Dual Rectangular S antenna for Switched Beam Applications

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Abstract—A broad-band dual S antenna with four feeding points on its four arms is presented for switched beam applications. The antenna generates a tilted beam covering a particular quadrant space for a particular feeding point, thus covering the entire space in front of the antenna. Tilted beams have θ_{max} = 45^{o} for four ϕ_{max} directions. The antenna impedance (10 dB) bandwidth for each beam is more than 3.6 GHz, obtained in the UWB region. The antenna gain for each feeding configurations is 8.42 dBi.

I. **INTRODUCTION**

Due to the requirements of phase shifters, multiple antenna elements and digital processing, the phase array antenna technique has not yet been implemented in handsets or small wireless transceivers nor does it seem to be a viable proposition. Instead the focus has been shifted for some time to develop and implement simple single element antenna structures with switches for beam steer-ability, as reported by the authors and others in [1-2-3]. Single element beam steer-able antennas are small, facilitate the maintenance of high quality link for transmission and reception for users on move. and have potential to improve surface absorption rate (SAR) [4]. The spiral antenna techniques described in [1-2-3] enable generation of switched beams radiation patterns under electronic control without need for a complex feeding network. The direction of the antenna beam is controlled through a set of hard-wired or electronic switches (micro electro mechanical switches, MEMS), shorting or opening the spiral antenna arm at selected points. However, due to excitation of a switch, there is a change in the current distribution of the antenna arm which results in a change in the antenna polarization [1-2-3] which is switch dependant. Thus, the antenna beam can have a dominant polarization (E_θ / E_ϕ or CP) under one switching arrangement and this can change drastically under the next switching arrangement. In some applications this change of polarization is not favorable. To overcome this problem a dual rectangular S antenna with four port feeding network in proposed in this paper, Fig. 1.

The dual rectangular S antenna which is similar to rectangular spiral antenna [1] generates a tilted beam in a quadrant when fed at any of its arms. This tilted beam is due to a combination of radiations from its fed S antenna arm and the second auxiliary coupled S antenna arm. Upon changing the feeding point, the direction of the tilted beam also moves to a different quadrant. Since there is no switching involved on the antenna arm, the antenna polarization sense stays the same for all the tilted beam directions. Also, the dual rectangular S antenna exhibits a broad-band. Thus, this antenna is useful in applications pertaining to smart mobile handsets/wireless trans-receivers and ultra wide band (UWB) systems. The results given in this paper is based on simulations. The simulations are performed using ADS–momentum software [5]. The antenna characteristics, including the radiation pattern, gain, and reflection co-efficient S_{11} are obtained in the UWB spectrum from 3.1GHz to 10.6 GHz.

II. ANTENNA CONFIGURATION

Fig. 1 shows the dual S antenna which is composed by aligning two S antennas orthogonal to each other. The antenna is on a dielectric substrate and is backed by a conducting ground plane; both are assumed to extend to infinity. Since ADS is a 2.5 dimension solver, the antenna structure is well suited for analysis with this software. The centre point of the dual S antenna is termed as O. Analogous to [1], the antenna height is 12 mm and the arm width 1.5 mm and the substrate permittivity 3.7. The net length of a single S antenna is 60 mm with L_1 = 15 mm and L_2 = 30 mm. The four feeding points (A, B, C and D) are located at a distance of 5.6 mm from point O on the antenna center arms. It was found through an initial standard micro-strip antenna calculations and then by simulation that this is the optimum distance to achieve the widest impedance bandwidth. Based upon the antenna feeding points a total of 4 antenna configurations (Cfg_A, Cfg_B, Cfg_C and Cfg_D) are analyzed. Therefore, if the antenna is fed at point A the configuration is referred to as Cfg_A.

III. RESULTS

Fig. 2 shows the return-losses, S_{11}, of the Cfg_A configuration. As this figure shows the −10 dB bandwidth covers a wide frequency range in the C band, ie; from 4.2 GHz to 7.8 GHz. Since the antenna and feeding structure are symmetrical, the S_{11} for the remaining three configurations (Cfg_B, Cfg_C and Cfg_D) are similar to that for Cfg_A to within the computational accuracy.

As regards the radiation pattern, $E_{net} = (|E_\theta|^2 + |E_\phi|^2)^{1/2}$ is the net electric field intensity in this paper. The θ and ϕ co-ordinates of the direction of maximum E_{net} are referred to as θ_{max} and ϕ_{max}. Within the wide bandwidth of the antenna, the antenna test frequency is chosen to be 4.8 GHz.

Fig.3 shows the 3-dimensional radiation patterns (1 dB cone) for all the four configurations of the feed (A, B, C and D points on the antenna, Fig.1). The Cfg_A beam has $\theta_{max} = 45^\circ$ and $\phi_{max} = 276^\circ$, Cfg_B has $\theta_{max} = 45^\circ$ and $\phi_{max} = 186^\circ$, Cfg_C has $\theta_{max} = 45^\circ$ and $\phi_{max} = 96^\circ$, and Cfg_D has $\theta_{max} = 45^\circ$ and $\phi_{max} = 6^\circ$. From these readings, it can be noted that the ϕ_{max} for each tilted beam is approximately multiple of 90°. Each of the four configurations radiates a tiled beam in a different space quadrant each time, thus realizing a switched beam antenna. In practice the antenna can be fed from the bottom using coplanar waveguide incorporating switches and a particular feeding port out of the four could be selected electronically. This technique offers ease of implementation and will not hamper the antenna radiation pattern as would be the case in [1-2-3] where the switches are incorporated on the top of antenna arm.

Fig. 4 shows the vertical (elevation) and conical (azimuth) radiation pattern cuts for all the Cfg_A in the direction of maximum radiation, i.e. radiation pattern at $\phi = \phi_{max}$ as a function of θ [Fig. 4(a)], and at θ_{max} as a function of ϕ [Fig. 4(b)]. The radiation pattern at $\phi = \phi_{max}$ as a function of θ reveals that for all the three configurations, the half-power beam-width is less than 75°, yielding high gain beams. Once again due to the antenna and its feeding being symmetrical the radiation patterns are similar for the remaining three configurations as well.

The circular polarization axial ratio for all the 4 cases is approximately 5.86 dB and this is not a function of the switching. Thus the dual rectangular S antenna radiates an elliptically polarized wave. From Fig. 4 it is also seen that the wave polarization is dominant in E_θ direction by margin of about 3 dB over E_ϕ direction. This is a big advantage since with this antenna beam diversity is achieved with polarization being the same in all directions, thus overcoming the limitations of prior techniques. The gain in the direction of maximum radiation for the four configurations is 8.4 dBi.

IV. CONCLUSION

A dual rectangular S antenna with four points for feeding is proposed for switched beam applications. The feeding points located on the four centre arms when excited one by one, generate four tilted beams in different quadrant, thus yielding a beam adaptive antenna. These four feeding points results in four antenna configurations for analysis, namely, Cfg_A, Cfg_B, Cfg_C and Cfg_D. The impedance bandwidth for these configurations was found to be in excess of 3.6 GHz in the UWB. In all of the four configurations, high gain tilted radiation is achieved, with the average gain value of 8.4 dBi. The CPAR for the beams is about 5.86 dB with polarization dominance staying constant in the E_θ direction.

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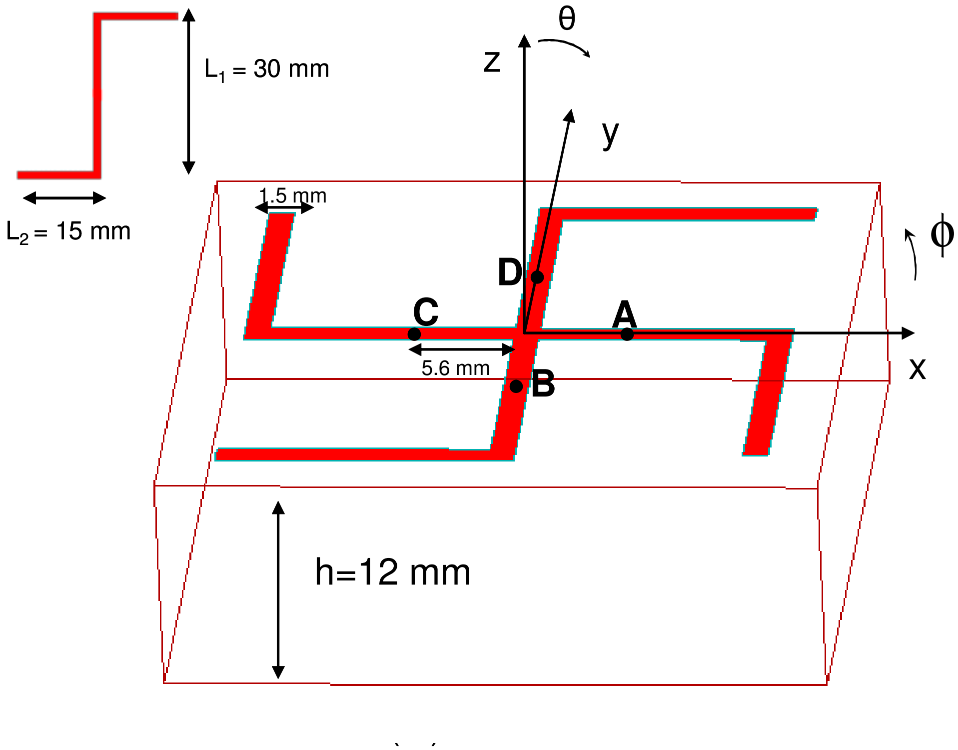

Fig. 1. Schematic structure of a dual rectangular S antenna

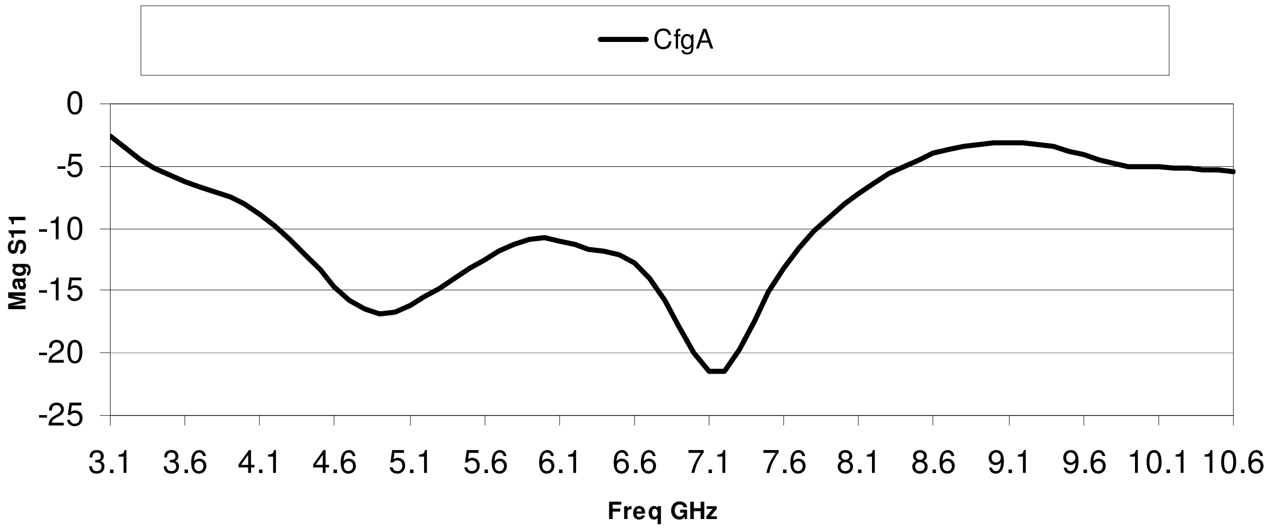

Fig. 2. Return-losses for Cfg_A antenna configuration

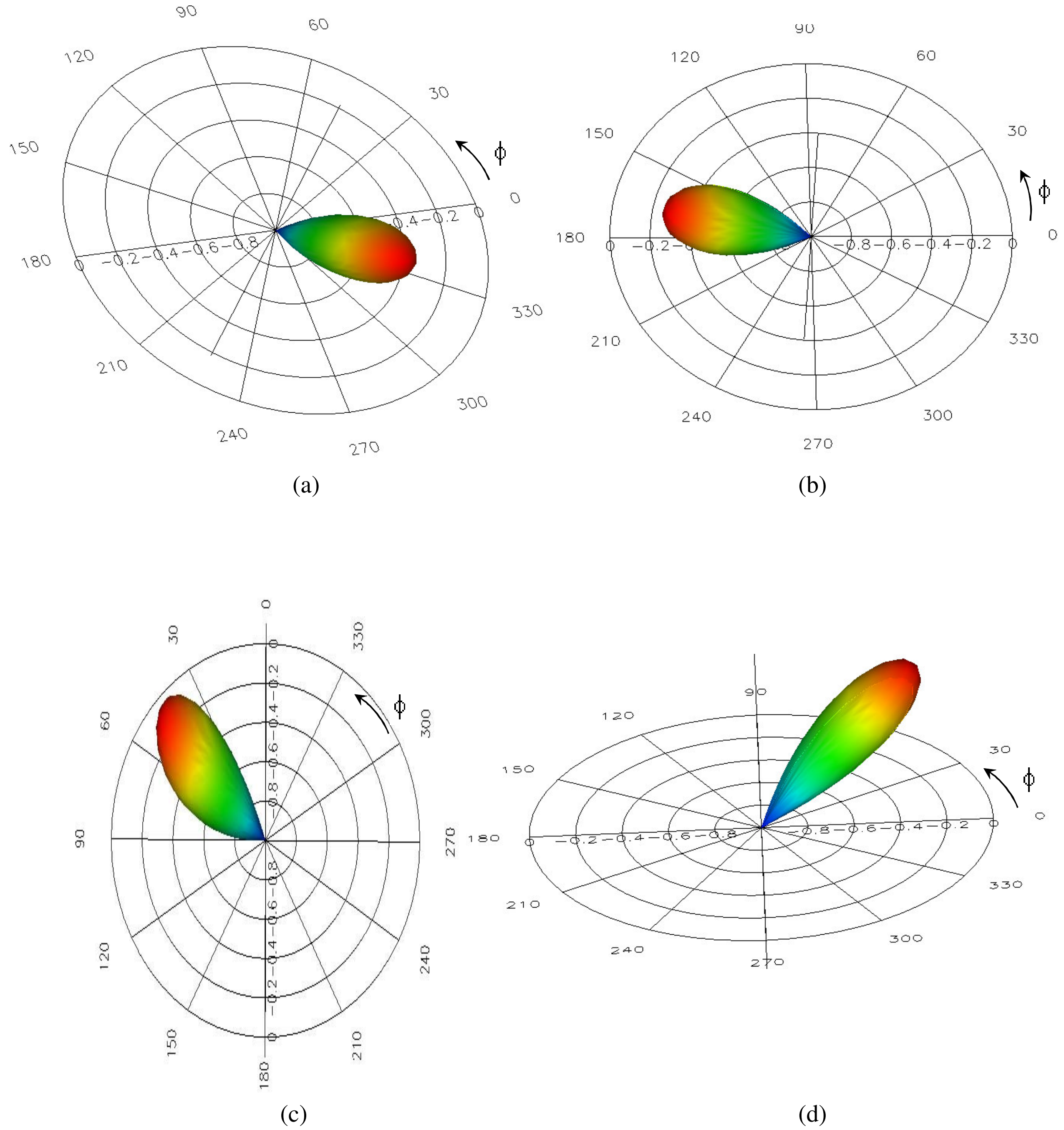

Fig. 3. 1 dB radiation cone for (a) Cfg_A, (b) Cfg_B, (c) Cfg_C, and (d) Cfg_D

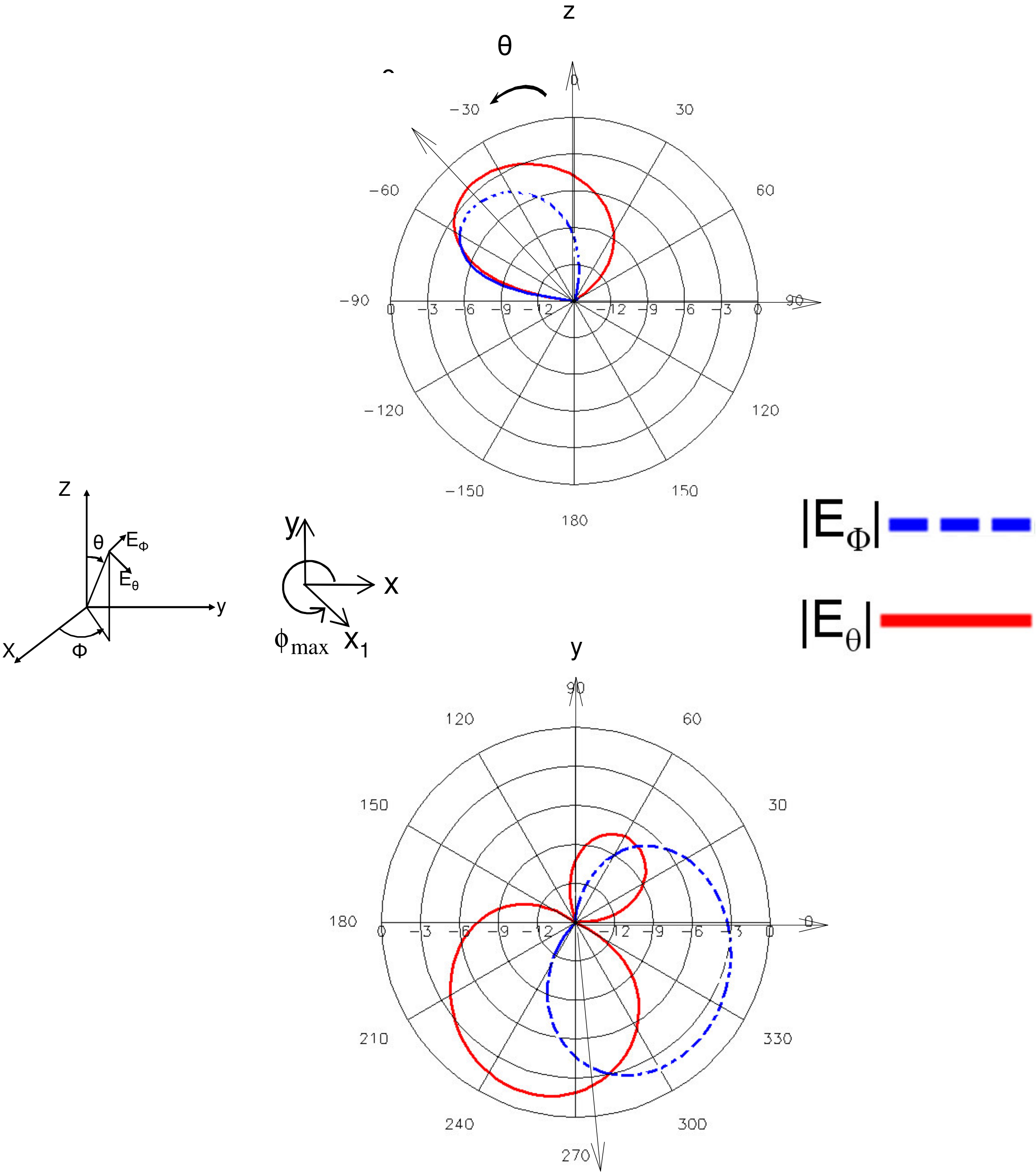

Fig. 4. Radiation pattern for the Cfg_A configuration. (a) θ variation for Cfg_A at $\phi_{max} = 276^o$ and (b) ϕ variation for Cfg_A at $\theta_{max} = 45^o$