Design of Patch Antenna for Military Applications

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ABSTRACT

A patch antenna that is best suited for military applications is designed. This patch is made of thin PEC printed on a FR4 substrate having a dielectric constant of 3.6.The patch is impregnated on the substrate and is fed by coaxial coupling through inner conductor(PEC). The rectangular structure of microstrip patch antenna provides better bandwidth and gain. By choosing a suitable offset feed position, a characteristic impedance of 50 Ω is obtained that improves the impedance matching. The main advantage of this feed is reduced return loss by impedance matching. Owing to the fact with high gain, small size, low profile it can be applied for missile systems in military applications. The software used in this design and simulation is CST Microwave Studio.

Keywords - **Patch antenna, Perfect Electrical Conductor(PEC), FR4 substrate, return loss, military applications.**

I. INTRODUCTION

The main component which is used for communication between wireless systems is antenna. The unique advantages of microstrip antennas are conformal,low cost and compactness features and so they are widely used in all fields. The main reason for the implementation of microstrip patch antennas is that they are easy and compact to fabricate.Efficient compactness in missile system will include innovative designs, high integration and active radiating elements. Compact electronic circuit design is efficient on low dielectric constant substrates and PCB, whereas the optimum patch antennas are built on low permittivity substrate for efficiency. The antenna characteristics like radiation pattern, gain and return loss should be stable within this operating range. At the same time it should be of small size, conformal, low cost and should be easily integrated into the RF circuits. Since, the microstrip patch antenna requires materials with low cost, easy to manufacture and light weight. These characteristics make microstrip patch antennas ideal for use in military applications. microstrip patch antenna consists of a dielectric substrate, with a ground plane on the other side. The substrate that is used here is FR4 material to achieve maximum return loss, good impedance matching and high gain. The size of the microstrip patch antenna is inversely proportional to its frequency.For this reason, microstrip patch antennas are generally used for ultra-high frequency signals. Microstrip patch antenna is capable of sensing frequencies lower than microwave would be too large to use.

II. DESIGN TOOL

CST studio suite is a software package for designing,simulating, and optimising systems and networks. It is used in leading technologiesand companies around the world.The simulation of antenna design using a software in all frequency bands which has high performance can be achieved using CST, and it also supports third-party products. One of the competencies of CST software is the simulation of high frequency electromagnetic fields, ranging from RF up to optical frequencies. CST MWS enables the fast and accurate analysis of high frequency (HF) devices such as antennas, filters, couplers, planar and multi-layer structures and SI and EMC effects.CST includes tools for a very wide range of microwave, RF and optical applications. Antennas are designed and optimized and it can also be a part as installed in a device and on a larger structure such as a building, aircraft, ship, or satellite. Planar and waveguide RF components are optimized individually as part of a larger system and increasingly the gigahertz, optical and photonic devices. CST tool helps to design both treatment devicesand cutting-edge imaging, and in the analysis of tissue heating exposure and specific absorption rate (SAR) in the biomedical field. This Technology provides engineers,a powerful toolset for studying antenna and its performance. CST offers a broad range of technologies, which operates in both the time and frequency domain. It is also capable of using surface meshes and Cartesian,tetrahedral volume meshes.

III. DESIGN OF PROPOSED ANTENNA

Due to its light weight, low profile, and ease to fabricationmicrostrip patch antennas are widely used in various fields. To improve the impedance, bandwidth there are different feeding techniques that can be applied and using those techniques losses can be also reduced. Better efficiency is achieved by using FR4 substrate.Choosing the right substrate is another way to get better results and also the size of antenna can be reduced.The reason behind using the FR4 epoxy material is that, it has minimum ε which is inversely proportional to the electric field.

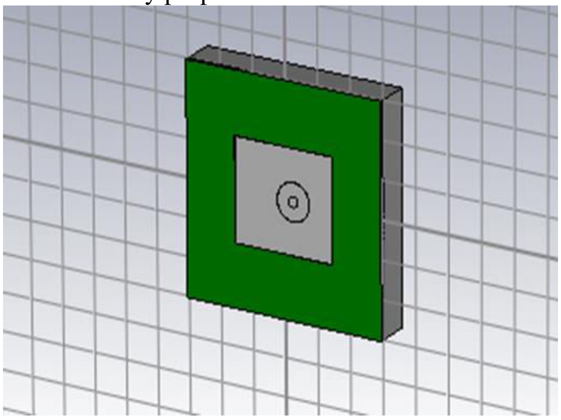


Fig.1 Perspective view of rectangular patch

The simulation and theoretical calculation is also done and it is being compared with simulation results.A rectangular patch is impregnated on the substrate having dielectric constant of 3.6 with dimensions 6x6x0.1 cm.

IV. CALCULATIONS USING FORMULAE

i. To find Width of the patch,

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

ii. To find effective dielectric constant,

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{\frac{-1}{2}}$$

iii. To calculate effective length of the patch,

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

V. DIMENSIONS

PARAMETER	VALUES
Frequency band used	ISM band
Operating frequency	2.4 GHz
Wavelength in free space/vaccum	125 mm
Dimension of Rectangular patch	3x2.7x0.01 cm
Substrate dielectric material	FR-4 epoxy
Substrate dielectric constant	3.6
Substrate thickness	0.1 cm
Feeding technique	Coaxial feeding
Feed point location from center	(0.3,0)
Ground plane	6x6x1 cm

The thickness of ground tried to be kept at certain limit so that we can achieve a perfect dip at the minimum return loss as shown in Fig.2. Eventhough, the gain is high the reflection coefficient determines the accuracy of the signal. Both the reflection coefficient and signal accuracy are inversely proportional.

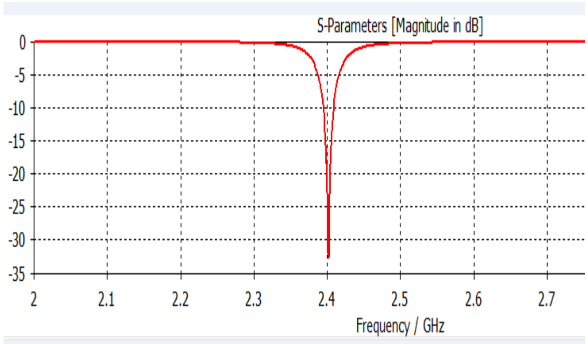


Fig.2 A sharp dip in the S-parameter graph

It achieved 3.3% bandwidth and 4.016 dB gain in Fig.3. The unidirectional radiation which is shown was achieved in the ISM band frequency of 2.4 GHz in Fig.6 and Fig.7. Microstrip patch antenna is used at 2.4 GHz as resonance is achieved at this point. Coaxial feeding technique is used in the design because of its feature that it is easy to obtain input matching by adjusting feed position. Input impedance matching plays an important role in achieving required reflection coefficient as shown in Fig.2, if it doesn't then efficiency will be lower but a good efficiency is obtained and shown in Fig.3.

VI. RADIATION PATTERN IN 3D PLOT

Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=2.4) [1]
Component	Abs
Output	Gain
Frequency	2.4 GHz
Rad. effic.	0.9873
Tot. effic.	0.9820
Gain	4.016

Fig.3 Parameters analysed in 3D Plot

Since, this application requires high gain and considerable directivity to cover wide area so that the missile is being accessed through antenna by the . The antenna will be faced towards the transmitter side to deliver and receivedesired information. High gain is achieved in far field radiation in Fig.5.

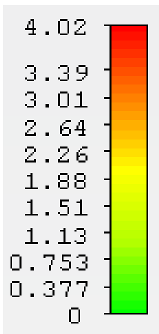


Fig.4 Gain level[dB] in the radiation pattern

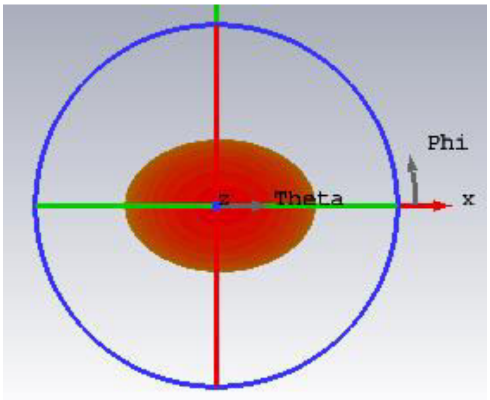


Fig.5 Front view of radiation pattern

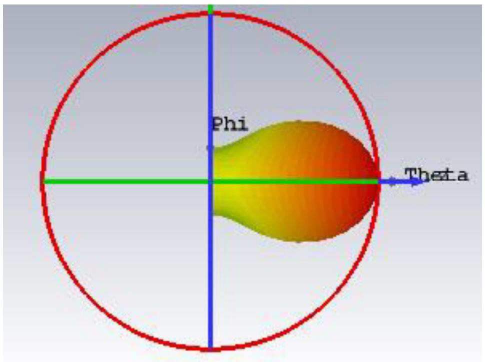
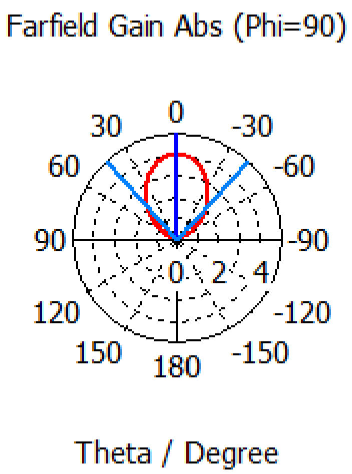


Fig.6 Side view of radiation pattern

A coaxial feed is given to antenna through inner conductor by making hole in substrate and ground of PEC type material.The inner conductor plays a major role by confining the signals between patch and coaxial cable. The proposed antenna is placed in the Missile system.Antenna boresight is the axis of maximum gain (maximum radiated power) of a directionalantenna. The boresight gain is obtained in 0 degree axis where the missile guider is located at the other end of the radiation pattern in Fig.7.The missile guider will send the latitude and longitude information about the Target position. Now antenna receives the information and sets the count down time for the launch. Then, the destruction is made at the required target.

VII. Radiation Pattern In Polar Plot



The resonance frequency is 2.4 GHz and the gain obtained in that is around 4 dB. The Half Power Beam Width(HPBW) of the pattern is 85 degrees.

Frequency = 2.4 GHz
Main lobe magnitude = 4.02
Main lobe direction = 0.0 deg.
Angular width (3 dB) = 85.0 deg.

Fig.7 Radiation Pattern and Parameters analysed in polar plot

VIII. Conclusion

Microstrip patch antenna with FR4 as a substrate material capable of operating frequency up to 2.4 GHz has been proposed. The gain and directivity of the proposed antenna are 4.2 dB and 4.1 dB. The overall reference impedance and VSWR are nearly 50 Ω and 1. The minimal return loss of the simulated antenna is observed to be -33 dB at corresponding resonant frequency of 2.4 GHz. The substrate variation of the proposed antenna results in minimum return loss and reduced impedance bandwidth, which helps for effective performance in Military applications.

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