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A SINGLE SPIRAL ANTENNA WITH STEERABLE BEAM.

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1. ABSTRACT

Steerable antenna is required for adaptive beam direction. For this purpose, a single spiral antenna including switches is proposed. Current flow on the outer circumference of the spiral antenna is varied by applying open and short circuits at various points on the antenna arm. Open and shorting are accomplished for both one-point and two-points. It is shown that the antenna beam is steerable in various directions depending upon the location of the open/short circuit(s) switch, with the gain staying uniform within $\pm$1.5 dB and VSWR staying within acceptable limits for most of the configurations. The Limitations of this technique are also discussed.

2. INTRODUCTION

At present some smart antenna systems using phased array have been successfully implemented. Phase array antennas are acceptable for the base stations where stringent requirements for phase shifters, space for multiple antenna elements and cost can be met. However the same is still not implemented in handsets or small wireless transceivers.

Different configurations of the Spiral antenna have been studied and investigated [1-4]. Spiral antenna exhibits even and odd mode of radiation. The first mode of radiation is from the first wavelength ring, the second from the second ring and so on. An axial beam is radiated by the odds mode (1, 3, 5), and a beam having a maximum gain in the direction of the plane of the spiral is radiated by the even modes (2, 3,). Upon simultaneous excitation of both first and second mode, the resultant radiation is a tilted beam (beam cock) [1]. This paper exploits this effect further to achieve beam steer-ability in an arbitrary direction.

In this paper, a steerable single element spiral antenna without the need of a complex feeding network is proposed. The direction of the antenna beam is controlled through a set of open/short circuit elements located at the selected positions on the antenna arm after the first wavelength ring.

3. RESULTS

Using Momentum of the ADS software [5], a single arm rectangular spiral antenna, Fig. 1(a), is analyzed, for a tilted beam, as specified in [2]. The substrate has thickness h = 12 mm, square length L = 51.3 mm, substrate strength ε_r = 3.7. The total length of the spiral conductor is l = 291 mm with width w = 1.2mm. The feeding conductor is of diameter d = 1.2 mm.

As compared with the two arm spiral, this antenna has the advantage of being directly fed by the coaxial line without the need of a balun [2]. The dielectric substrate is backed with a flat ground plane to increase the gain [3].The operating frequency, 3.3 GHz, excites simultaneous even and odd modes, with the spiral conductor staying at distance of approximately $\lambda_g/4$ from the ground plane. The radiated beam is circularly polarized due to the winding sense of the rectangular spiral [2]. It has also been found that the antenna is a good match for 50 ohm feeding line when the conducting ground plane is at the distance of $\lambda_g/4$.

Our analysis of the spiral antenna matched to those in [2] and for brevity, is not repeated here again. It is found that the direction along which the tilted beam achieves its maximum intensity is $\theta_{\max} = 33^\circ$ and $\phi_{max} = 291^\circ$.

As mentioned earlier, the tilted beam is due to the combination of the first mode and the second mode radiation, concurrently radiated. Therefore, beyond the first wavelength ring, open and short circuits are applied at different positions on the spiral arm in order to change the current

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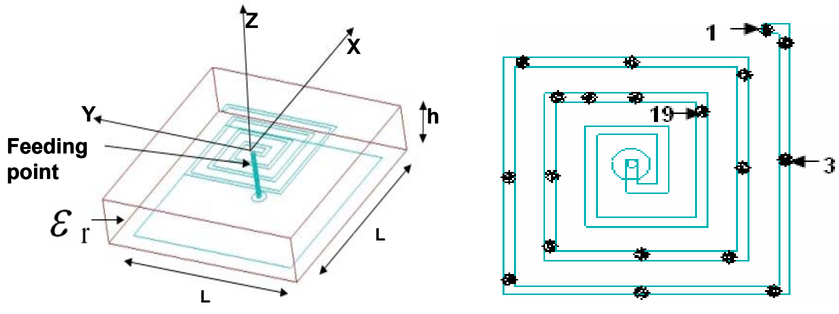

Fig.1 (a) Single arm spiral antenna. (b) Locations of short circuits.

distribution, the radiation characteristic of the second ring and hence, the overall radiation pattern.

In Fig.1(b) the black spots show the locations of the open/short circuits. All the points are not opened/shorted simultaneously. Here one-point and two-point open/short circuiting is used. Fig.2 shows examples of open/shorting the spiral arm at one-point and at two-points respectively. PIN diodes or MEMS switches can be used for practical implementation of open/short circuits.

A total of four configurations are analyzed, one-point open, one-point short, two-point open and two-point short. In the one-point open/short only one switch is activated at a time, giving 19 switching cases whereas in the two-point open/short, two consecutive points are activated at a time, resulting in 18 switching cases. By ADS-momentum software these configurations are analyzed and the directions of the beam (θ_{max} and ϕ_{max}) are obtained, Fig.3.

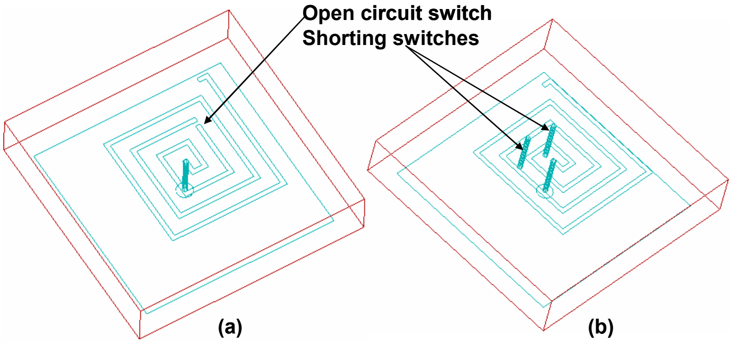

Fig.2 Antenna switches (a) one-point open circuit (switch no. 19) and (b) two-points shorting (switch no. 18).

In the simulations the vias of perfect conductivity are used to achieve the short circuits, with their diameters being the same as the diameter of the feed conductor (probe). The gap on spiral conductor arm for open circuit is kept at 1 mm, same as the length for some existing MEMS Switches.

From the Fig. 3, it can be seen that out of four configurations, the one-point open circuit provides the max variation in the ϕ_{max} while the two-point shorting provides the maximum variation in the θ_{max} . With the former the maximum variation of (θ_{max} and ϕ_{max}) is about 15^o and 174^o and with the later, it is about 39^o and 144^o.

With reference to Fig. 3, in the two-point shorting (right figure) corresponding to switch no. 13, it can be inferred that only two arms of the second wavelength ring have appreciable current for radiation having a phase shift of 180^o, thus only an axial beam is radiated with θ_{max} around 6^o.

Fig.4 shows the three-dimensional plots for the net electric field for the one-point open circuit (switch no. 19) and two-point short circuits (switch no. 18), Fig.2. The one-point open circuit causes the beam to be tilted in the positive theta direction and two-point short circuit results in a tilted beam in the negative theta direction. It should be noted that with every switch case of each configuration the position of (θ_{max} and ϕ_{max}) of the radiated beam steers to a new spot; hence in net effect by switching on/off various switches in a predefined algorithm, the beam can be steered smoothly into various desired directions.

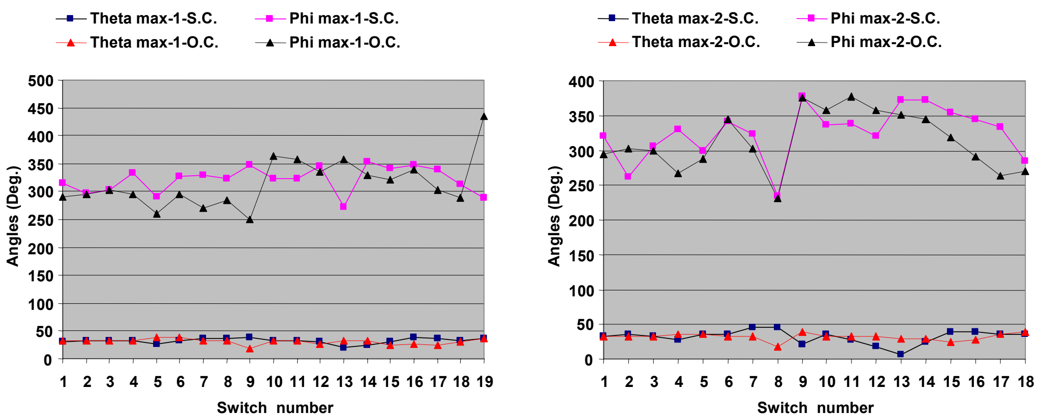

Fig.3 θ_{max} and ϕ_{max} versus location of switches on antenna for all four configurations.

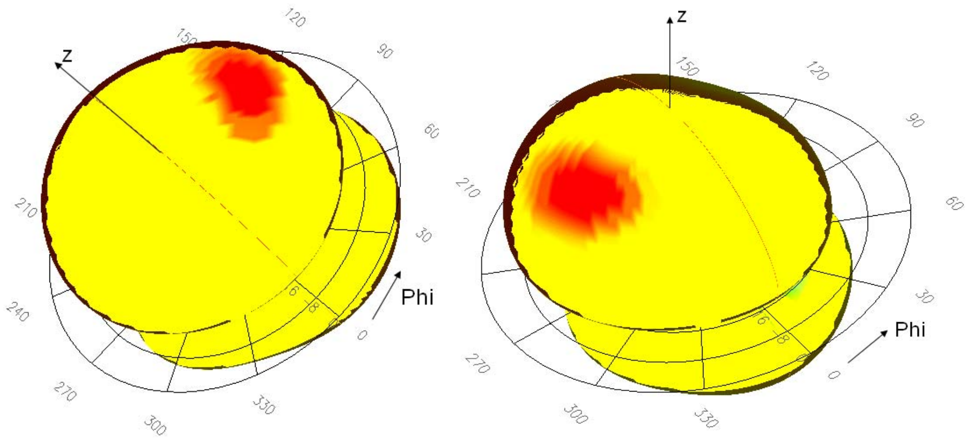

Fig.4 Three-dimensional radiated pattern for one-point open and two-point short circuit.

Fig.5. shows the beam signature (3 dB-contour plot) for the radiated beam for one-point open circuit. It depicts how by switching switch nos. 3,5,9,10,14 and 19 one at a time, the beam can be steered smoothly from one spot to another. In similar fashion the beam signature for other three configurations would also portray the beam steering phenomenon. With the present switching topologies the antenna is capable of scanning majority of space in front of the antenna.

It should be noted that generally with the introduction of switches in the antenna arm the beam tends to loose the circular polarization sense, however in many application this is not an issue. Also, the VSWR, Fig. 6, relative to $50\,\Omega$ feed line, for both the open circuit configuration, go beyond 2 for six different switching cases, thus for those cases the antenna would need some extra power to achieve same level of radiation as others. However, in both the shorting configurations the VSWR remains under or around 2, which implies that the VSWR is not affected strongly by the short circuits. Fig.6 shows the gain for different configurations which stays within $\pm$1.5 dB around 7.5 dB average value.

4. CONCLUSION

A single rectangular spiral antenna with beam steering capability was proposed for adaptive beam applications. This antenna radiation pattern is controlled by the insertion of open/short circuits after the first wavelength ring on the antenna arm. The switching can be of one, two or multiple point(s) at the same time, either in open or shorting mode. Four configurations of one-point and two-point open/short were considered in this work. The one-point open provides a larger variation in

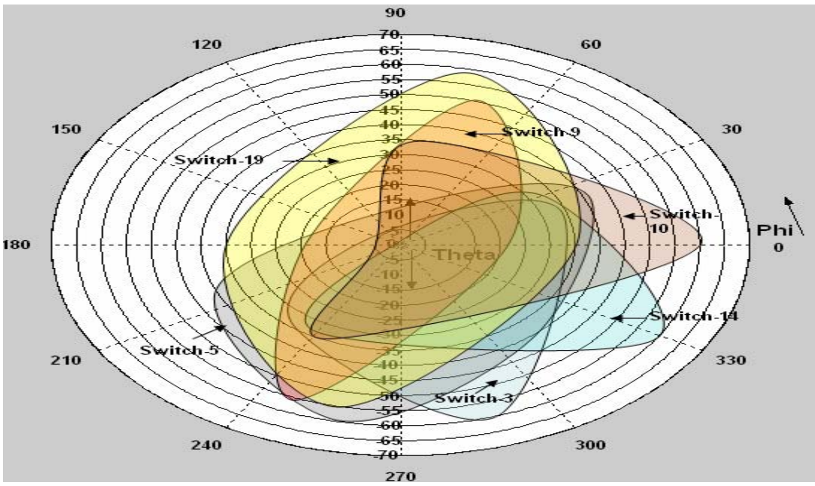

Fig.5 Beam Signature for one-point open circuit.

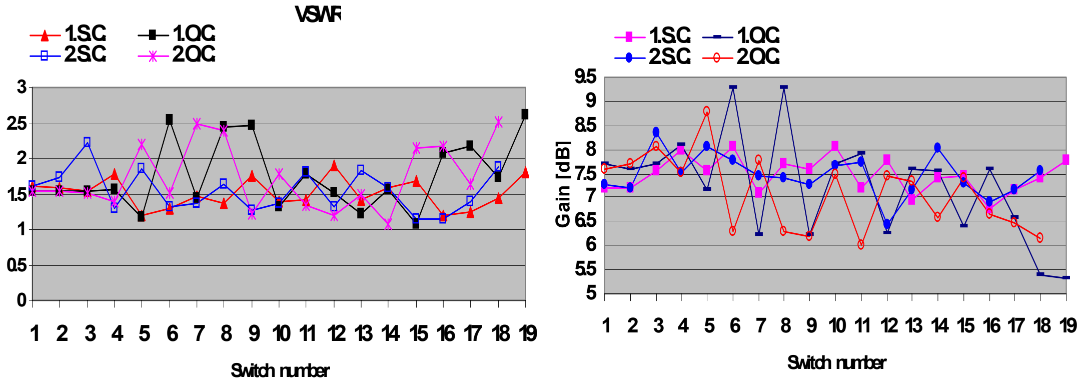

Fig.6 VSWR and gain for the spiral antenna with all four configurations.

the beam ϕ_{max} direction where as the two-points shorting yields larger variation in the θ_{max} direction. The VSWR for open circuit configuration is above 2 in six cases where as it stayed around 2 for the shorting configurations. The gain for all four configurations stayed around 7.5 dB with $\pm$ 1.5 dB variation.

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