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Practical realization of dual S arm antenna for beam steering applications*

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Abstract: A dual S shaped micro strip antenna with a realistic feed is proposed for generation of tilted beam radiation pattern pertaining for beam steering applications. To achieve this, four feeding points are located at a distance of 5.6 mm from the antenna centre. These feeding points when excited one by one generate four tilted beams in four different space quadrants, thus yielding a beam steerable antenna. Importantly, since the proposed antenna is symmetrical in the structure, all the four tilted beams have the same radiation pattern characteristics. A further enhancement of the antenna bandwidth is also achieved using 100-μm capacitive coupling between the feed and the antenna strip.

Key words: Beam steerable antenna, S antenna, Switched beams
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INTRODUCTION

Single-element antennas for beam steering applications have been proposed and successfully implemented (Mehta *et al.*, 2006a; Jung *et al.*, 2006; Huff and Bernhard, 2006). They have enormous potential for implementation in small wireless transceivers where due to limited space a large phase antenna array cannot be incorporated.

These antennas are of single- or multi-turn spiral type employing switches on the antenna arm to vary the current distribution, which in turn changes the antenna radiation pattern. However, due to excitation of switches, the antenna characteristics (polarization, VSWR) also change for different radiation patterns. Hence, although the beam steers in space, it has different parameters for different beams, and this can make the communication futile if the link is polarization dependent.

To solve this problem, a model of dual S arm antenna with four feeds was recently proposed by Mehta *et al.*(2006b). However, it was only a basic introduction to a dual S arm antenna using just the simulations, and moreover it did not reveal any practical feeding mechanism for the antenna. In this paper, for the first time a practical realization of the dual S arm antenna is presented, and along with it a capacitive coupling between the feed and the antenna strip for impedance matching is also proposed. This antenna is symmetrical in the *x*-*y* plane and generates four tilted beams of constant parameters in four different quadrants, realizing a beam steerable antenna. The results are well supported by simulations and measurements.

ANTENNA CONSTRUCTION AND RESULTS

The practical dual S arm, composed by aligning two S antennas orthogonal to each other, has the single S length of 60 mm with L_1=15 mm and L_2=30 mm, feeding located at a distance of 5.6 mm from the center and a net height of 12 mm (Fig.1). Fig.1a shows the single arm rectangular S antenna and Fig.1b shows the perspective view for the composed

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dual S arm antenna. The antenna is fed from the bottom, has track width of 3 mm, and is backed by a ground plane of 50 mm×50 mm. The feeding coaxial line has a feeding diameter of 1.3 mm. The merge point of coaxial line with that of antenna strip is referred to as feeding point *A*. In case, if all four S arms are to be used for feeding mechanism, the feeding points would be referred to as *B*, *C* and *D*. In this work only *A* is used. Fig.2 shows the top view of the prototype developed.

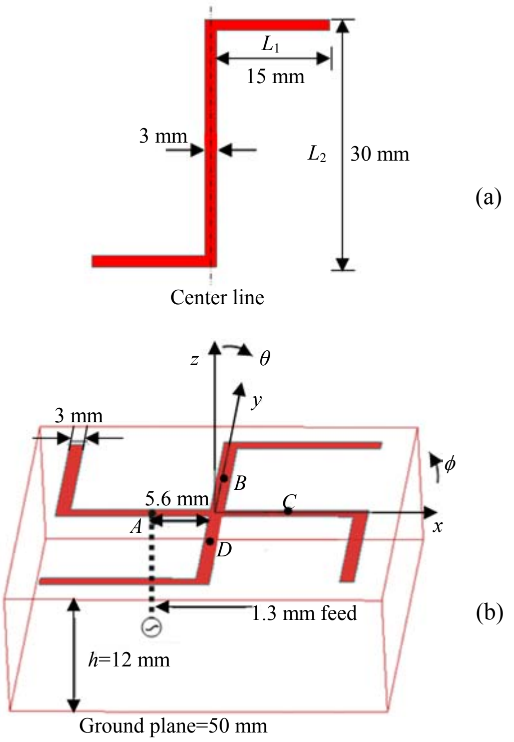


Fig.1 Schematic structure of a dual rectangular S antenna. (a) Single rectangular S antenna; (b) Perspective view for dual S arm antenna

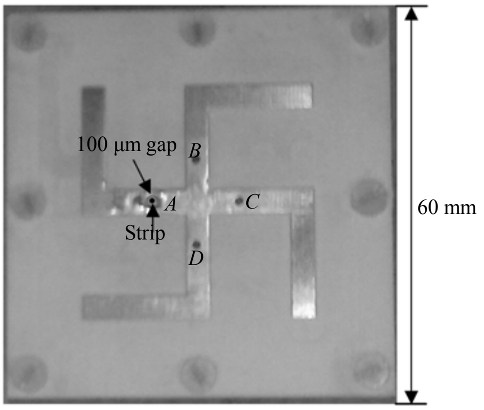


Fig.2 Prototype top view: dual S antenna with capacitive coupled feed

For ease of construction, as in (Mehta *et al*., 2006a), the substrate comprises two layers stacked together and has a net permittivity of 3.45. The simulations are undertaken using the 2.5-dimension ADS momentum software (Advanced Design System, 2003) and measurements are done using the Agilent network analyzer.

The location of antenna feeding points on the antenna arm is a compromise between the generation of tiled beam and 50-Ω impedance bandwidth. The input impedance is zero at the center and then gradually increases towards 50 Ω as the feed point is moved away from the center. On the other hand, the radiation pattern has a very sharp tilted beam ($\theta_{\max}$=48°) for center feed and then it gradually becomes axial as the feeding moves outwards from the center. Thus, the feeding is chosen to be 5.6 mm from the center, in order to have a tilted beam with sufficient impedance bandwidth.

Fig.3a shows the S11 for dual S arm antenna for feeding point *A*. As can be seen from Fig.3a, the antenna has a −6 dB impedance bandwidth of 300 MHz with a resonance at 3.6 GHz. Hence the test frequency is kept at 3.6 GHz. The small discrepancy between the simulated and measured results is attributed to the use of nylon screws for holding the two dielectric layers of the substrate, which is not accounted in simulation.

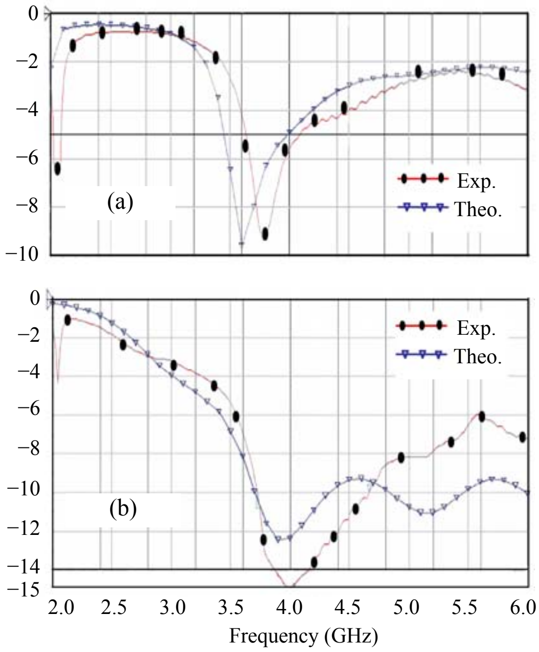
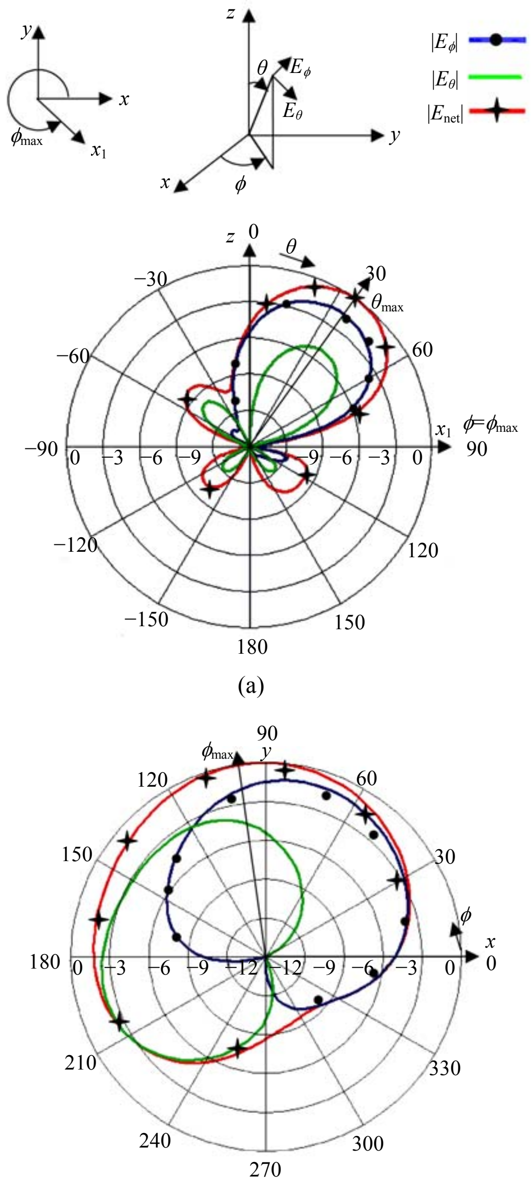


Fig.3 Reflection coefficient for (a) dual S antenna and (b) capacitive coupled dual S antenna

The antenna impedance bandwidth is further improved by using a capacitive coupling between the coaxial feed and the antenna strip. Incorporation of a small circular gap (100 μm) between the feed and the antenna strip cancels out the inductive effect due to the 12 mm feeding pin. This is clearly depicted in top view of the antenna prototype (Fig.2). The improvised return loss of the capacitive coupled antenna is shown in Fig.3b. It shows that the coupled antenna has −10 dB measured impedance bandwidth of 950 MHz (3.7~4.65 GHz). Note that the −10 dB simulated bandwidth is slightly less (700 MHz) than the measured one, this attributed to the fact that the ADS momentum cell size may undertake some approximations for encompassing the small circular gap of 100 μm. Again, at frequencies beyond 4.8 GHz, due to relatively large cell size in the theoretical model at the higher frequencies, there are discrepancies between simulated and measured results. However these are not relevant because the range of interest is primarily in the 3.6~4.6 GHz band, where simulated and measured results are in good agreement with each other.

The radiation beam for the whole band (3.6~4.6 GHz) stays tilted, hence a test frequency could be selected anywhere in this band for realizing a steerable antenna. Although the S antenna has a very large −6 dB bandwidth (3.4~6 GHz), tilted beam generation will occur only up till 5.2 GHz, as beyond that the antenna gets electrically large and the radiation patterns start to distort.

For the test frequency, Fig.4 shows the theoretical vertical (elevation) and conical (azimuth) radiation pattern cuts in the direction of maximum radiation, i.e. radiation pattern at $\phi=\phi_{\max}$ as a function of θ (Fig.4a), and at $\theta_{\max}$ as a function of ϕ (Fig.4b). It is revealed that the antenna has a tilted beam with $\theta_{\max}=36°$ and $\phi_{\max}=93°$, i.e., the antenna beam is approximately towards a 90° clockwise direction from the feeding point *A*. The radiation pattern at $\phi=\phi_{\max}$ as a function of θ reveals that the half-power beam width is less than 60°, and that the antenna radiates a high gain beam of 7.7 dBi. Since ADS is 2.5-dimension solver, it assumes the substrate to be of infinite extent, i.e., ADS does not compute electric field at θ=90° and hence, in the radiation pattern plots (Fig.4), the electric field is shown to be touching zero at θ=90°. The antenna axial ratio is 12.2 dB with polarization dominance in the E_θ direction.



(a)

(b)

Fig.4 Radiation patterns in the direction of maximum radiation. (a) θ variation at $\phi_{\max}$=93°; (b) ϕ variation at $\theta_{\max}$=36°

Hence, in practice, using four feeds (*A*, *B*, *C* and *D*) and selecting one feed at a time, the tilted beam ($\theta_{\max}$=36°) can be switched in four different quadrants ($\phi_{\max}$=93°, 3°, 273° and 183° for *A*, *B*, *C* and *D* respectively) realizing a complete beam steerable antenna. Importantly, since the antenna is symmetric, all the four beams will have the same polarization and other antenna characteristics. Electronic switches as shown in (Jung *et al*., 2006; Huff and Bernhard, 2006; Mehta *et al*., 2006c) could be used for selecting one of the exciting feed out of the total four. In addition, all of the control circuits can be easily mounted on the back of the ground plane, as in (Mehta *et al*., 2006c), without adversely affecting the radiation patterns, as would be the case in (Jung *et al*., 2006; Huff and Bernhard, 2006) where the switches are incorporated on the top of the antenna arm.

CONCLUSION

This paper presents a practical prototype of dual S arm rectangular antenna. The antenna is fed from the bottom and generates a tilted beam in a quadrant, proving the concept of symmetrical constant parameter beam switching. Additionally, using capacitive coupling between the feed and the antenna strip, the antenna is matched and its input impedance bandwidth is enhanced to 950 MHz. The gain of the antenna is 7.7 dBi with the antenna axial ratio being 12.2 dB.

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