Microstrip annular ring slot antenna; for mobile applications

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An annular slot on triplate feed is discussed which is suitable for use with vehicular mobile satellite systems. The slot is excited in a higher order mode and circularly polarised to give a conical radiation pattern. The slot can operate on a high dielectric base and a superstrate improves the gain.

Introduction; One aim of recent work regarding mobile communications is to integrate an antenna with its associated RF circuitry into an MMIC device on silicon or gallium arsenide. Work has been done regarding the annular microstrip ring higher order TM_{21} mode with a possible application for mobile satellite communications in non-equatorial countries [11]. The higher order microstrip ring modes have a null in the direction normal to the plane of the patch and the TIM_{21} mode peaks at an elevation of 55° from the azimuthal plane. There are however, some disadvantages with using microstrip radiating elements, namely surface waves giving rise to diffraction from substrate edges, poor radiation efficiencies on high dielectric materials and high crosspolar levels for antennas fed electromagnetically through the substrate with a microstrip feed.

To overcome the problems mentioned above an investigation into narrow annular microstrip slot antennas (width < $\lambda/20$) has been carried out to establish the properties of the first higher order mode which has not been reported on before.

Slot antenna design: A slot antenna, shown on a triplate feed structure in Fig. 1, has the advantage of reducing cross-polarised fields by screening the feedline while also constraining all radiation to the forward hemisphere. The triplate feed structure can allow parallel plate modes to propagate which may give rise to problematic edge diffraction. Spurious radiation at low elevation angles and ripple in the main beam can be removed by metalising the substrate edges and/or adding via pins.

As the aperture fields exist at the air-dielectric interface, the electrical slot size is virtually unaffected by the dielectric constant of the substrate, a situation very different to that of a microstrip antenna where the structures fields permeate through both substrate and free space.

The fundamental mode radiation pattern of a microstrip annular slot is well known, with ka = l, where wave number, $k = 2\pi/\lambda$ and a = average slot radius. This mode radiates with maximum gain in a direction normal to the plane of the slot. The antenna presented in this letter was designed such that ka = 2, the aperture field distribution being shown in Fig. 2. The triplate feed was formed from Duroid 5870, ε_r = 2.33 and total height = 1.58mm. Resonance occurred at 7.1GHz for an average slot radius of13.5mm with a slot width of l mm.

Slot antennas results; The E- and H-plane patterns were measured and are shown in Fig. *3a*. The beam peaks at an elevation of 55° making the antenna suitable for higher latitude satellite applications. A 2:l SWR bandwidth of 2.6% was measured for the mode, a value that compares with that of the microstrip ring in the TM_{21} mode. The H-plane gain was 4.5dB higher than that of the E-plane and exhibited asymmetry which was attributed to the feed. Adding an alumina superstrate, ε_r = 10.4, height = 0.6mm, reduced the feed asymmetry to 0.8dB and also caused the power in the E- and H-planes to equalise (Fig. *3b).* Low elevation radiation in the E-plane was increased by the addition of the superstrate due to diffraction from the alumina edges which were unscreened in this measurement. The resonant frequency was reduced to 6.1 GHz. The peak beam gain of the slot at ka = 2 was measured to be -2.6dBi. This was increased to 4.6dBi by adding the superstrate. A good prediction of the composite dielectric constant ε_{reff}, caused by introducing the superstrate is given by eqn. 1 [2]

$$\varepsilon_{r_{eff}} = \frac{\varepsilon_h \varepsilon_d (d+h)}{\varepsilon_h d + \varepsilon_d h} \qquad (1)$$

where d and h refer to substrate and superstrate heights, respectively. The slot radius is then given by

$$a = \frac{\lambda_0}{\pi \sqrt{\varepsilon_{r_{eff}}}} \qquad (2)$$

where λ_0 is the wavelength in free space.

Circularly polarised slot antennas: To be of practical use; a mobile antenna used in conjunction with a satellite system would need to be circularly polarised. Budgetary constraints in receiver manufacture require components to be inexpensive and so a non-complex method for producing circular polarisation was sought. A simple way to excite circularly polarised fields from annular slots operating at the ka = 1 mode has been reported by [3] where notches are placed 45° and *225°* from the feed point. Fig. 4 shows a far field measurement extrapolated from the near field of the ka = 2 antenna, where four 2mm x 2mm notches were placed midway between the E- and H-planes at 22.5° and 112.5° from the feed. It can be seen that the radiation field was conical in all planes, the field independence around the azimuthal plane making the antenna suitable for mobile applications. Peak beam axial ratio was measured to be less than 3dB. Use of the notches removed the necessity to provide orthogonally phased feedlines beneath the slot and so reduced the component complexity significantly.

Conclusion: A slot antenna operating at a higher order mode has been proposed with a possible application for mobile systems as an alternative to microstrip antennas. The slot antenna has an advantage over microstrip patches because of the screened feed which prevents spurious radiation. Higher order mode fields can be excited that are both circularly polarised and conical in shape. Gains of over 4dB were measured when an alumina superstrate was added. A strong advantage of this type of antenna is its lack of dependency on the dielectric substrate making it suitable for integration with high ε_r semiconductor materials, a development of considerable interest to recent mobile communication design.

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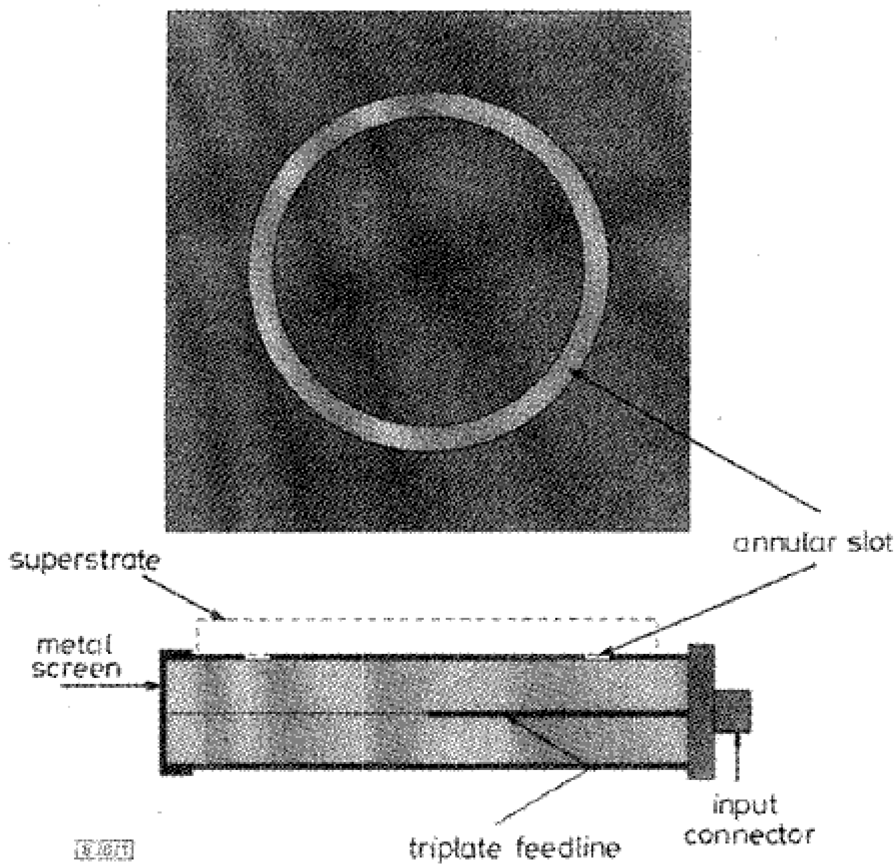

Fig. 1 *Microstrip annular slot geometry*

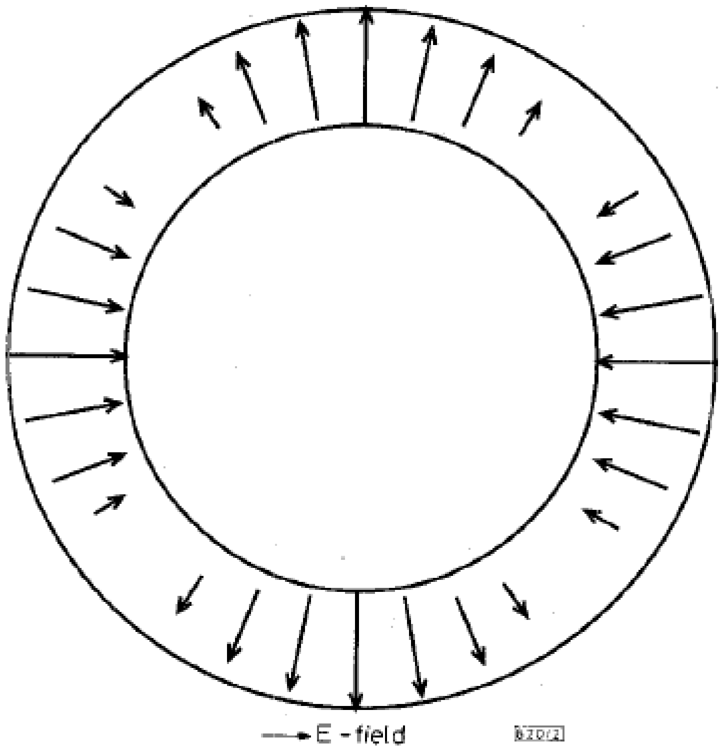

Fig. 2 *Annular slot electric field distribution; ka = 2*

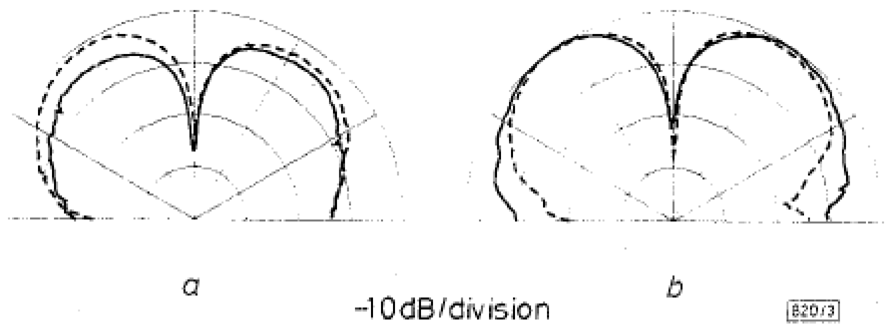

Fig. 3 *Measured radiation patterns*

a Measured radiation patterns; $ka = 2$
b Radiation patterns with alumina superstrate
——— E-plane
– – – – H-plane

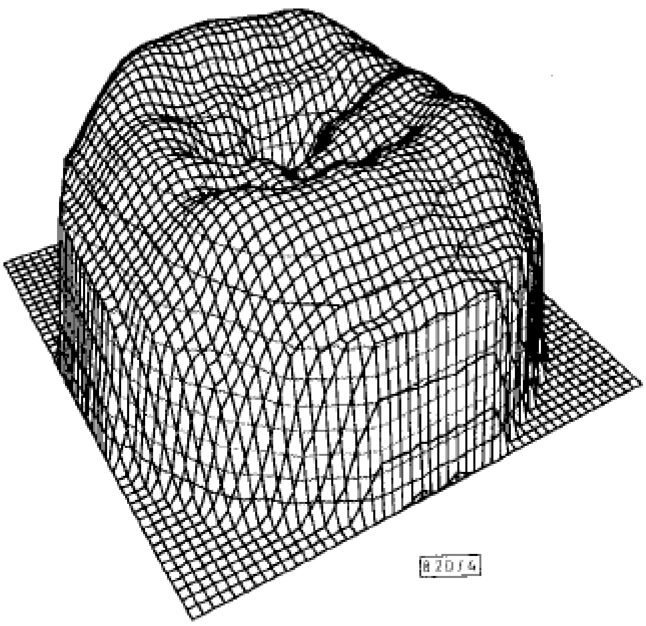

Fig. 4 *Circularly polarised far-field measurement*