A Novel Compact Monopole Antenna for C band/Wi-Fi/IEEE 802.16 Systems

Rashmi Sharma, Kirti Vyas

Abstract— A novel compact rectangular monopole antenna with four rectangular slots in radiating patch is proposed for wireless fidelity (Wi-Fi) applications and in IEEE 802.16 systems. The proposed antenna has simple and compact structure, and the prototype of the proposed antenna has been fabricated and measured. The designed antenna, fed by a 50Ω microstrip transmission line, is only 10mm in length and 3.2mm in width. The dual band antenna has operating bands with 10-dB return –loss bandwidth of about (46%) 3.1 GHz centered at 6.639 GHz and (24%) 2.9GHz centered at 12.02 GHz. Also, good radiation performance and antenna gain over the two frequency ranges have been obtained.

Index Terms— C-Band, Microstrip patch, resonating Frequency, satellite communication.

I. INTRODUCTION

C-band is a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 4.0 to 8.0 GHz, which is followed by radar manufacturers and users. The C-band and its slight variations contains frequency ranges that are used for many satellite communication transmissions, some Wi-Fi devices, cordless telephones, and weather radar systems[6]. For satellite communications, the microwave frequencies of the C-band perform better under adverse weather conditions in comparison with Ku band (11.2 GHz to 14.5 GHz) microwave frequencies, which are used by another large set of communication satellites. Microstrip patch antennas are widely used in C band because they are of light weight, compact, easy to integrate and cost effective [3][9-13]. However, the serious problem of patch antennas is their narrow bandwidth due to surface wave losses and large size of patch for better performance. As a result various techniques to enhance the bandwidth are proposed[2] . Techniques to reduce size include different structural techniques, shorting techniques, where a microstrip line or patch is shorted with the ground plane of the antenna. Different loading techniques can be used; such as using external lumped components to reduce the size of the antenna which result in reduced overall performance and gain, while increasing the cost of the antenna [4]. Keeping in view of inserting slots in patch antenna , a low profile microstrip line fed Rectangular patch antenna with rectangular slots at the four corners and ground has also square shape slots is proposed. Various antennas for c-band have been proposed [7-8] keeping in view of WLAN applications. The characteristics of proposed antenna parameters such as return loss , VSWR, gain along θ, Ø directions, radiation pattern in 2D & 3D, E & H field distributions, current distributions are simulated using HFSS 13.0 which is a high-performance full-wave electromagnetic(EM) field simulator for arbitrary 3D volumetric passive device modelling that takes advantage of the familiar Microsoft Windows graphical user interface.

Manuscript Received on November, 2012.

Rashmi sharma, Department of Electronics & Communication Engineering, Arya College of Engineerin & IT, Kukas, Jaipur, Rajasthan, India.

Kirti Vyas, Department of Electronics & Communication Engineering, M.tech Coordinator,Associate Professor Arya College of Engineerin & IT, Kukas, Jaipur, Rajasthan, India.

A. Microstrip Patch Antenna

A microstrip patch antenna consists of a conducting metallic patch on one side of the substrate and a conducting ground plane on the other side. Due to their simple structure they are highly preferred in modern communication systems. Despite of their dimensions and shapes, the characteristics of all of the microstrip antennas are almost same because all the microstrip antennas behave like the dipoles. Typically these antennas have gain between 5 dB to 6 dB.

II. ANTENNA CONFIGURATION

A. Design Components of Printed Monopole Antenna

The construction of any antenna requires number of individual components which are used to build the antenna. Typically, the microstrip patch antennas may require relatively large number of components for its composition. Because there are many challenges related to the patch antennas regarding their size compaction, simple structure, and ease of fabrication and the insurance of sufficient bandwidth to make it practical for the desired application. In this section the components used to design and built the antenna are discussed briefly.

➢ *Dielectric Material and its Characteristics*

The first step in designing an antenna is to choose an appropriate substrate. The substrate in microstrip antennas is principally needed for the mechanical support of the antenna metallization. To provide this support, the substrate needs to consist of dielectric material which drastically affects the electrical characteristics of the antenna and transmission line. Substrate choice and evaluation are essential parts of the design procedure. Many substrate properties need to be considered. The dielectric constant, loss tangent and their variation with temperature and frequency, homogeneity, isotropicity, thermal coefficient and temperature range, dimensional stability with processing and temperature and thickness uniformity of the substrate are all of importance. Similarly, other physical properties such as resistance to chemicals, impact resistance, strain relief, formability, bond ability and substrate characteristics when clad are important in fabrication. Traditional microstrip antennas at microwave frequencies use substrates such as PTFE, quartz and honeycomb for good radiation efficiency. These offer excellent electrical performance but the resulting substrate costs are often too high for commercial civilian applications such as data transmission direct broadcasting satellite reception and so on.

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Antenna efficiency can be increased by loading high dielectric material surrounding it. Antenna's dimension can be reduced by high permittivity material. Generally the shape and the permittivity of the dielectric affect the size reduction. However, the main drawbacks of high permittivity dielectric are the higher dielectric losses in practice and are commonly considered in the antenna construction. In case of our proposed antenna, FR4 is used as substrate with dielectric constant 4.4. The price of built printed antenna is directly related to the substrate and connectors costs. FR4 is a widely used material for planar mobile antenna and digital circuit boards nowadays. Its low cost, easy availability and ease of fabrication are its strengths.

➢ *Effect of finite ground plane*

It is observed in the analysis and design of planar monopole antennas that the size of ground plane can be finite, infinite or partial .Finite ground plane is implemented for proposed antenna. Finite ground plane also gives rise to scattered radiation in the backward direction. It gives rise to diffraction of radiation from the edges of the ground plane resulting in changes in radiation pattern, radiation conductance. The ground plane effects on the resonant frequency of antenna. It is observed that the ground plane having size equal to the patch, gives the higher resonating frequency than the one with infinite size. It is also observed that the effect of finite plane is higher on E-plane than that on the H-plane. Since in our design we have focused more on the E-plane, therefore we have used the full ground plane having size equal to that of patch size.

Figure 1shows the structure and dimensions of the proposed antenna, which is fabricated on an inexpensive FR4 substrate with the dielectric constant of 4.4 and the substrate thickness of 1.6 mm. The antenna shape and its dimensions were first searched by using the Ansoft's High Frequency Structure Simulator (HFSS) and then the optimal dimensions were determined from experimental adjustment. The dimensions of the designed antenna, including the substrate, are 30mm×20 mm. A 50Ω microstrip feed line with 3.2mm width and 10 mm length, is used for feeding the antenna. The dimensions of rectangular patch are 14.75mm×14.5mm. Four slots are cut inside the rectangular patch. These slots in patch provide improved return loss. The partial ground has dimensions 30mm×4.6 mm. In ground there are fifteen slots (S1 to S15), all having dimensions of 1mm×1mm. Space between these slots is 2mm. The yellow part shows substrate, the blue part shows patch and the green part shows ground. Feed position is optimized to get the wide band width and higher the resonating frequency. Here the table is given it shows length and width of proposed antenna. Where L1 and L2 are height and width of the substrate, L3 and L4 height are width of the outer patch, L and L7 shows feed dimensions and G1, G2 represents dimensions of the ground. L5 and L6 shows length of these inner strips and w represent width of these strips.

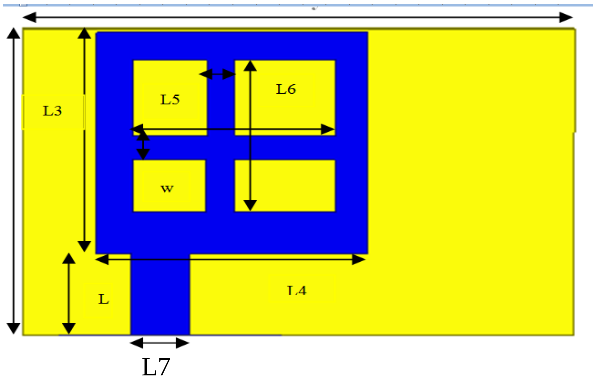

Fig1 (a): Front part of the proposed antenna

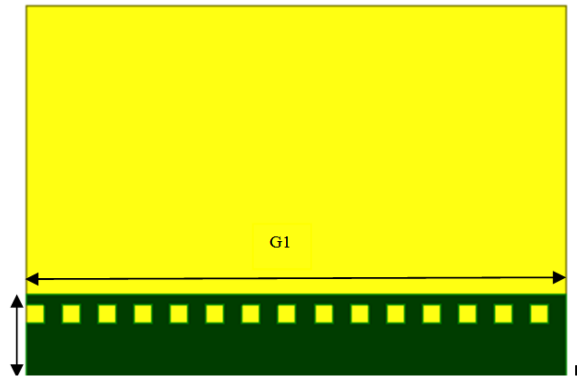

Fig1 (b): Ground (Back) part of the proposed antenna

The table below shows different dimensions for proposed antenna

Table1: Various parameters of proposed antenna

L	10mm	L4	14.75mm
L1	30mm	L5	11mm
L2	20mm	L6	10mm
L3	14.5mm	L7	3.2mm
G1	30mm	G2	4.6mm

FABRICATED ANTENNA GEOMETRY

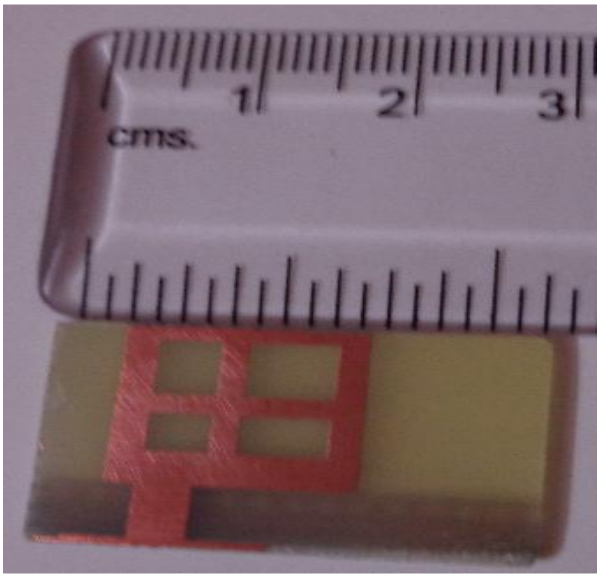

Fig: Front part of the proposed antenna

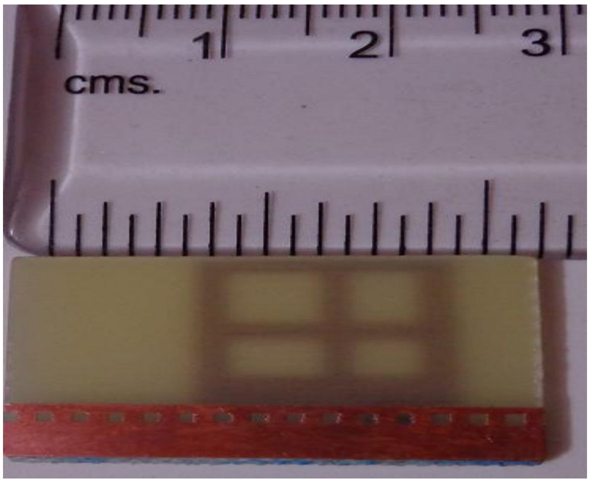

Fig: Grond(Back) part of the proposed antenna

III. SIMULATION RESULTS

A. Return Loss

It is a measure of the reflected energy from a transmitted signal. It is commonly expressed in positive dB's. The larger the value; the less energy that is reflected. The resonance of any Antenna depends on its design and structure. Resonant antennas radiate into radio signal for frequencies close to its desired frequency. An important parameter of the antenna design is the operating frequency or the resonant frequency. It provides the range of frequencies for which antenna operates. The proposed planar monopole antenna resonate at three different frequencies 6.639 GHz, 12.02 GHz and 20.59GHz which are the middle frequencies for the lower and the upper frequency bands within the available spectrum. The first band started from 5.65GHz to 8.712GHz. Second band started from 10.34GHz to 13.30GHz and the last third band is a wide band.

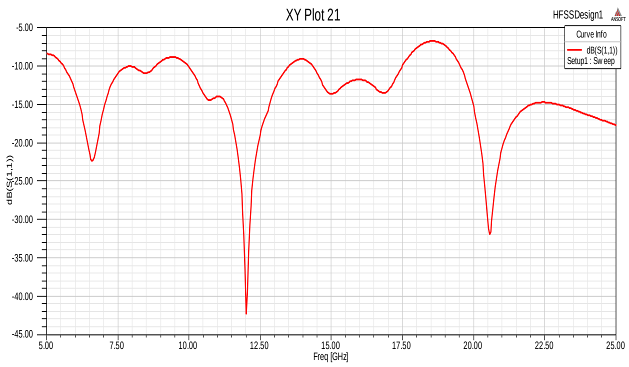

Fig2: Return loss obtained at solution frequency at 12.02GHz

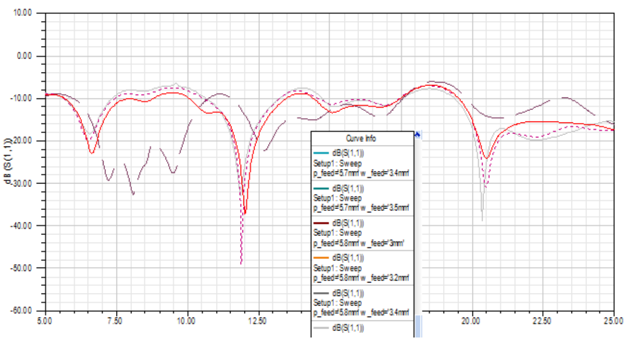

Fig3: Return loss(Parametric observation) at solution frequency at 12.02GHz

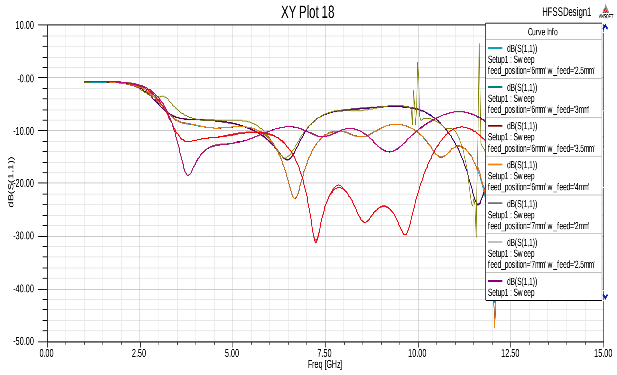

Fig4: Return loss(Parametric observation) at solution frequency at 8GHz

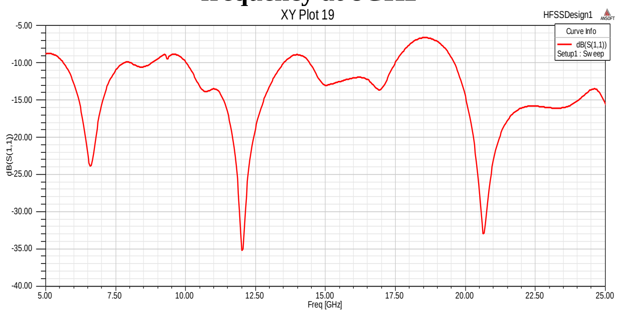

Fig5: Return loss obtained at solution frequency at 8GHz

B. Gain

The antenna gain is the ratio of intensity in a specified direction to the radiation intensity of an antenna isotropic ally radiating the power in all directions. Gain can be determined by following equation.

$$G = 4\pi U(\theta, \phi) / Pin$$

Where, G is the antenna gain and Pin is the total input power.

As described earlier that the C-Band communication systems work over two frequency bands, so the antenna used for satellite and wireless applications should have relatively higher than 3 dB for lower frequency and higher than 5 dB for the higher frequency band. The planar monopole antenna behaves very well over two prescribed frequency bands regarding expected gain for C-Band applications which will be shown in the simulation part. The gain of the proposed antenna is 6dB.

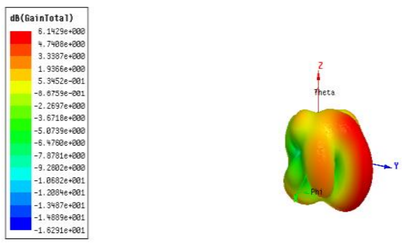

Fig6: Gain of the proposed antenna

C. VSWR:

The input impedance of antenna, Z in is defined as the real and reactive part as seen at the port of antenna.

$$Z\,in = Res + jXa$$

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Where, Res (resistance) shows the radiated power and jXa (reactance) shows the reflected power. As discussed earlier, the reflections of an antenna depend upon how goodly or badly it is matched to its load. Along with the chosen substrate, its thickness and the geometry of the design, the impedance also depends upon the effective feed and the skin depth to some extent. The basic parameter when working with radio frequencies or the microwave frequencies is to focus its impedance. Since all the rest of other parameters are interlinked with it. If, unfortunately there is a bad mismatch between source and load, the reflections will arouse and resulting in an accusation narrower bandwidth. In our case, the antenna is subjected to its use for 50 Ohm system, so the printed circuit on the board carries the optimized thicknesses and lengths of the strips and other slot lines. Likewise, the feed point of the microstrip feed-line greatly influences the matching of antenna. It is proven that the input should be given at the centre of the feed-line to the antenna.

In that graph we got the VSWR less than 2 at the frequency range 5.653GHz to 8.712GHz and 10.34GHz to 13.30GHz.

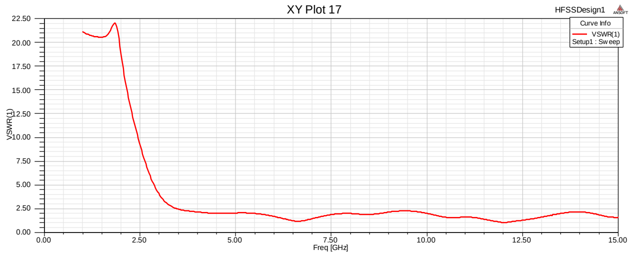

Fig7: VSWR of the proposed antenna

D. Smith chart:

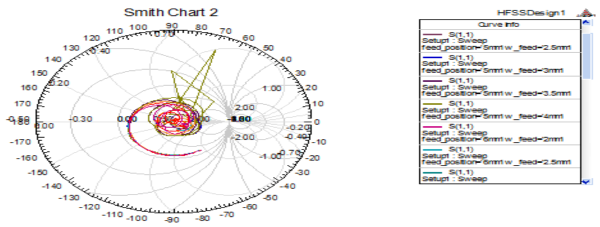

Fig8: smith chart of the proposed antenna

E. Radiation pattern:

1) Radiation pattern at ϕ=0 degree:

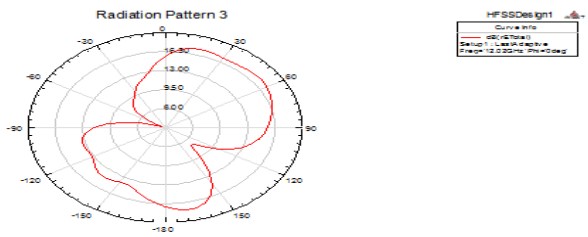

Fig9(a): Radiation pattern at ϕ=0 degree

2) Radiation pattern at ϕ=90 degrees:

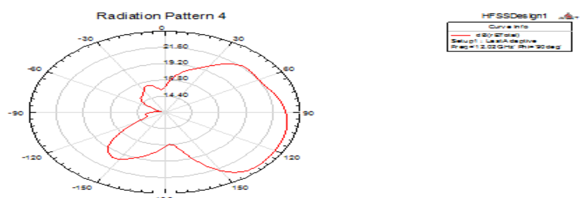

Fig9(b): Radiation pattern at ϕ=90 degrees

IV. CONCLUSION

A novel compact dual band antenna was presented. After various parametric studies and taking into account the possible trade-offs. The optimum design was obtained. The performance of the proposed antenna has been evaluated using different electromagnetic simulation software packages and the results obtained have been compared against measurements with very good agreement. Thus, the proposed antenna is a very attractive solution for small portable devices and for spatial diversity systems where compact antennas that can operate with a small ground plane are required. The antenna has small size with the maximum gain of 6dB.

ACKNOWLEDGEMENT

Author is thankful to Mrs. Kirti Vyas, Assistant Professor in Arya College of Engineering & IT, Kukas, Jaipur, Rajasthan, India, for her kind permission to submit the research paper in this journal.

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