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FREQUENCY RECONFIGURABLE MICROSTRIP SLOT ANTENNA LOADED WITH VARACTOR DIODE

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ABSTRACT

This paper presents the simulated results of a compact varactor diode integrated conventional circular patch antenna and also compares the results with a similar patch antenna. Proposed microstrip patch antenna (MSA) was designed and simulated using HFSS.V.13 and CST MWS and its various parameters such as return loss, VSWR and input impedance were determined, and shape of this MSA was modified by cutting various slots in it at appropriate positions. The diode is modeled as a switch for the frequency band from 2.85 to 3.0 GHz. The proposed antenna also gives CP radiation with slots. In addition to it is observed that the proposed antenna shows frequency agility behavior in the frequency ranges 2.85 to 3.0 GHz with bias voltage varying from 0 to 5V or in ON and OFF state. A bandwidth enhancement and miniaturization is also achieved.

Keywords: Bandwidth enhancement; Circular polarization(CP); Varactor diode

I. INTRODUCTION

Microstrip patch antenna consists of a metallic radiating patch backed up by a dielectric substrate and a ground plane below that. Now days, MSAs is widely used in many applications due to their advantages such as low profile, lightweight, planer configuration and ease of fabrication. However the main limitation of MSAs is their inherently narrow BW [1]. In order to improve the BW of MSA, the idea of integrating active devices has been implemented for last many years. Such types of antennas are known as active integrated antenna. The active integrated antenna (AIA) has been a growing area of research in recent years.

An AIA can be regarded as an active microwave circuit in which the output or input port is free space instead of a conventional 50 Ω interface. Active antennas reduce size, weight and cost over conventional designs which are very useful in microwave systems [2-4]. Active antennas overcome several limitations of traditional microstrip antennas [5]. They are almost frequency independent that is their bandwidth is depends on the active circuitry rather than the radiating element. Also a careful design of the connected amplifier may ensure broadband characteristics of the antenna. Similarly the gain of the antenna can also be controlled by using the amplifiers. Since the active antenna is electrically small compared to the passive one, the overall length is much less than the conventional antenna, and thus can be used in places where there is limitation of space.

Integrated Antennas and Active integrated antennas (AIAs) are widely used in the area of wireless communications, both for civilian and military purposes. In particular, AIAs are devices in which a passive antenna element and an active circuitry are integrated together on the same substrate. The integration of active solid state devices like oscillators, varactor diode, gun diode, amplifiers,and mixers grants greater compactness, lower costs and higher power efficiencies with respect to conventional passive layouts[6-11].

In this paper, a varactor diode has been modeled in CST MWS and integrated with a hexagonal microstrip patch antenna with unequal side to form an active antenna latter which is modeled in HFSS and CST. The reason behind selecting the hexagonal microstrip antenna that, it has smaller size compared to the square and circular microstrip antennas, as well as better impedance bandwidth over rectangular and square microstrip antennas for a given frequency. Therefore, authors have designed a coaxial fed hexagonal patch antenna and circularly polarized radiation has been achieved by adjusting the position across the antenna. It is found that the obtained results are encouraging for practical applications. As it enhances BW of HMSA a comparative analysis of the various geometries of MSA obtained by cutting slots inside the radiating patch indicate considerable improvement in BW without much sacrifice on other performance parameters of MSA such as return loss, VSWR and its input impedance. Also when slots are inside the radiating patch it shows the good circular polarization

Frequency agility is the ability of a radar system to quickly shift its operating frequency to account for atmospheric effects, jamming, mutual interference with friendly sources, or to make it more difficult to locate the radar broadcaster through radio direction finding [12]. Frequency agility behavior of the proposed antenna will also be used in these applications.

II. CALCULATIONS

(i)Resonant frequency

The resonance frequency of a CMSA is obtained using the given formula [3].

$$f_o = \frac{K_{mn} c}{2\pi a_e \sqrt{\varepsilon_e}}$$

where K_{nm} is the mth root of the derivative of the Bessel function of order n . For the fundamental TM_{11} mode, the value of K_{nm} is 1.84118. The a_e and ε_e are the effective radius and the effective dielectric constant of the MSA, respectively. The fringing fields along the circumference of the given MSA are taken into account by replacing the patch radius a by the effective radius a_e.

$$a_e = a\left[1 + \frac{2h}{\pi a \varepsilon_r}\left\{\ln\left(\frac{a}{2h}\right) + 1.41\varepsilon_r + 1.77 + \frac{h}{a}(0.268\varepsilon_r + 1.65)\right\}\right]^{\frac{1}{2}} \quad (6)$$

The value of ε_e is obtained using

$\varepsilon_e = C(a, h, \varepsilon_e, \varepsilon_r)/C(a, h, \varepsilon_e)$ (7)

where $C(a, h, \varepsilon_e, \varepsilon_r)$ and $C(a, h, \varepsilon_e)$ are the total capacitances of the dominant TM_{11} mode of MSA with and without a dielectric substrate respectively. These can be calculated as [3]

$$C(a.h, \varepsilon_o, \varepsilon_r) = \frac{0.8525\,\varepsilon_o \varepsilon_r \pi a^2}{h} + 0.5C_f \quad (8)$$

In (8), the first term is the main capacitance of the disc and the second term is the fringing capacitance, C_f, which is given by

$$C_f = 2a\varepsilon_o\left[\ln\left(\frac{a}{2h}\right) + 1.41\varepsilon_r + 1.77 + \frac{h}{a}(0.268\varepsilon_r + 1.65)\right] \quad (9)$$

$C(a, h, \varepsilon_e)$ is calculated by putting $\varepsilon_r = 1$ in (8) and (9). For thin substrates, ε_r should be used instead of ε_e in (6.1), and for thick substrates ($h > 0.05\lambda_o$), ε_e should be used.

(ii) Actual radius of the Patch

Using equations 6 to 9 and taking the values of different parameters as follows, we can calculate the value of actual radius of the patch.

K_{mn}=1.84118; c=3x10^8m/s;

ε_o= 8.86x10^{-12}F/m; ε_r=4.2;

h=1.6 mm; Frequency(f_o)=2.1GHz

We can now calculate the value of the fringing capacitance C_f, $C(a, h, \varepsilon_{e,}\ \varepsilon_r)$, $C(a,h, \varepsilon_e)$, ε_e and effective radius a_e followed by the value of the actual radius 'a' which come out to be 24mm.

III. DESIGN OF CIRCULAR MSA

The geometrical configurations of top and side views of the circular patch antenna are shown in Fig 1 & Fig 2. The resonant frequency for the dominant as well as for the higher order modes can be calculated from the formula of the circular disc by replacing radius *a* by equivalent radius a_{eq}[6-7] i.e.

$$f_{np} = \frac{X'_{np}.c}{2\pi a_{eq}\sqrt{\varepsilon_r}} \qquad (1)$$

Where X'_{np} are the zeros of the derivative of the Bessel function $J_n(x)$ of the order n and the equivalent radius a_{eq} is determined by comparing areas of a regular hexagon and a circular disk of radius a_{eq} i.e.

$$\pi a_{eq}^{2} = \frac{3\sqrt{3}S^{2}}{2} \qquad (2)$$

$a_{eq=}$0.9094S

Thus the resonant frequency of a hexagonal element may be expressed as:

$$f_r = \frac{X'_{np}.c}{2\pi(0.9094\ S).\sqrt{\varepsilon_r}} = \frac{1.1X'_{np}.c}{2\pi S.\sqrt{\varepsilon_r}} \qquad (3)$$

And for the lowest order mode TE_{11}

X'_{np}=1.84118

Hence f_r =2.8 GHz

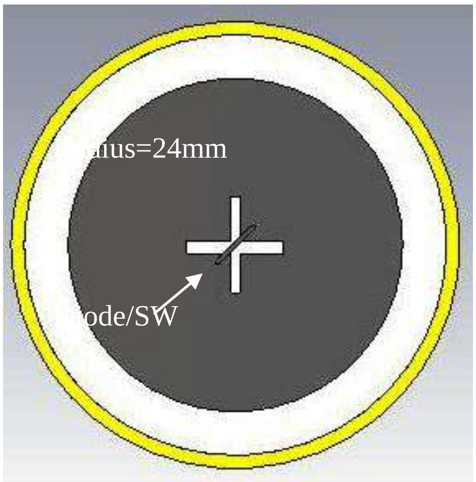
IV. DESIGN SPECIFICATIONS AND CALCULATIONS

Design specifications for the proposed patch antenna are as follows.

Parameter	Value
Substrate	FR4
Thickness	1.6
Radius of Patch	24 mm
Slot	(1x1.5)x11 in x and y direction
Diode/SW position	(2,2,1.6) and (-2,-2,1.6)

V. RESULTS AND DISCUSSION

Using these design parameters and mathematical expressions, the proposed antenna has been designed and performances are examined using HFSS and CST MWS, and the obtained results are described in the following sections.



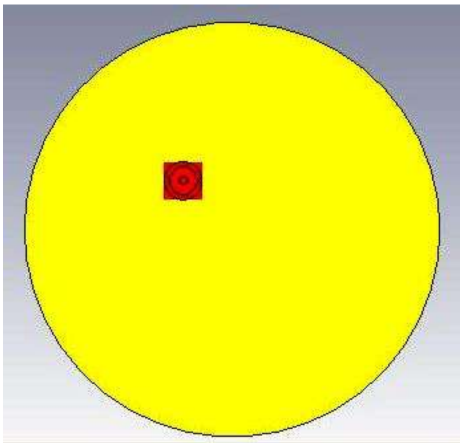
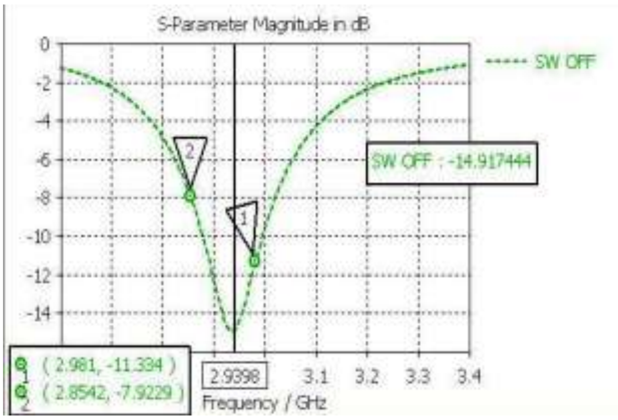


Fig1. Top View of Reconfigurable Patch **Fig2. Bottom View**

Here a feed location point is to be found out on the conducting patch where patch impedance is 50 Ω. This feed point gives maximum radiation because of proper matching with 50 Ω coaxial feed. At first the feed position is varied and its effect on the input impedance, S_{11} and VSWR are measured. The variation in return loss with frequency is shown in Fig 3,4 and 5 which shows that the varactor diode/Switch is in ON and OFF state.



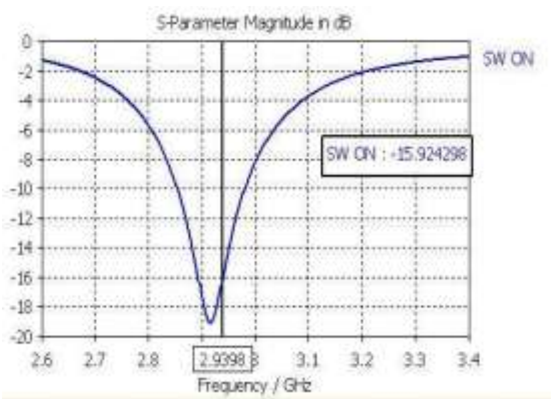


Fig3. Return Loss when diode/SW is in OFF State **Fig4. Return Loss when diode/SW is in ON State**

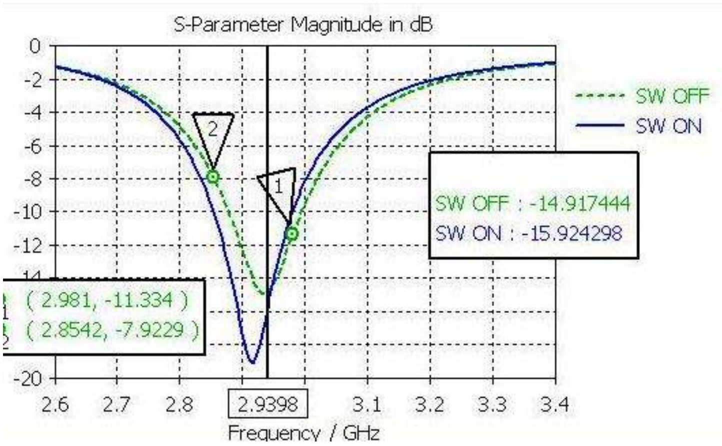


Fig2. Comparative Return Loss when diode/SW is in OFF/ON State

The radiation pattern near the resonant band frequencies shows that with an increase in frequency, the radiation pattern varies and the cross polar level increases significantly to the extent that the radiation becomes maximum along $\Phi = 0°$ at 2.7 GHz. The radiation pattern of the antenna also shows that it is Omni directional as well as circularly polarized with small levels of cross polarization. The other parameters are also found as given in

Table

Characteristics	Diode/SW ON	Diode/SW OFF
Resonance Freq	2.91GHz	2.94 GHz
Axial ratio (dB)	0.255	1.48
BW(GHz)	0.132	0.127
Gain (dBi)	3.7	2.1

VI. CONCLUSION

In this paper, design, simulation of conventional and varactor integrated circular patch antenna has been presented. The active device and the patch antenna have been considered as a composite unit instead of taking them as independent units whereas in conventional wireless or other communication systems antenna and circuit they are being considered as separate element. The antenna has been designed at 2.45GHz (ISM Band) and excited using coaxial feeding techniques and its performance characteristics such as return loss, axial ratio, VSWR, input impedance and radiation pattern has been calculated. The antenna with slots gives circular polarization (AR < 3 dB) as compared to the antenna without slots in addition to gain and bandwidth improvement. The differential bandwidth of antenna system when SW/Diode is in OFF state is 0.127 GHz whereas it becomes 0.132 GHz when the SW/diode is in ON position. The resonance frequency is also shifted from 2.94 GHz to 2.91 GHz clearly showing the property of antenna miniaturization.

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