Wideband double-element ring slot antenna

N. Behdad and K. Sarabandi

A new technique for bandwidth enhancement of microstrip-fed annular ring slot antennas is presented. Using this technique, a wideband antenna is designed that has consistent radiation parameters across the entire band and has a bandwidth that is six times larger than that of an ordinary ring antenna.

Introduction: Annular ring slot antennas are considered to be among the narrowband resonant antennas and occupy an area of $\lambda^2/4\pi$ at their first resonance [1]. Multi-element concentric ring slots have been used to design multi-band antennas [2]. However, because of transmission zeros that exist between the different resonances, these resonances cannot easily be merged to obtain a wideband response. In this Letter, we present a new way of feeding the double-element ring antenna to remove this transmission zero and obtain a wideband antenna. It is shown that the new antenna has a bandwidth of 36% which is about six times that of the bandwidth of each antenna alone. This increase in the bandwidth is obtained without putting any constraints on radiation patterns, antenna efficiency (gain), or adversely affecting the antenna polarisation purity.

Antenna design and simulation: A narrow, annular ring slot antenna is a relatively narrowband antenna with only a few per cent of usable bandwidth. This antenna can be fed with an open-circuited microstrip line, and the length of the open-circuited stub can be changed to obtain a good match. To increase the bandwidth of this antenna, without significantly increasing its occupied area, a double-element antenna topology, such as the one shown in Fig. 1, can be used. Here, two concentric ring slots are fed in series with a microstrip feed line. Each antenna acts as a series load of the microstrip line and the wide arc-shaped section of the microstrip line acts as a parallel capacitor, which comes between the two resonators. The value of this capacitor, which is determined by the arc angle, can be chosen such that the first resonance of the smaller antenna and the second resonance of the larger antenna merge and result in a much larger bandwidth. The feed network of the proposed antenna consists of a 50 Ω microstrip line connected to a 110 Ω line that is extended by the length L_m beyond the second antenna. Matching is performed by tuning the length of this open-circuited line (L_m).

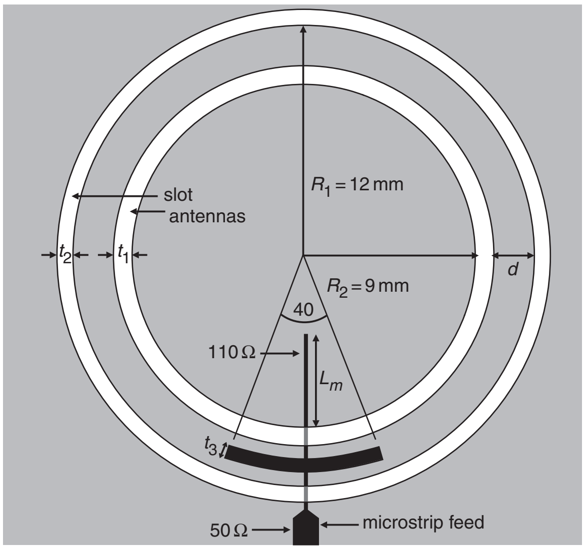

Fig. 1 *Geometry of double-element concentric ring slot antenna*

$t_1 = t_2 = t_3 = 1$ mm, $d = 2$ mm

Results and discussion: To compare the improvement in the antenna bandwidth, the double-element ring antenna and one of its building blocks (the outer ring) were simulated using IE3D [3] and fabricated on a 0.5 mm thick, RO4350B substrate with dielectric constant of $\varepsilon_R = 3.4$ and total ground place size of 11 × 10 cm. Fig. 2 shows the measured return losses of the double-element and single-element slot antennas. It is seen that the single-element narrowband ring antenna has a −10 dB bandwidth of 6% whereas the double-element antenna has a bandwidth of 36%. This shows a bandwidth improvement by a factor of six without significantly increasing the area occupied by the antenna or introducing any difficulty in the design of the feed network. The radiation patterns of the double-element ring antenna were measured in the anechoic chamber of the University of Michigan at three different frequencies. From these measurements, it is observed that the antenna patterns over the entire bandwidth are similar to each other and to that of the ordinary ring antenna. For brevity, only the measured result at 4.5 GHz is presented in Fig. 3. It can be observed that the cross-polarisation levels are very small at boresight but intensify around ±45° in the E-plane. This is also observed in the radiation patterns of the ordinary ring slot antennas and is attributed to the circular radiating current distribution. Measurement results indicate that the cross-polarisation levels at these angles are very close to those of the ordinary ring, which shows that the proposed topology does not have any adverse affect on the cross-polarisation levels. The antenna gains at different frequencies are also measured using a double ridge horn antenna and are given in Table 1.

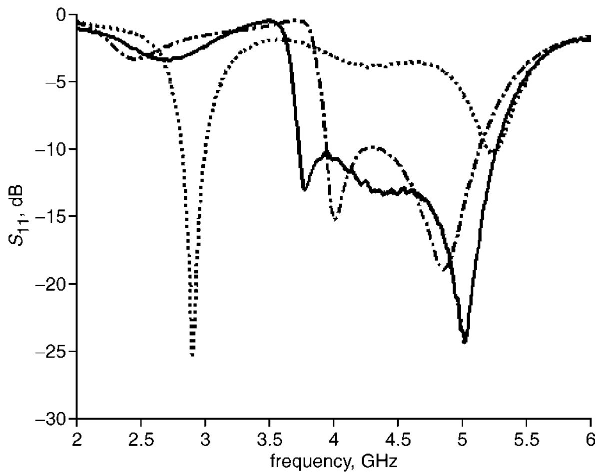

Fig. 2 *Measured return losses of double-element wideband ring antenna and single-element outer ring*

——— double-element antenna (measurement)
– · – · – double-element antenna (simulation)
· · · · · · single-element ring antenna (measurement)

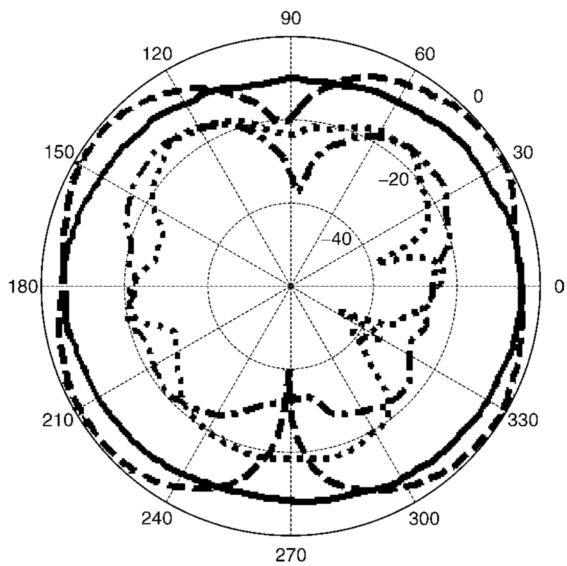

Fig. 3 *Measured radiation patterns of double-element ring slot antenna*

——— E-plane co-pol
– · – · – E-plane cross-pol
– – – – H-plane co-pol
· · · · · · H-plane cross-pol

Table 1: Measured values of antenna gain at different frequencies

Frequency, GHz	4	4.5	5
Gain, dBi	2.4	2.5	2.9

Conclusions: A new technique for bandwidth enhancement of concentric ring slot antennas is presented. Using this technique, significant improvement in the bandwidth of otherwise narrowband antennas can be obtained without putting any constraints on the radiation parameters of the antenna or worsening cross-polarisation levels.

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3 (IE3D, Simulation and optimization software, Zeland Software Co.