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Investigation on Heptagonal Structure Microstrip Antenna for operation in the X-Band Communication Applications

Jasmeet Singh
Assistant Professor, Guru Kashi University Talwandi Sabo, Bathinda

***Abstract* - In this paper heptagon shape planar microstrip slot antenna is presented. Heptagonal antenna can find applications in wireless & mobile communications in the X band for radar & space –craft utilizations. The antenna is fed by a 50 Ω microstrip line and printed on a dielectric Fr4 substrate of dimension (15mm X 15 mm) permittivity εr =4.4 and height h = 1.6 mm. The optimization on the planar heptagonal microstrip has been done to accomplish an ultra-wide 10 dB return loss bandwidth. Moreover, in comparison with a simple rectangular shaped antenna, the proposed design enhances the bandwidth and improves input return loss. Better than 94.26 % radiation efficiency has been achieved in the range 3.1 to 12 GHz. The parameters like substrate dimension, feed size and ground plane which affect the performance of the antenna in terms of its frequency domain and time domain characteristics are investigated.**

***Index terms:* Directional patterns, finite ground plane, microstrip line feed, microstrip slot antenna, omni-directional patterns, ultra wideband.**

I. INTRODUCTION

The frequency spectrum from 3.1 GHz to 10.6 GHz has been recognized as the ultra-wideband (UWB) by the federal communications commission (FCC) in the year 2002. MSA technology has progressed a lot and is still emerging in the field of wireless & mobile communication. It has created increased interest in the planar forms of the antennas can also be integrated between the radio frequency (RF) front end circuitry and the radiating structure. The simplest way to implementing planar forms of the MSA antenna is using the microstrip feeding technology, which is widely used in wireless applications.

Microstrip antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the bottom side of the substrate. However, many other shapes, such as the square, circular, triangular, semicircular, hexagonal, and annular ring shapes are also used. Microstrip antennas are popular because of its compact size, light weight, low cost, low profile, high efficiency and economical fabrication features [1], [2]. Out of the different forms the simplest form of the microstrip antennas is the microstrip slot antenna, which radiates omni-directional radiation patterns. Microstrip slot antennas fed by a microstrip line have shown wideband and ultra wideband performances [3][4].

The simulation results of antenna design were obtained by employing the Ansoft Corporation High Frequency Structure Simulator (HFSS) v11.0 tools, which are finite element method (FEM), based commercial full wave analysis programs [5].

II. ANTENNA GEOMETRY AND SIMULATION RESULTS

A. Antenna Geometry: Fig. 1 illustrates the evolution of the proposed Microstrip Antenna on the Fr4 substrate.

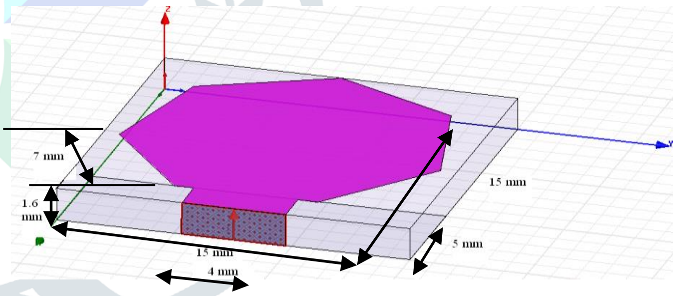


Fig. 1 The proposed Heptagonal Microstrip antenna (a) Simulation Model

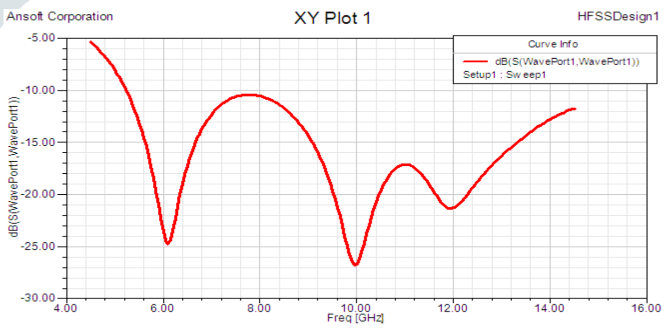
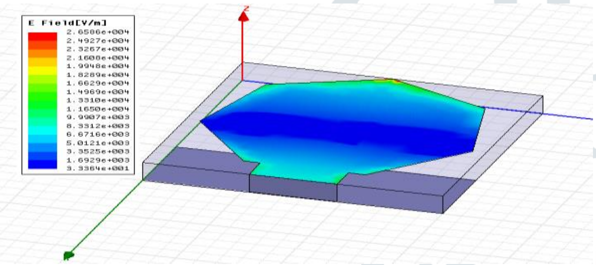


Fig.2.The reflection coefficient (S11, dB) versus frequency (GHz) plot

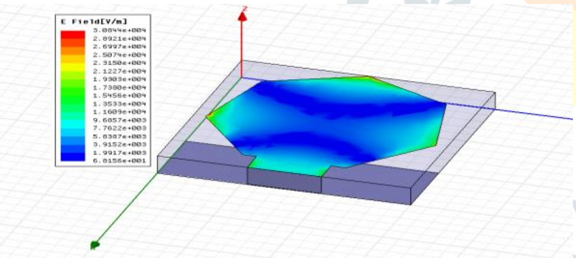
From the simulations & measurements of the microstrip antenna the optimized dimension are 15 mm x 15 mm (l x b) and thickness of 1.6mm. The offset feeding strip is generally 1.6 mm thick. Fig.1 (a) shows the microstrip antenna with heptagonal structure and finite system ground plane. However, the Efficiency Vs Frequency characteristics of microstrip antenna vary for the different frequency of simulation. In order to further reduce the overall size of the microstrip antenna structure a rectangular slot can be cut at the Heptagonal radiator. As an example the microstrip antenna fabricated on a Fr4, εr=4.4 & 1.6 mm in thickness. The position of feed point to the antenna structure can be varied to vary the result. The microstrip antenna substrate is enclosed in a radiation box. The radiation box of the antenna is generally larger in dimension (lxb) and it is approximate four times larger in height. The antenna structures are then assigned with the analysis set-up which encloses solution frequency, start & stop frequency of simulations, step size, Max. no. of passes etc..It should be noted that in the simulation process the microstrip antenna design structure was feed by a microstrip feeding with a 50 ohm internal resistance which is provided without any RF feeding cables. The ground plane size selection is also based on the study presented in [6], [7] on the microstrip slot antennas.

III. ELECTRIC FIELD DISTRIBUTION AT DIFFERENT FREQUENCIES: The electric field distributions of the Heptagonal microstrip antenna at the different frequency of simulation (5 GHz, 10 GHz & 15 GHz) are demonstrated as below:

At 5 GHz



At 10 GHz



At 15 GHz

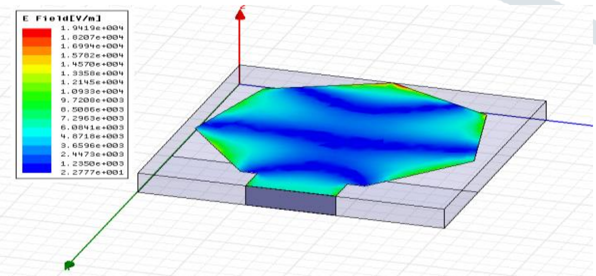
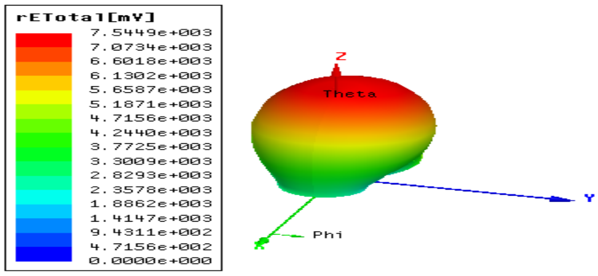


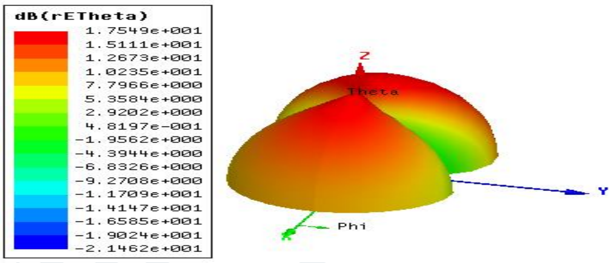
Fig. 3illustrates the simulated current distributions on the antenna at (a) 5GHz (b) 10 GHz (c) 15GHz

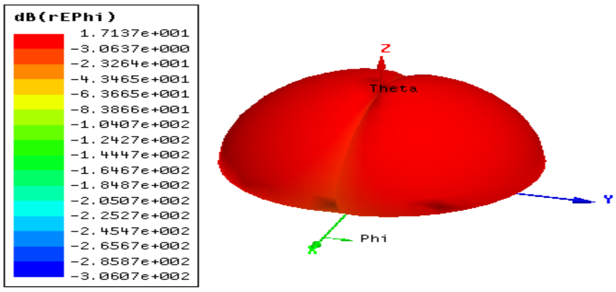
At 5 GHz, it can be observed that the majority of the electric currents is concentrated except around the central portion of the radiator Therefore, the effects of the RF cable and ground plane on the antenna performance at the lower frequencies can be minimized effectively [8]. At higher frequencies, most of the electric currents are distributed on the feeding strip, the junction of the heptagonal radiator, and the top strip. As a result, the currents on the ground plane are stronger than those at 5 GHz. At 15 GHz the field distribution are stronger as compared to 5 GHz. Feed size of antenna operates as a impedance matching circuit. Consequently, the feed gap greatly affects the impedance matching.

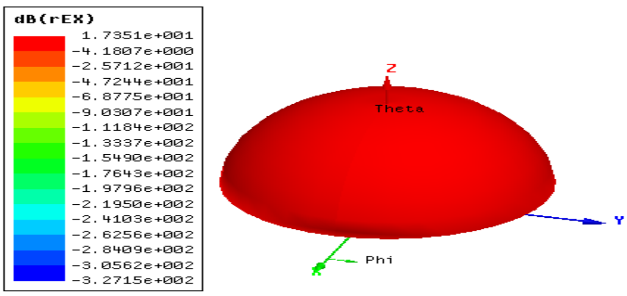
IV. Radiation Pattern of Heptagonal MSA

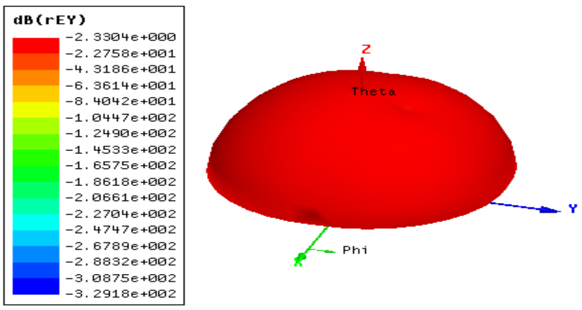
At 7 GHz

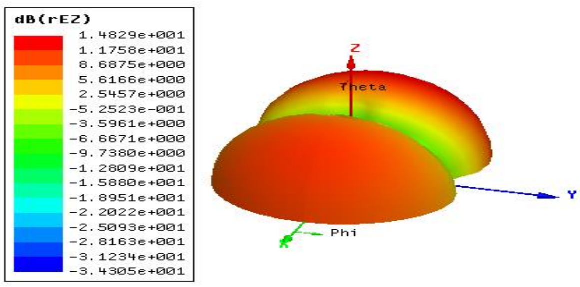












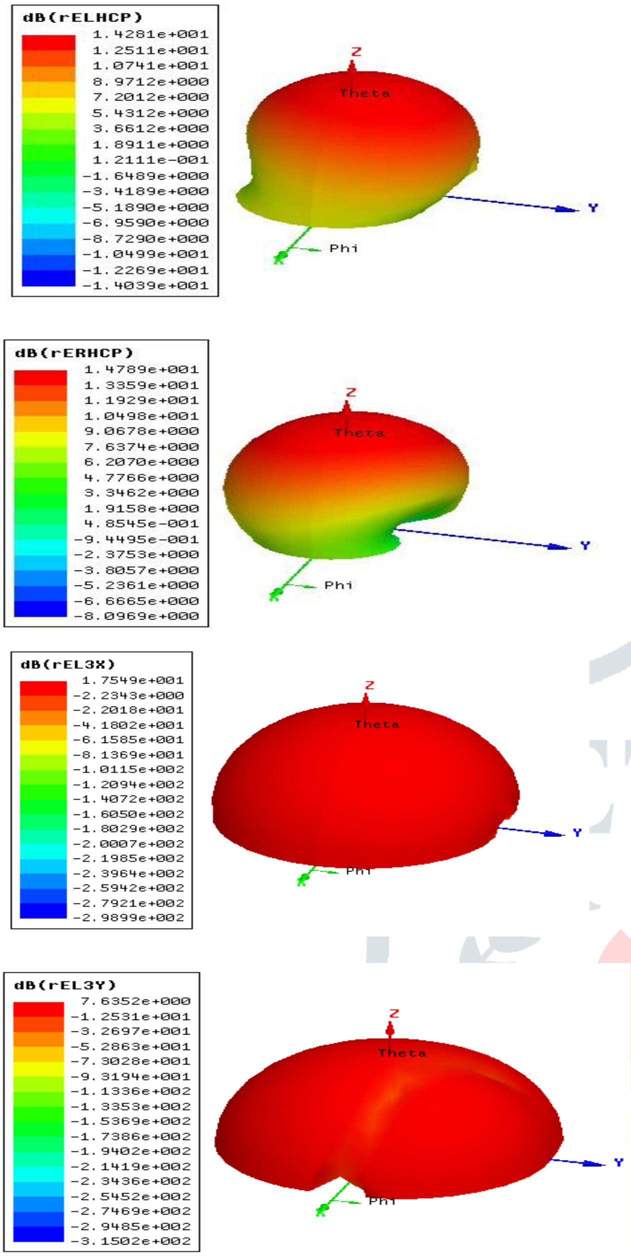


Fig.4 illustrates the effect of the different radiation pattern of Microstrip antenna

This design of a compact size heptagonal microstrip antenna suitable to be specially utilized its performance for radar where VSWR is defined in terms of the input reflection coefficient Γ as:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

The Γ is a measure of reflected signal at the feed-point of the antenna. It is defined in terms of input impedance *Zin* of the antenna and the characteristic impedance *Z*0 of the feed line as given below:

$$\Gamma = \frac{Zin - Zo}{Zin + Zo}$$

The BW is usually specified as frequency range over which VSWR is less than 2 (which corresponds to a return loss of 9.5 dB or 11% reflected power).

V. FREQUENCY Vs EFFICIENCY GRAPH:

From the below graph of Frequency Vs Efficiency it has been observed that the max. efficiency of antenna i.e (94.26 %) obtained at 12 GHz.

communication applications where a three-dimensional (3-D) omni-directional radiation and high radiation efficiency are desirable. The 3-D radiation patterns for total radiated electric fields were measured at frequencies of 7 GHz ,where the red colour indicates the stronger radiated E-fields and the blue colour the weaker ones. It is seen from the figure that the radiation at 7 GHz is almost 3-D omni-directional, because the x and y–components of the electric currents on the antenna are both strong as shown in Fig. 4(a). The radiation pattern of antenna is slightly weak along the –y and –x axis directions. With the measured 3-D radiation patterns, the radiation efficiency can be attained. The measured radiation efficiency varies from 18.98 % at 3 GHz to 94.26% at 12GHz.

The directivity of the microstrip antenna can also be calculated with the following mathematical relationship:

$$D = 2.2W+6.6+10 \log \left(\frac{1.6}{\sqrt{\epsilon_r}}\right)$$

The gain of the antenna structure can be calculated as the mathematical derivation:

$$Gain = 4\Pi \left(\frac{U}{P_{acc}}\right)$$

U: Radiation intensity in W

P_{acc}: Accepted Power in w

Furthermore the efficiency of the antenna structure in its symmetrical form can be estimated. The efficiency of the microstrip antenna can be expressed in terms of the peak directivity & peak realized gain of the antenna.

$$Efficiency = \frac{Peak\ Realizzed\ Gain}{Peak\ Directivity} * 100$$

The VSWR or impedance BW of the microstrip antenna is defined as the frequency range over which it is matched with that of the feed line within specified limits. The BW of the microstrip antenna is inversely proportional to its quality factor *Q* and is given by

$$BW = \frac{VSWR-1}{Q\sqrt{VSWR}}$$

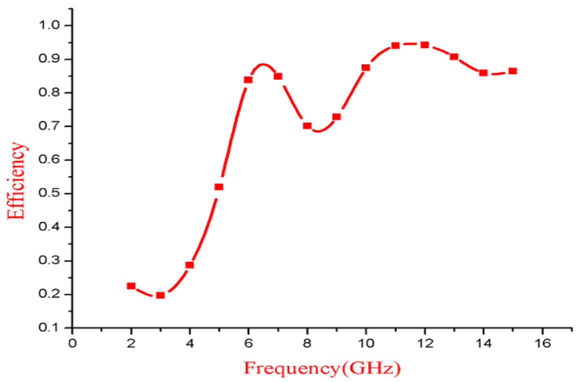


Fig. 5 The frequency (GHz) versus efficiency plot for the Microstrip antenna design

VI. Frequency Vs Peak Realized Gain Graph:

From the below Graph of Frequency Vs Gain it has been observed that the max. gain of microstrip antenna i.e. 4.65

obtained at 14 GHz.

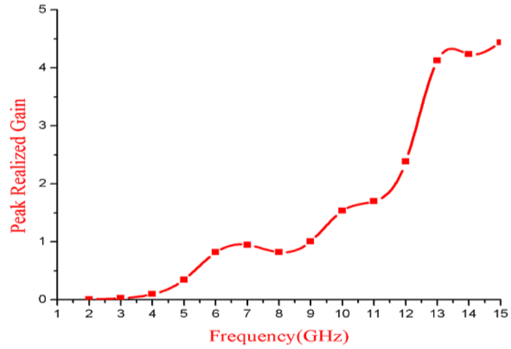


Fig.6 The frequency (GHz) versus Gain plot for the Microstrip antenna design

VII. Effect of Parameter variation on Antenna Performance*:*

A Effect of Substrate Material Roer4003 on S Parameter

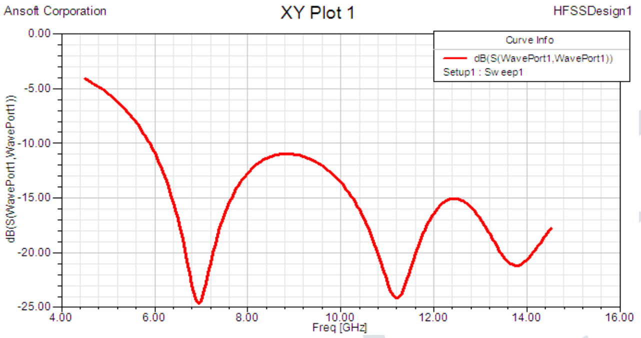


Fig.7.The reflection coefficient (S11, dB) versus frequency (GHz) plot with FR4 as a substrate material for the Microstrip antenna design

B Effect of Substrate Material (FR4) on Efficiency & Peak Realized Gain*:*

In this design of antenna we are taking two substrates to calculate their effect on efficiency , realized gain & calculation of S11 parameter. With the use of FR4 as

C. Effect of Ground Size on performance: In this design variation of ground size has a little effect on the efficiency. The S parameter value of first lobe is -51 with ground size of 5mm whereas it increases to -54 with a ground of 9 mm**.**

At5mm

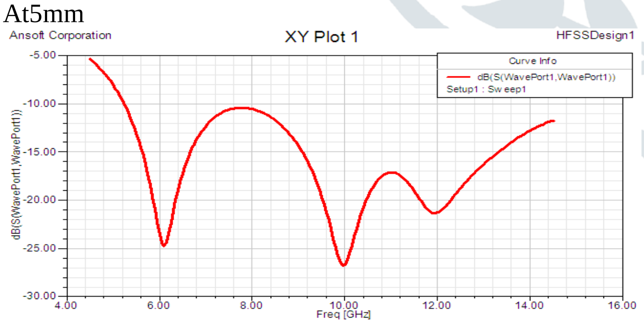
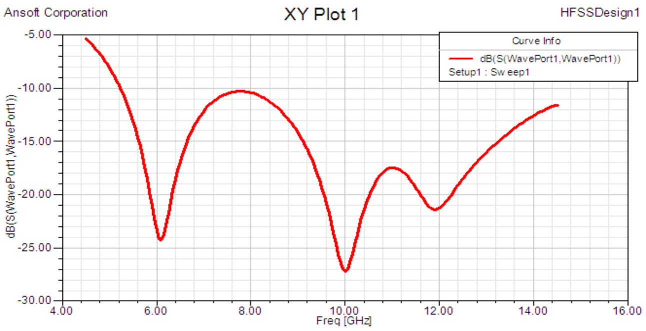


Fig.10.The reflection coefficient (S11, dB) versus frequency (GHz) plot with Ground size of 5 mm



substrate the max. efficiency of antenna 94.26 % has been obtained whereas the use of Roger4003 as a substrate there is a reduction in efficiency i.e 87.49% .With Roger as a substrate there are also reduction in lobe size in the calculation of S11 parameter. With the use of Fr4 the max. peak realized gain of 4.65 has been obtained whereas the use of Roger4003 as a substrate reduces the max. peak realized gain to 3.4.

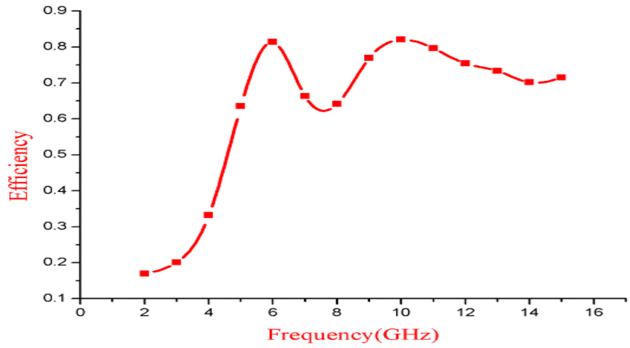


Fig.8The frequency (GHz) versus efficiency plot with FR4 as a substrate for the Microstrip antenna design

At 9 mm

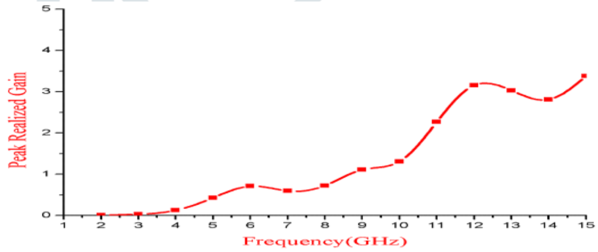


Fig.9 The frequency (GHz) versus Gain plot with Roger4003 as a substrate

Fig.11.The reflection coefficient (S11, dB) versus frequency (GHz) plot with Ground size of 9mm

VIII. CONCLUSION

In this paper, a planar ultra wideband (UWB) heptagonal shape microstrip slot antenna is investigated for the impedance matching and radiation pattern characteristics. The antenna can find applications in portable wireless communication devices. However, the antenna design almost met the UWB frequency range requirements and provides the omni-directional patterns. From the heptagonal microstrip antenna design it has been observed that the max. omni-directional pattern is obtained at the central solution frequency (7 GHz) of simulation. Investigations have also been carried out in this paper to analyze the design parameters of heptagonal Microstrip Antenna. With the use of heptagonal as a radiating element in UWB antenna efficiency up-to 94.26% has been achieved. Heptagonal Microstrip UWB antenna can also provide directivity up-to 4 & impedance bandwidth > 110% as the requirement of UWB technology [9]. The feed size of antenna is inversely proportional to the port impedance. The dimension of the microstrip antenna also has an impact on the antenna performance because the current is mainly distributed along the edge on the radiator. In a broad sense, the ground plane of the antenna design perform operation as an impedance matching circuit, and it tunes the input impedance and hence changes the operating bandwidth with variation of antenna feed size..Heptagonal microstrip antenna provide UWB characteristics with nearly omnidirectional radiation patterns over the entire bandwidth.

IX. ACKNOWLEDGMENT

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