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Broadband Double Psi (Ψ) Shaped Patch Antennas for Wireless Communications

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ABSTRACT: This paper presents the increase in bandwidth of a microstrip antenna using a simple slotted structure in microstrip antenna. The main aim of proposed work is to obtain a large bandwidth antenna with reduced size. A new double Ψ -shaped microstrip antenna is presented, which increased the bandwidth of the E-shaped microstrip antenna by cutting an additional pair of two slots on the other radiating edge of the E-shaped patch. The double Ψ -shaped patch yielded 135 MHz bandwidth at a centre frequency of 2.4 GHz with 4.0db gain. The proposed antenna is designed and simulated on the HFSS software.

KEYWORDS: MSA; Double Ψ -shaped microstrip antenna; HFSS; Bandwidth; Gain; Dual parallel slots; Modes.

I. INTRODUCTION

The field of wireless communication demands simple, small, reliable, economical, low profile and lightweight and mechanically robust antennas for various applications like mobile and satellite communication, phased array, electronic warfare, radar, missile telemetry, space and airborne microwave remote sensing systems etc.

With the development of MIC and HF semiconductor devices, microstrip and printed circuits have drawn the maximum attention of the antenna community in recent years.

In spite of its various attractive features like light weight, low cost, easy fabrication, conformability on curved surface and so on, the microstrip element suffers from an inherent disadvantage of narrow bandwidth and low gain.

Several techniques are available in literature for improving the bandwidth of microstrip antennas such as the use of impedance network, parasitic patches stacked on the top of main Patch, incorporating slots using multimode resonators etc.

1. Necessity:

Among these the slotting technique is simple to enhance the bandwidth as compared to the other techniques because it has the freedom to add desired slot on the radiating element of the Microstrip antenna.

The slots in the Microstrip patches may be of various shapes like U-slot, E-shaped slot, L-shaped slot, W-shaped slot etc.

That's why in this paper we propose a modified psi shaped microstrip antenna which will increase the bandwidth by incorporating the higher order modes.

2. Objectives:

The objective of proposed system is as given below

- To design a rectangular microstrip antenna for the ISM band (2.4 GHz).
- Incorporate the slots and see its effect on the different parameters like bandwidth, gain, VSWR, radiation pattern etc.
- Optimize the design for the accurate values.
- Obtain the increased bandwidth comparable with gain and size of the antenna.

II. HISTORY OF MSA

Microstrip antenna was first introduced in the 1950s. However, this concept had to wait for about 20 years to be realized after the development of the printed circuit board (PCB) technology in the 1970s. Since then, microstrip



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antennas are the most common types of antennas with wide range of applications due to their apparent advantages. They have been widely engaged for the civilian and military applications. The technological advancement of the microstrip antenna is increasing day by day. A lot of research work is going on microstrip antenna for its better utilization in the future. Many techniques are coming into existence by compensating the gain and bandwidth of the Microstrip Antenna.

III. LITERATURE SURVEY

Deshmukh A. A, et al. [1] presented the paper "Analysis of Broadband Psi (Ψ)-Shaped Microstrip Antennas". The Ψ -shaped patch yielded a bandwidth of nearly 60% at a center frequency of around 5500 MHz. It gave a maximum gain of more than 10 dBi, which reduced to less than 4 dBi towards the higher frequencies of the bandwidth. A proximity fed design of the Ψ -shaped patch in the 1000 MHz frequency band was also proposed. It gave a bandwidth of more than 50% with a broadside radiation pattern, and a gain of more than 8 dBi over the complete bandwidth.

A.A.Deshmukh and coauthors have presented the analysis of broadband pair of slot cut equilateral triangular microstrip antenna. They have realized the antenna with slots having different shapes like, U-slot, V-slot and rectangular slot at an appropriate position inside the patch [2].

To improve the bandwidth of a micro-strip antenna used in sensing moisture contents in materials, such as soil and concrete, a design method of circular double-layer micro-strip antenna is studied in this paper. The antenna band is greatly improved by introducing a passive patch which meets working band requirements of the microwave moisture sensor. The numerical simulation results agree with the designed parameters [3].

In this paper Deshmukh A.A, et al. [4] presented a broadband configuration of a shorted-plate folded L-slot-cut folded-feed rectangular microstrip antenna was reported, which gave a bandwidth of 2840 MHz (133%). The broader bandwidth was obtained due to the coupling between various modes, which were either a half-wave or a quarter-wave in length. Also explained how we can obtain increased bandwidth of 3504 MHz (139.2%) by optimizing the folded feed length. Over the bandwidth, this configuration showed a radiation pattern with higher cross-polarization levels and with a gain of more than 5 dBi.

The design and experimental of a broadband coplanar waveguide (CPW)-fed hexagonal slot array patch antenna has been explained here. The results of the return loss (S11), gain and radiation pattern of the proposed antenna have been simulated by using antenna analysis software IE3D program. The transmission line and ground plane have been designed to be on the same plane with antenna slot to be applicable for wideband operation. It is found that the proposed antenna is accessible to bandwidth about 107.69%, a very large bandwidth comparing with conventional microstrip antennas, which mostly 1-5% bandwidth [5].

The analysis to study the effects of slot on the broadband response of slot cut patch is presented in this paper. Through the analysis it was observed that the slot modifies the resonance frequencies of higher order modes of the patch and yields broadband response. The bandwidth of more than 550 MHz (> 45%) is obtained. The antenna gives broadside radiation pattern with a gain more than 5 dBi over the operating bandwidth [6].

Deshmukh, A.A. presented by using a combination of the proximity feeding technique and a thicker substrate, various broadband configurations of gap-coupled rectangular microstrip antennas, E-shaped and half-E-shaped microstrip antennas, and gap-coupled half-E-shaped microstrip antennas are proposed. All of these configurations give bandwidths in excess of 350 MHz (> 35%), with gains of more than 7 dBi, in the 800 to 1200 MHz frequency band, with a broadside radiation pattern [7].

Modal variations, for modified E-shaped antenna are studied. It has been observed that the slot affects the resonance frequency of higher order mode, which along with modes of E-shaped patch, realize higher bandwidth. Also the broadband proximity fed variation of modified E-shaped antenna in 950 MHz frequency range is proposed. This antenna gives a larger BW of 47% with broadside radiation pattern with a peak gain of approximately 10 dBi [8].

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IV. ANTENNA DESIGN

A. Essential three design parameters:

- Frequency of operation (f_0): The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for design is 2.4 GHz.
- Dielectric constant of the substrate (ϵ_r): The dielectric material selected for design is glass epoxy which has a dielectric constant of 4.4.
- Height of dielectric substrate (h): For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6 mm.

B. Design steps for Rectangular Patch Antenna for 2.4GHz(ISM band):

Step 1: Calculation of the width of Patch (W):

The width of the Microstrip patch antenna is given as

$$W = \frac{c}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} \quad \text{eq. (4.1)}$$

Step 2: Calculation of effective dielectric constant:

Fringing makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air.

An effective dielectric constant is introduced, given as:

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{w} \right]^{-1/2} \quad \text{eq. (4.2)}$$

Step 3: Calculation of Length of Patch (L):

The effective length due to fringing is given as:

$$L_{\text{eff}} = \frac{c}{2f_0 \sqrt{\epsilon_{\text{reff}}}}$$

Due to fringing the dimension of the patch as increased by ΔL on both the sides, given by:

$$\Delta L = 0.412h \frac{(\epsilon_{\text{reff}} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{\text{reff}} - 0.258) \left(\frac{W}{h} + 0.8 \right)}$$

Hence the length of the patch is:

$$L = L_{\text{eff}} - 2\Delta L \quad \text{eq. (4.3)}$$

Step 4: Calculation of Substrate dimension:

For this design this substrate dimension would be

$$L_s = L + 2 \cdot 6h$$

$$W_s = W + 2 \cdot 6h \quad \text{eq. (4.4)}$$

Step 5: Calculation of feed point:

For this feed would be given by

$$L/4 \quad \text{eq. (4.5)}$$

V. SOFTWARE REQUIREMENTS

A. ANSYS HFSS v11 for Antenna Simulation:

It was originally developed by Professor Zoltan Cendes and his students at Carnegie Mellon University. Prof. Cendes and his brother Nicholas Cendes founded Ansoft and sold HFSS stand-alone under a 1989 marketing relationship with Hewlett-Packard, and bundled into Ansoft products.

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ANSYS® HFSS™ excels at a wide variety of high frequency, full-wave, electromagnetic applications including antenna design and placement since it uses multiple advanced solver techniques to simulate not just the antenna but also the effects of its interaction with the entire system, including the feeding system as well as the platform. A key feature of HFSS is automatic adaptive mesh refinement which generates an accurate solution based on the physics or electromagnetics of the design. Principles of open source development.

VI. RESULT ANALYSIS

A. Measured return Loss:

The bandwidth and gain of the antenna for the designed modified Psi shaped antenna has been analyzed. Below comparison table shows that the bandwidth of an antenna has been increased for the proposed antenna comparable to gain.

From the return loss performance we can see that the antenna operating bandwidth extends from 75 to 135 MHz.

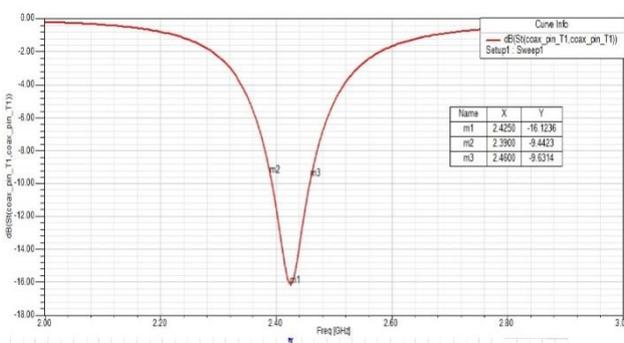


Fig 6.1:Return loss of Rectangular MSA

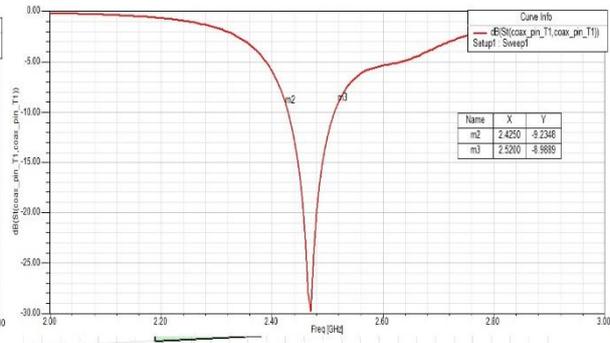


Fig 6.2: Return loss of E shaped MSA

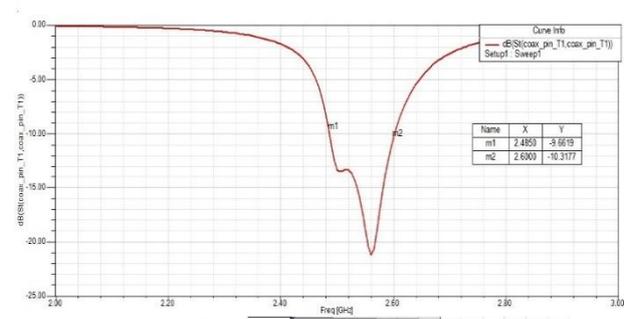


Fig 6.3:Return loss of Psi shaped MSA

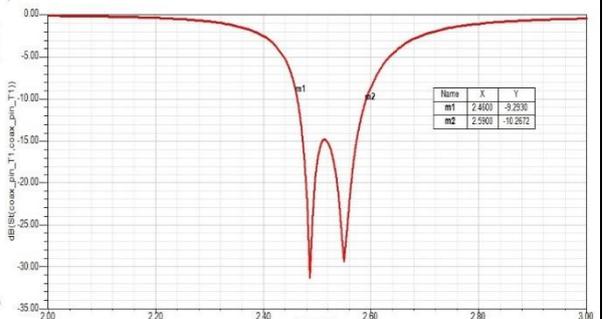


Fig 6.4: Return loss of modified shaped MSA

B. Measured Antenna Gain:

The gain of the designed proposed antennas measured with HFSS are shown in fig. 6.5-6.8 Maximum measured gain of receiving antenna obtained is 4.00 db. at the proposed structure.

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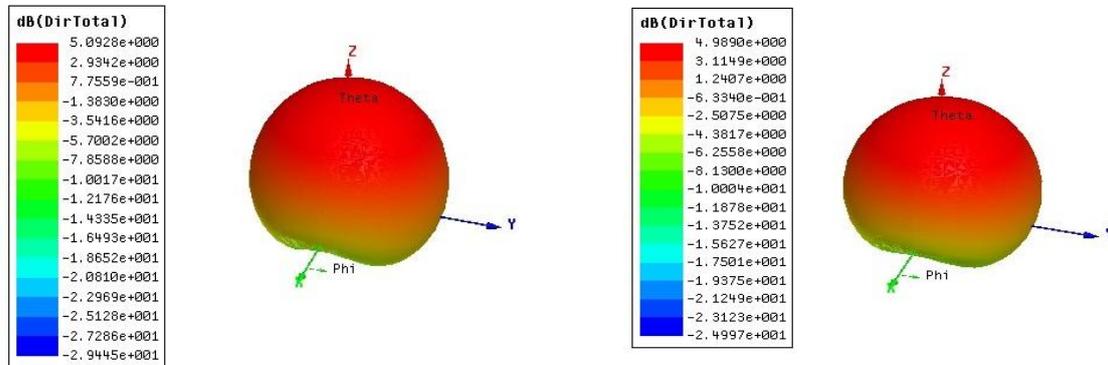


Fig 6.5: Gain of Rectangular MSA Fig 6.6: Gain of E shaped MSA

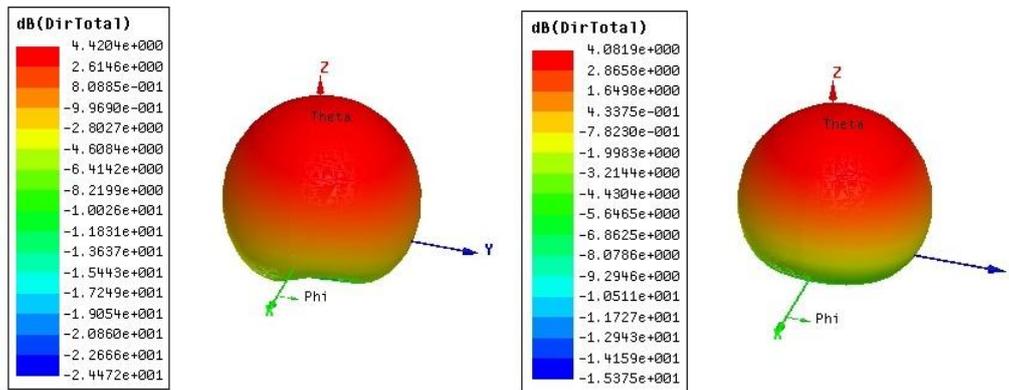


Fig 6.7: Gain of Psi shaped MSA Fig 6.8: Gain of Modified Psi shaped MSA

C. Comparisons of different shapes in MSA:

Table 6.1 gives the comparison between the different shapes of antenna. The double Ψ -shaped patch yielded 135 MHz bandwidth at a center frequency of 2.4 GHz with 4.0db gain.

Table 6.1 Comparison table for different shapes in MSA

Sr.No	Shape of Antenna	Frequency (GHZ)	VSWR	Bandwidth (MHZ)	Directivity (dB)
1.	Rectangular MSA	2.39-2.46	1.38	70	5.0
2.	E shape MSA	2.42-2.51	1.07	90	4.9
3.	Psi shape MSA	2.48-2.60	1.20	120	4.5
4.	Modified psi MSA	2.46-2.59	1.05	135	4.0

VII. CONCLUSION AND FUTURE WORK

The broadband response of the reported Ψ -shaped microstrip antenna was studied. The Ψ -shaped microstrip antenna was realized by cutting an additional pair of double slots on the other radiating edges of the E-shaped microstrip antenna. The bandwidth-curve plots and surface-current distributions for the equivalent rectangular microstrip antenna, the E-shaped microstrip antenna, and the Ψ -shaped microstrip antenna were studied. The Ψ -



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shaped micro strip antenna in the 2.4GHz frequency band were proposed. They yielded simulated bandwidths of more than 130 MHz with a broadside radiation pattern and a maximum gain very close to 4.0 db.

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