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An Investigation into the Equivalnce of Radiation Characteristics of 90^0 Circular Sector Microstrip Antenna vis-à-vis Circular Microstrip Antenna

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***Abstract*—In this work, authors have investigated feed-probe influence on radiation characteristics of 90^0 circular sector microstrip antenna (CSMA). It is observed that by exciting a 90^0 CSMA with a feed-probe at two different feed-probe positions, two different modes TM_{01} and TM_{21} can be excited within the antenna structure. The resonant frequencies of these two modes are different but both of these modes have broadside radiation patterns in E and H plane. It is also observed that a 90^0 CSMA resonating at higher order TM_{01} mode has nearly equivalent radiation characteristics with a circular microstrip antenna resonating at dominant TM_{11} mode resonating at nearly same frequency. Therefore, the 90^0 CSMA becomes a suitable alternative to a circular microstrip antenna.**

Keywords—Circular Sector Microstrip Antenna, Electromagnetic Modes, Circular Microstrip Antenna.

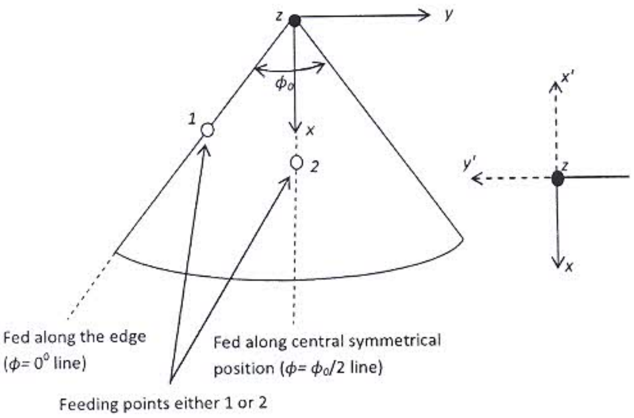

Fig. 1. Schematic representation of patch of a CSMA for two different feed-probe positions. (Point 1 is along edge $\phi = 0^0$ line and Point 2 is along central symmetrical $\phi=\phi_o/2$ line). The substrate and ground plane are not shown in the figure.

I. Introduction

In recent years, there is an increased emphasis on exploring the radiation and input characteristics of circular sector microstrip antenna (CSMA). In comparison with other regular shaped microstrip antennas i.e. rectangular, circular, square; circular sector geometry exhibits compactness and conformality over curved surfaces etc. Also, a CSMA is highly beneficial because it's less space requirements compared to that of a conventional microstrip antenna of common geometries. In fact, numerous number of applications of CSMA were published in the last two decades. The investigation of the radiated field, resonant frequency and polarization of the CSMA was presented in [1]. A study of a CSMA with 70^0 sector angle was reported in [2] which was based on simulations. Some advanced applications of CSMAs were reported in [3]-[4]. Proximity coupled probe fed CSMA for broad banding was reported in [3], [4]. The investigation reported in [5] emphasized on the possibility of using fractional modes in CSMA. Applications of CSMA in class F amplifier and Ku band applications were reported in [6], [7] respectively. The concept of mixed boundary condition for 120^0 CSMA and the application of CSMA for circular polarization were presented in [8], [9] respectively. Application of meta-material in CSMA was reported in [10] recently. It is found from these works that effect of feed locations on the excited modes of CSMA have not been considered in these work.

The formulation for resonant frequency of a CSMA using the cavity model was first reported in [11]. Following [11], a generalized transmission line modeling of CSMA was published in [12]. In both the works, the effect of fringing fields was not taken into purview for computation of the resonant frequency of a CSMA. Therefore, they fail to predict the accurate computation of resonant frequency of such CSMA. The theoretical and experimental investigation of CSMAs including the effect of fringing fields were reported in [13] and [14] for calculating the resonant frequency of the antenna. However, the resonant frequency of the antenna could not be accurately predicted and the determination of proper dominant mode is not apparent from the literatures. One very recent work [15] by present authors addressed the issues of fringing as well as effective dielectric constant for quick and accurate computation of the frequency of the dominant and higher order modes for a CSMA with certain sector angle. Following [15], radiation characteristics of circular microstrip antenna and that of semicircular CSMA has been compared and reported in [16] by the present authors.

However, further investigations with CSMAs reveal to the present authors that feed-probe position in CSMA has a substantial effect on the excitation of electromagnetic modes

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in CSMA [17]. It was observed in CSMA that the feed-probe position has a primary effect on the mode excitation and different modes can be excited by properly optimizing the feed location of CSMA [17].

Therefore, it leads the present authors to the quest for exploring effect of feed-probe on the radiation patterns of CSMA with small sector angle (ϕ_0). With this in view, in this paper, authors have presented a study on the effect of feed-probe on the radiation characteristics of a 90^0 CSMA. From the view of lesser space requirement, the CSMAs with a small sector angle $\phi_0 = 90^0$ has been considered in the present investigation (Fig. 1). It is noted that by exciting a 90^0 CSMA with a feed-probe at two different feed-probe positions, two different modes TM_{01} and TM_{21} can be excited within the antenna structure. Following modified cavity model analysis presented in [15], it can be found that TM_{21} mode is the dominant mode and TM_{01} mode is the higher order mode in a 90^0 CSMA. The resonant frequencies of these two modes are different but both of these modes have broadside radiation patterns in E and H plane.

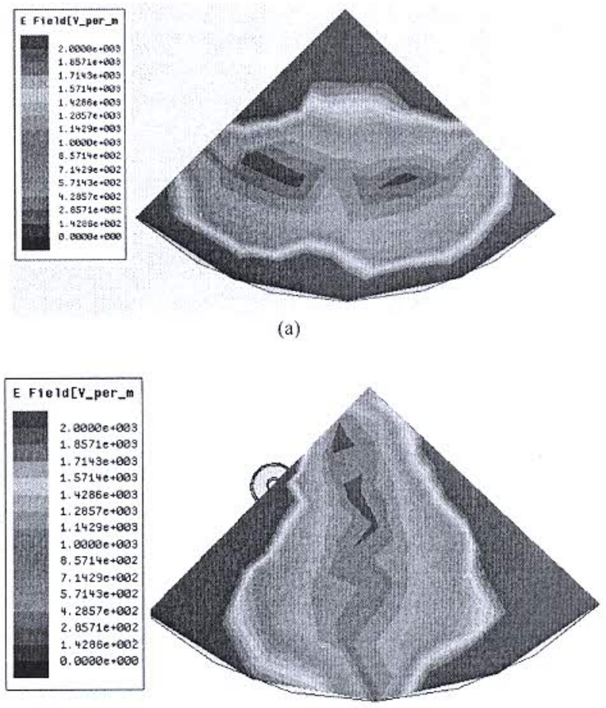

Fig 2. The magnitude of simulated [18] electric field distribution over patch surface of CSMA for two feed-probe positions. (CSMA parameters: radius a = 10 mm, ε_r=2.33, substrate height h= 1.575 mm.) (a) CSMA with $\phi_0 = 90^0$ fed along $\phi = \phi_0/2$ line (b) CSMA with $\phi_0 = 90^0$ fed along $\phi = 0^0$ line.

It is also observed that a 90^0 CSMA resonating at TM_{01} mode has nearly equivalent radiation characteristics with a circular microstrip antenna resonating at dominant TM_{11} mode at nearly frequencies. Moreover, it is found that 90^0 CSMA can be a suitable alternative to circular microstrip antenna.

II. Different Configurations of 90^0 CSMA

In this work, 90^0 CSMA with two different feed-probe position has been studied. In both cases, the patch radius (a)= 10 mm, PTFE substrate (ε_r = 2.33) with dimension 60 mm × 60 mm and ground plane dimension 60 mm × 60 mm have been considered for simulation [18]. Antenna 1 is fed along central symmetrical $\phi = \phi_0/2$ line at ρ_c= 5 mm, where ρ_c

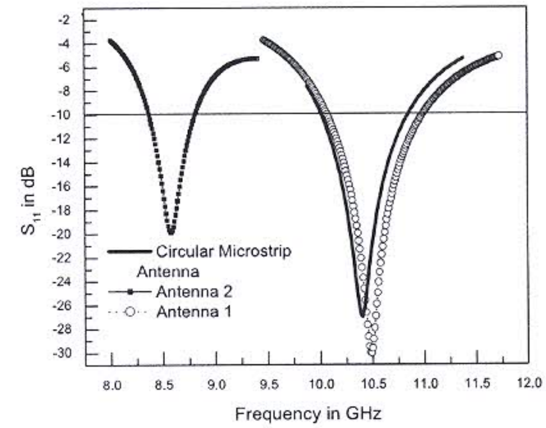

Fig. 3. Simulated reflection coefficient profile of antenna 1, antenna 2, circular sector microstrip antenna.

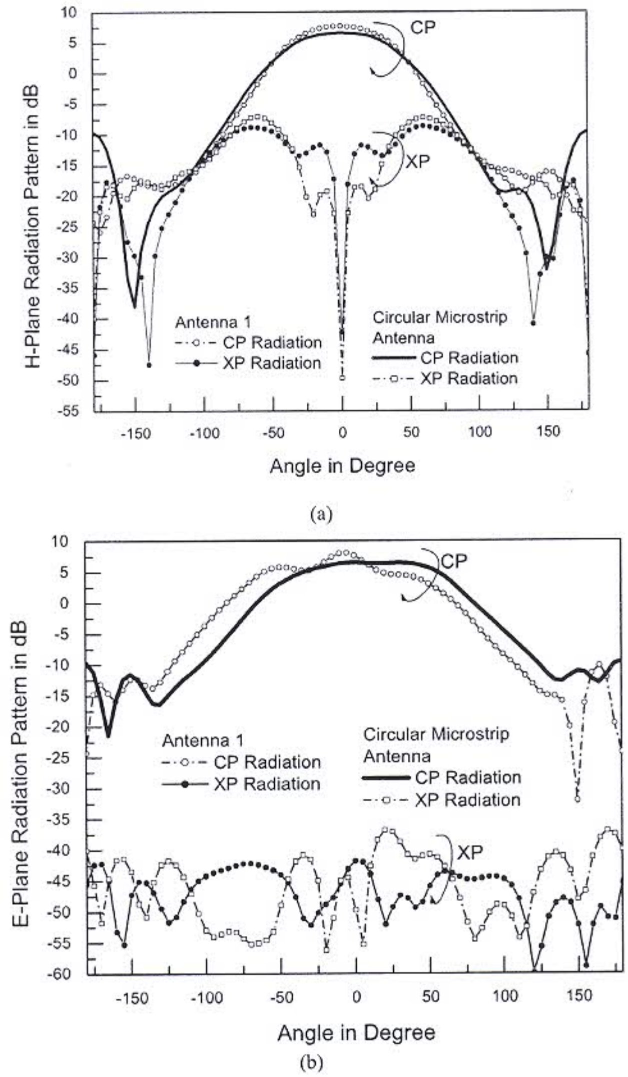

Fig. 4 . Radiation patterns for antenna 1 at higher order TM_{01} mode (*f= 10.5 GHz*) and circular microstrip antenna at dominant TM_{11} mode (*f= 10.38 GHz*).

is the optimized distance from the apex of the patch to the feed point and antenna 2 is fed along the edge (i.e. $\phi = 0^0$ line) at ρ_c=3 mm, respectively.

III. Results And Discussions

A. Antenna 1: 90^0 CSMA with feed -probe along central symmetrical $\phi=\phi_0/2$ line

It is observed that when the 90^0 CSMA is fed along central symmetrical $\phi=\phi_0/2$ line by a feed-probe, higher order TM_{01} mode is excited. The simulated [18] electric field distribution over the patch surface for 90^0 CSMA is presented in fig. 2a. The simulated [18] reflection coefficient is presented in fig 3. The antenna 1 exhibits around 9% impedance bandwidth. The H plane and E plane radiation pattern are presented in fig. 4. It is also observed that the antenna show broadside radiation pattern and have comparable radiation characteristics with that of a circular microstrip antenna of same resonant frequency. The simulated gain of antenna 1 is 7.72 dBi whereas, the gain of circular microstrip antenna in 6.1 dBi. Although the antenna 1 is resonating at higher order higher order TM_{01} mode the peak co-polar (CP) to cross-polar (XP) isolation or (CP-XP isolation) of antenna 1 is nearly 3 dB better that of a circular microstrip antenna resonating at dominant TM_{01} mode. Both of the antennas have equivalent radiation efficiency although not shown in the paper. The 3dB beamwidth of both the antennas are around 70^0 and 95^0 in H and E-plane, respectively.

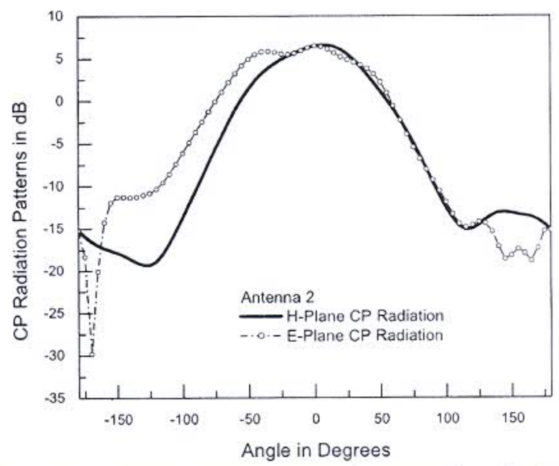

Fig. 5. H and E plane radiation patterns for antenna 2 at dominant mode frequency (*f= 8.56 GHz*).

B. Antenna 2: 90^0 CSMA with feed -probe along edge ($\phi=0^0$ line)

Now, the same CSMA is fed along edge ($\phi=0^0$ line) by a feed-probe. It is observed that instead of TM_{01} mode, dominant TM_{21} mode is excited. It is further observed that TM_{21} is excited up to the feed-probe position $\phi_f=30^0$ line and beyond that this mode ceases to exist. The simulated [18] electric field distribution over the patch surface for 90^0 CSMA is presented in Fig. 2b. The simulated [18] reflection coefficient is presented in fig 3. The CSMA exhibits around 5% impedance bandwidth. The simulated [18] CP H plane and E plane radiation patterns are presented in fig. 5. The CP-XP isolation is around 10 dB and no improvement is observed.

IV. Conclusions

In this paper, influence of feed-probe on the radiation characteristics of 90^0 CSMA is thoroughly presented. It is found that when the CSMA is fed by feed-probe along edge ($\phi=0^0$ line) and central symmetrical $\phi=\phi_0/2$ line, dominant TM_{21} mode and higher order TM_{01} mode get excited. 90^0 CSMA resonating at higher order TM_{01} mode has nearly equivalent radiation characteristics with a circular microstrip antenna resonating nearly at same frequency. Therefore, it is found that 90^0 CSMA can be a suitable alternative to circular microstrip antenna.

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