILE COMMUNICATIONS ARRAY**

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## **INTRODUCTION**

In mobile and satellite communications there is a need for low cost and low profile antennas which have a toroidal pattern. Antennas that have been developed for mobile communications include a L-Band electronically steered stripline phased array, a Ka-Band mechanically steered elliptical reflector antenna and a Ka-Band printed dipole [1]. In addition, a L-Band mechanically steered microstrip array [2], a L-Band microstrip phased array tracking antenna for mounting on a car roof [3] and a X-Band radial line slotted waveguide antenna [4] have been demonstrated. In the above electronically scanned printed arrays [1] and [3], the individual element radiates normally to the plane of the array and hence require a phase shifter to scan the beam towards the horizon. Scanning in the azimuth is by mechanical or electronic steering. An alternate approach [5] is to mount microstrip patch radiators on the surface of a cone to achieve the required elevation angle. The array then scans in the azimuth by beam switching.

In this paper a planar circular array with endfire linearly tapered slot antenna (LTSA) elements [6] is described. The LTSA has several advantages which include high element gain, wide bandwidth, equal beam width in the two orthogonal planes by proper choice of flare angle and simple construction. The circular array radiates in the radial direction in the azimuth plane and hence eliminates the need for phase shifters and mechanical scanning hardware. To achieve the elevation angle a ground plane is placed below the array which causes the beam to tilt above the horizon. The ground plane also simulates the metal roof top of vehicles. The feed network consists of a sixteen way radial power splitter which is electromagnetically coupled to the LTSA circular array. Electromagnetic coupling eliminates pin and solder connections and therefore improves reliability and lowers the cost. It also results in a wider bandwidth. This type of feed network is very simple and therefore has potential applications in several other configurations of planar microstrip patch arrays also.

## **FEED NETWORK AND ARRAY DESIGN**

The feed network and the LTSA array shown in Fig.1 are designed for operation at a center frequency  $f_0$  of 18 GHz. The microwave power is surface launch by a modified OS-50 coaxial connector to the input of the power splitter. The microstrip line through a series of tee junctions and right angle bends divides into sixteen radial output ports. The characteristic impedance  $Z_{0m}$  of the

microstrip line is maintained as  $50\ \Omega$  throughout the splitter. In the tee junction compensation of discontinuity reactances is done by removing a portion of the line in the shape of an isosceles triangle with angle  $\theta = 45^\circ$  [7]. The measured excess insertion loss and return loss of the tee junction is 0.3 dB and 11 dB respectively at  $f_0$ . The transition consists of a microstrip line and a slotline which are orthogonal to each other and on opposite sides of a substrate (see inset in Fig.2). Further, the microstrip line is terminated at a distance of  $L_m$  in an open circuit and the slotline is terminated at a distance of  $L_s$  in a short circuit from the junction. The slotline width  $W_s$  is chosen from ease of fabrication as 0.127 mm and the characteristic impedance  $Z_{0s}$  is  $112\ \Omega$  [8]. To provide good impedance match  $Z_{0m}$  has to be less than  $Z_{0s}$  by 10 to 20 ohms [9]. Hence  $Z_{0m}$  of  $100\ \Omega$  is chosen for the microstrip line. The corresponding  $W_m$  is 0.21 mm. The lengths  $L_s$  and  $L_m$  after correcting for discontinuity end effects are 0.207 and 0.214 times the respective guide wavelength at  $f_0$ . The performance of the transition is evaluated both with and without a right angle bend (see inset in Fig. 2). The right angle bend is compensated by chamfering the corner such that the distance from the inner corner to the opposite edge is 0.828 times the microstrip line width  $W_m$  [7]. The insertion loss and return loss of two back-to-back transitions with 4 mm of slotline in between as measured in the test fixture is shown in Fig. 2. For each half the insertion loss is about 1.1 dB and 1.6 dB without and with a right angle bend respectively at  $f_0$ . The corresponding return loss is about 25 dB and 17 dB respectively. The LTSA is formed by gradually flaring the width of the slotline. The measured return loss of a single LTSA with the above transition is better than 15 dB at  $f_0$ . The dimensions of the circular array is presented in Fig.1.

### **FEED NETWORK AND ARRAY PERFORMANCE**

The measured H-plane pattern is shown in Fig. 3(a). Also shown is the pattern without the ground plane. In the presence of a ground plane the pattern is displaced by about  $28^\circ$  in the elevation. The 3 dB beamwidth is about  $22^\circ$ . By tilting the array in the elevation, the E-plane pattern is measured and Fig. 3(b) shows a typical peak pattern. The ripple in the pattern is less than  $\pm 2$  dB. The E-plane pattern is also measured for each of the four quadrants by rotating the array sequentially by  $90^\circ$ . The four radiation patterns are found to be similar which demonstrates that the array has an omni directional characteristic in the azimuth plane. The measured return loss of the array at the coaxial port is shown in Fig. 4. The return loss is better than 10 dB (2:1 VSWR) over the frequency range of 18 to 20 GHz. The array has a gain of about 10 dB.

### **CONCLUSIONS AND DISCUSSIONS**

The measured characteristics of a microstrip-to-slotline transition and its application in the feed network of a sixteen element circular LTSA array is presented. The pattern measurements show that the array has omni directional characteristics in the azimuth plane. In the elevation plane, the main beam is displaced by about  $28^\circ$  and the 3 dB beam width is about  $22^\circ$ . The return loss is



better than 10 dB over the frequency range of 18 to 20 GHz. The array has a gain of about 10 dB. The height of the antenna is less than 10 mm.

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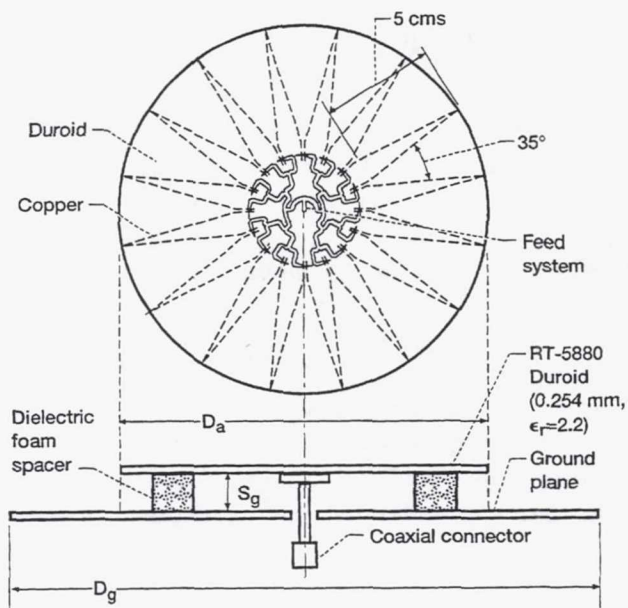


Figure 1.—Electromagnetically coupled microstrip-to-slot line feed network for a K-band circular sixteen element LTSA array.  $D_a = 16$  cms,  $D_g = 30$  cms &  $S_g = 5$  mm ( $0.286 \lambda_0$ ).

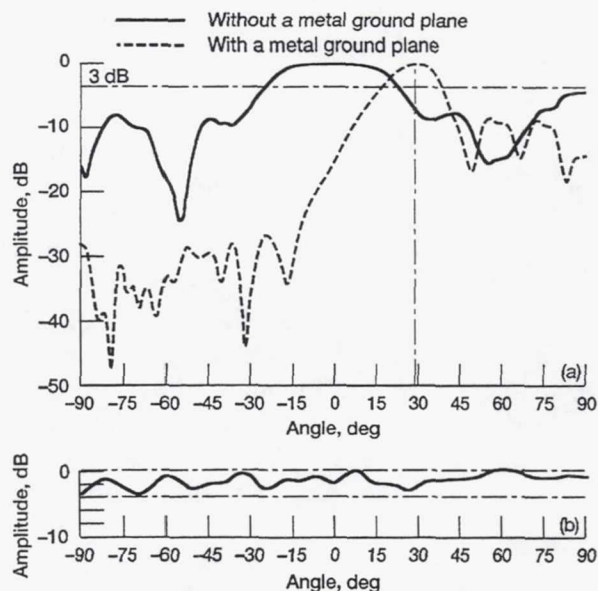


Figure 3.—Measured radiation pattern of the Array at 19 GHz. (a) H-Plane. (b) E-Plane with a metal ground plane and with the Array tilted.

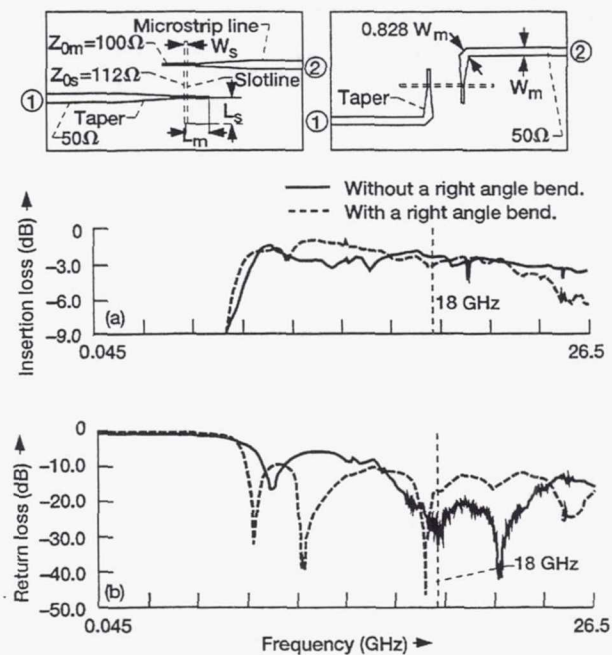


Figure 2.—Measured insertion loss and return loss of two back-to-back microstrip-to-slotline transition.

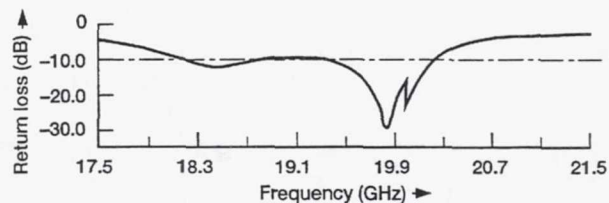


Figure 4.—Measured return loss at the coaxial port.

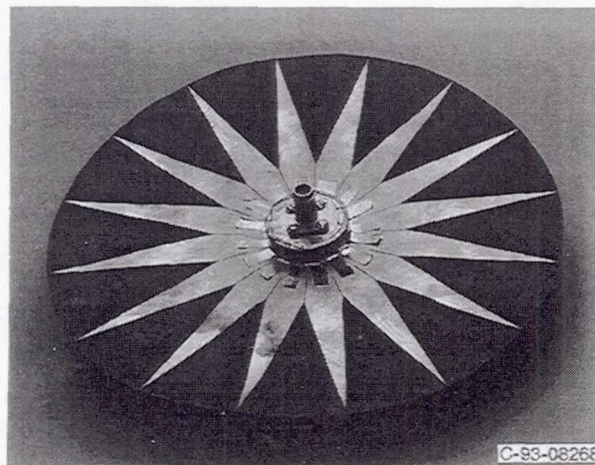


Figure 5.—Photograph of the antenna showing the coaxial feed.



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