JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Design of Compact Dual Band Microstrip Antennafor L band Applications

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***Abstract*—In this paper , design of a compact microstrip antenna which operates in dual band is presented. The proposed design for the miniaturization consists of hybrid techniques like Defected Ground Structure (DGS) and Shorting Post methods. DGS is applied by cutting slots in the form of circular shape on the Ground and for the additional reduction in size shorting post method is applied by drilling holes in order to short Patch and Ground through Substrate. By implementing these two methods into practice the antenna's electrical length increases along with the direction of current distribution. The finalized compact antenna is contrasted with a conventional antenna that was created without using size reduction techniques. The finalized antenna is 58.7% smaller than the typical antenna. The simulation process has been done using Computer Simulation Technology Studio Software. The characteristics of antenna such as Return Loss, VSWR, Gain, Co-polarization and Cross-polarization plots are determined for both 0.9 GHz and 1.8 GHz frequencies.**

***Index Terms*—Microstrip antenna, Defected Ground Structure(DGS), Shorting Post.**

I. Introduction

In these days, wireless sensing is increasing from day to day in the identification and tracking of various objects. Antenna plays important role in these wireless sensing . The best option for these wireless communication is microstrip patch antenna due to its lightweight, small size, easy to build and integrate.[1]

The wireless sensing consists of a transmitter, receiver and a sensor. The forward transmission of information from transmitter to sensor and the backward transmission of information from sensor to receiver occurs at same or at different frequency bands respectively. Different configurations like triangle,elliptical,angular ring,pentagon,circular,rectangular etc [2-7].In this proposed design rectangular configuration is used.

The proposed dual band microstrip antenna operates at two different frequencies, it receives the signal at f_0 frequency and it converts that f_0 input signal into an output harmonic response signal with nf_0 frequency , where n is an interger. In this paper the proposed antenna operates at second harmonic frequency $2f_0$ because at this frequency trans conversion effeciency is more[8,9]. In this paper the designed dual band microstrip antenna consists of two antennas and a schottky diode. In the two antennas one antenna acts as a transmitter which operates at 0.9 GHz and another antenna acts a receiver at 1.8 GHz frequency. These two antennas are connected used in this design due to its fast switching time and low through a non-linear element Schottky diode this diode 0.9 GHz input signal into 1.8GHz output signal. This diode is forward voltage.

In order to make compact antenna two size reduction techniques 1.Defected Ground Structure and 2.Shorting Post methods are used. In order to give feeding to the antenna there are different types of feeding methods are there like Microstrip line feed,coaxial probe feed,inset feed, aperture coupled and proximity coupled. Inset feeding is used in this design because it provides good impedance matching.[10]

This compact antenna is used for rescuing coal mine workers. The designed antenna which is of a credit card size so it can be placed inside the pocket of coal mine worker. It is designed using two microstrip antennas which are resonating at two different frequencies. If any accident occurs by using radar range equation the distance at which the worker buried can be found . So , the main motivation behind this design is to rescue people buried in coal mines and avalanche by designing a

- low profile
- small size
- low cost

dual band microstrip antenna using antenna size reduction methods .

The structure of this work is as follows; part II presents the design of antenna. Part III covered the size reduction techniques. The analysis and findings were covered in part IV. Part V touched on the conclusion.

II. Antenna Design

The proposed antenna is designed with substrate material FR-4 (ε_r = 4.3) with 1.6 mm thickness. Ground and patch are made up of copper (lossy) metal. Patch and ground have infinitesimally small thickness. This antenna is fed using microstrip inset feed line.

A. Mathematical Designing

In order to design any antenna first it is needed to find out the dimensions like length,width.These dimensions of the suggested antennas are designed using the formulae below[11].

- Width of Patch (W):

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

where
c = Speed of light in vacuum
f_r is resonant frequency

- Substrate height (h) :

$$W/h > 1 \tag{2}$$

- Effective dielectric constant (ε_{reff}) :

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-0.5} \tag{3}$$

- Patch length (L) :

$$L = L_{eff} - 2\Delta L \tag{4}$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \tag{5}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \tag{6}$$

- Ground Measurements :

$$L_g = L + 6h \tag{7}$$

$$W_g = W + 6h \tag{8}$$

- Inset Feed Point Distance :

The inset feed point distance y_o is obtained using the given formula where input resistance at y_o is 50 Ω :

- Input resistance Rin(y = y_0) is given as:

$$R_{in}(y = y_o) = R_{in}(y = 0)\cos^2\left(\frac{\pi}{L}y_o\right) \tag{9}$$

$$= \frac{1}{2G_1}\cos^2\left(\frac{\pi}{L}y_o\right) \tag{10}$$

Where L= Length of Patch
Input slot resistance R_{in} (y=0) = 1 / 2G1

- Slot Conductance G_1 is given by :

$$G_1 = \begin{cases} \frac{1}{90}\left(\frac{W}{\lambda_0}\right)^2 & W \ll \lambda_0 \\ \frac{1}{120}\left(\frac{W}{\lambda_0}\right) & W \gg \lambda_0 \end{cases} \tag{11}$$

Where W= Width of Patch
λ_0 = Wavelength

B. Design Calculations :

- By using given equations , the dimensions of the antenna having 0.9 GHz and 1.8 GHz were calculated. For the antenna before applying size reduction techniques the length and width are obtained as (160 x 110)mm. The below Table1 contains the detailed measurements of design.

III. Size Reduction Methods

The conventional microstrip antenna size is decreased by 58.7 % using the shorting post and the deformed ground structure method.

TABLE I
Values Of The Design Prior To Size Reduction:

Antenna Design Caluclations		
Parameter	**0.9 GHz**	**1.8 GHz**
Dielectric Constant of Substrate (ε_r)	4.3	4.3
Patch Length (L_p)(mm)	78.5	38.6
Patch Width (W_p)(mm)	75	50
Microstrip line Length(ML)(mm)	11	10.6
Inset Length(InL)(mm)	25	10

A. Defected Ground Structure Method :

Defects or slots are induced onto the ground plane of microwave planar circuits to create Defected Ground Structures. DGS is a very helpful approach for enhancing the characteristics of microwave circuits such low gain, cross-polarization, short bandwidth. This paper provides an overview and study of DGS [12]. A single defect or a large number of aperiodic and periodic defects can be used to create the DGS.

1) Working principle:: Transmission lines of the planar type, such as coplanar waveguides, microstrip lines, and coplanar wave guides with conductor backing, are used to implement the DGS in the ground plane [13–25]. DGS stands for ground plane faults that are added, which upset the ground plane's current distribution. This ground plane current distribution disturbance impacts the transmission line's properties by introducing or removing resistance, capacitance, and inductance. The effective capacitance, resistance, and inductance of the microstrip line will be impacted in a variety of ways by the addition of ground plane faults; hence, DGS will modify the microstrip line's properties.

2) Equivalent LC Circuit Model of DGS :: Distributed resistance, inductance, and capacitance are three variables that can be utilized to describe each metallic component of the microstrip antenna. As a result, the equivalent circuit made up of a resistor, inductor, and capacitor may be used to represent every component of a microstrip antenna. According to Babinate's idea, each slot has a metallic structure that is reciprocal to it, and each slot may be represented by its corresponding resistance, inductance, and capacitance. The analysis and design procedure for a traditional DGS is shown in Figure 1.

Figure 2 shows how DGS is represented using an analogous LC circuit model. The effective current route is extended as a result of the circular DGS pathways, changing the microstrip line's characteristics, including its effective capacitance and inductance. The slotted area of the DGS determines both the effective inductance and capacitance in a direct and inverse relationship, respectively. Therefore, the cut-off frequency will be reduced as the DGS's slotted area increases, whereas a decrease in the slotted area will result in an increase in the cut-off frequency.

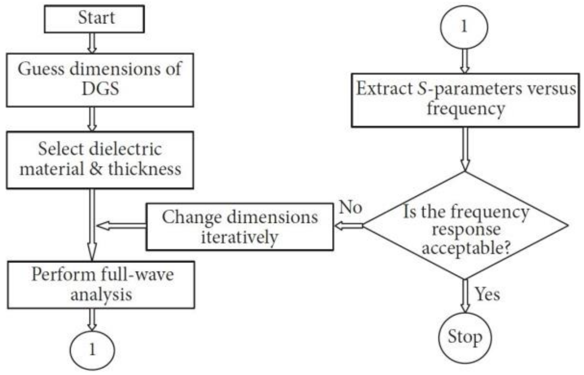

Fig. 1. Flowchart for design and analysis of conventional DGS [26]

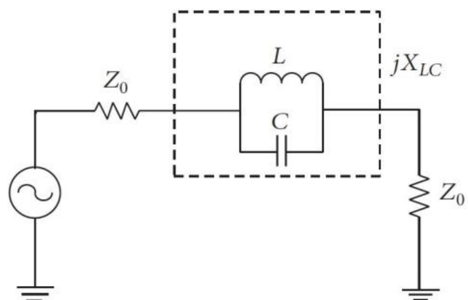

Fig. 2. LC equivalent circuit model of DGS[26]

The reactance of Butterworth low pass filter can be obtained as [26]

$$X_{LC} = \frac{1}{\omega_0 C}\left(\frac{\omega_0}{\omega} - \frac{\omega}{\omega_0}\right) \tag{12}$$

where ω_o is the resonance angular frequency. L and C of the circuit are calculated as

$$C = \frac{\omega_c}{Z_0 g_1} \cdot \frac{1}{\omega_0^2 - \omega_c^2}$$
$$L = \frac{1}{4\pi^2 f_0^2 C} \tag{13}$$

where f_0 and f_c are resonant frequency and cut-off frequency respectively.

B. Shorting Post Method :

A rectangular microstrip antenna with $\lambda/2$ length of resonant, operating in the fundamental TM10 mode; Figure 3 shows the voltage distribution throughout the length. The middle of the length of the resonance, or line OO, has zero potential field along it. Figure 4 illustrates the implementation of a small, short loaded microstrip antenna with a length of $\lambda/4$ by shorting the patch with the ground plane along the line OO, where the potential field is zero in the middle of the patch. Placing PTH (Plated Through Holes) from the ground to patch through the substrate is one way to execute the shorting post. Different combinations of shorting wall Microstrip Antenna configurations are simulated[27-30]. Because the shorting posts are working as LC Circuits, the size of the microstrip antenna grows smaller as the number of shorting posts increases and vice versa.

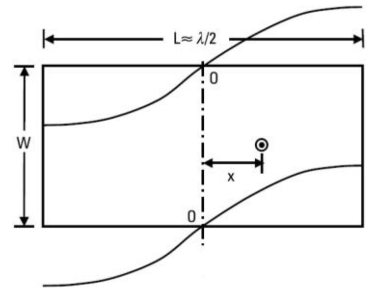

Fig. 3. Field distribution of the TM_{10} mode of Microstrip Antenna of length = $\lambda/2$ [30]

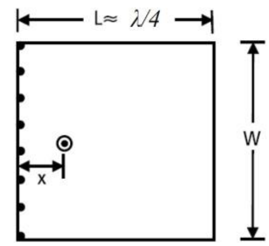

Fig. 4. Field distribution of the TM_{10} mode of shorted $\lambda/4$ Microstrip Antenna [30]

C. Design Calculations

- After using DGS and SP methods the size of the antenna is obtained as 87.5x75.5(L x W) which is 58.7% smaller than the antenna without DGS and SP.The below table shows the values of different parameters.

TABLE II
DESIGN VALUES AFTER SIZE REDUCTION

Antenna Design Caluclations		
Parameter	**0.9 GHz**	**1.8 GHz**
Dielectric Constant of Substrate ε_r	4.3	4.3
Length of Patch(mm) L_p	39.5	19.4
Width of Patch(mm) W_p	69	45.7
Microstrip line Length(mm) ML	5.3	4.8
Inset Length(mm) InL	35.5	15.8

IV. CONSTRUCTION AND RESULTS

A. Construction in CST:

The antenna is designed by using CST. The top and bottom view of the constructed design are shown in fig 5.

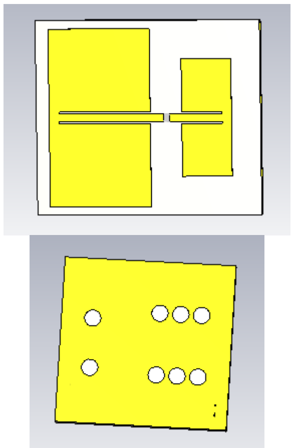

Fig. 5. Top and back view of constructed antenna

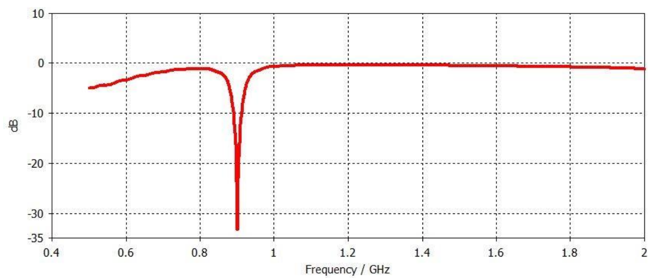

Fig. 6. Frequency Vs Reflection Coefficient plot of 0.9 GHz Antenna

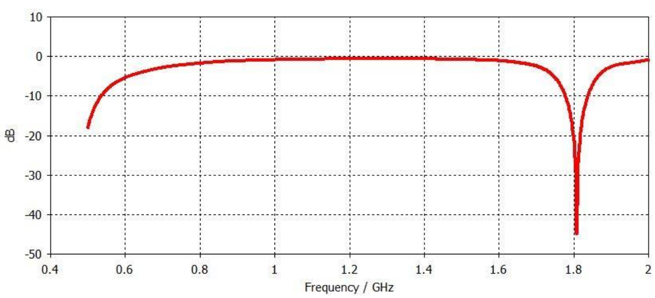

Fig. 7. Frequency Vs Reflection Coefficient plot of 1.8 GHz Antenna

B. Results:

Different desired characteristics like Return Loss, Gain and impedance bandwidth are noted for 0.9 GHz and 1.8 GHz frequencies. These characteristics are discussed below.

1) Reflection Coefficient:: The constructed compact antenna is resonating at 0.9 GHz and 1.8GHz with -33.31 dB and -44.78 dB respectively as the reflection coefficient and the bandwidth of 58.4 MHz and 60 MHz.The plot of Frequency Vs Return loss for the simulated results at 0.9 GHz is shown in Figure 6 and the plot of Frequency Vs Return loss for the simulated results at 1.8 GHz is shown in Figure 7.

2) Gain and Radiation pattern:: The simulated compact antenna has the poor gain value due to the defects in the ground i.e., due to DGS method. Because of that defects back lobe radiation occurs. The gain of the 0.9 GHz antenna has 1.475 dBi and the gain of the 1.8 GHz antenna has 2.2 dBi.

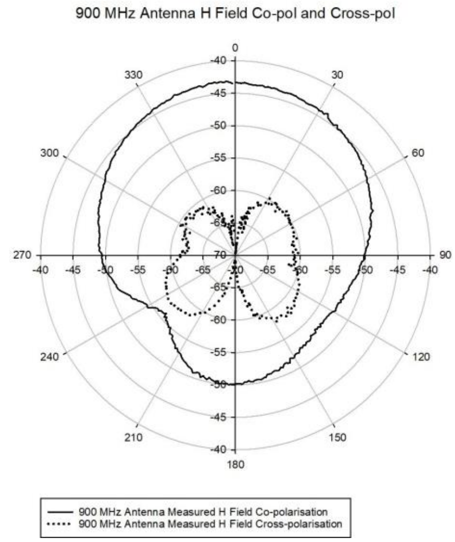

Fig. 8. 0.9 GHz Antenna H Field Radiation Pattern (ϕ = 90°)

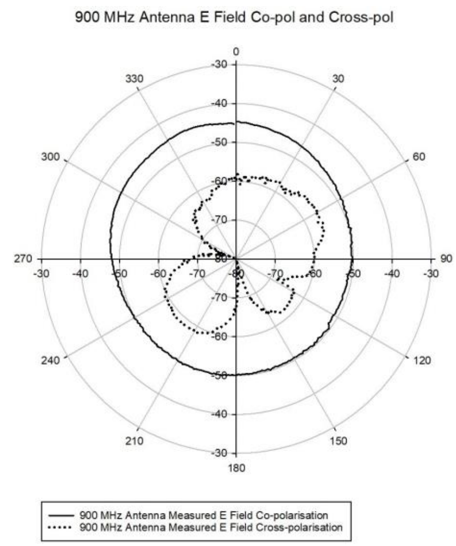

Fig. 9. 0.9 GHz Antenna E Field Radiation Pattern (ϕ = 0°)

The simulated Cross-pol and Co-pol plots of 0.9 GHz Antenna and 1.8 GHz Antenna are plotted. Figure 9 and 10 shows the simulated Cross-polarisation and Co-polarisation radiation pattern of 0.9 GHz H Field (ϕ = 90°) and E Field (ϕ = 0°) respectively . The simulated Half power Beam Widths (HPBW) of Co-polarisation plots of 0.9 GHz H Field and E Field are 75.7°and 88°.

Figure 11 shows the simulated Cross-polarisation and Co-polarisation radiation pattern of 1.8 GHz H Field (ϕ = 90°) .Figure 12 shows the measured Co-polarisation and Cross-polarisation radiation pattern of 1.8 GHz E Field (ϕ = 0°). The simulated Half power Beam Widths (HPBW) of Co-polarisation plots of 1.8 GHz H Field and E Field are 103.6°and 113.4°.

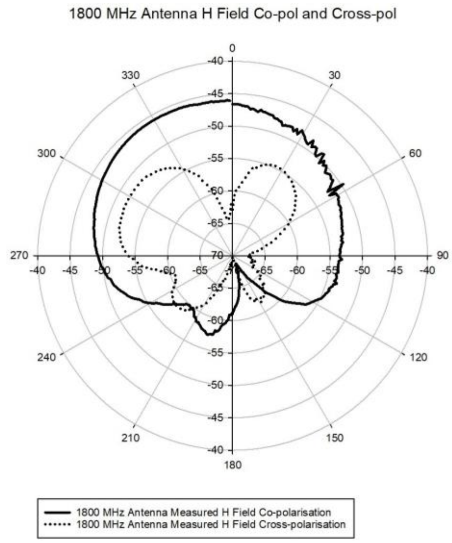

Fig. 10. 1.8 GHz Antenna H Field Radiation pattern (ϕ = 90°)

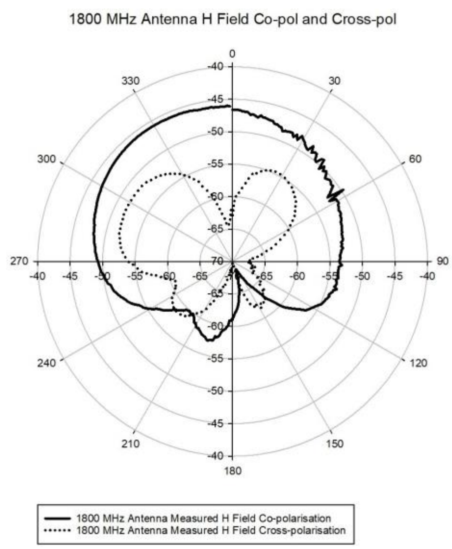

Fig. 11. 1.8 GHz Antenna E Field Radiation pattern (ϕ = 0°)

V. CONCLUSION

In this paper the compact antenna which operates in dual bands i.e, 0.9 GHz and 1.8 GHz frequency bands is constructed and simulated by using CST and their results are presented.Both the antennas are connected through Schoktty diode which acts as a frequency multiplier. After applying size reduction techniques the overall size was reduced from (160 x 100)mm to (87.5 x75.5)mm i.e, 58.7% size as reduced. These 0.9 GHz and 1.8 GHz antennas are providing good return loss as -33.31 dB and -44.78 dB.The VSWR as 1.06 and 1.04 and these antennas cover bandwidth of 58.4 MHz and 60 MHz. These antennas are having good directivity of 3.403 dBi and 5.972 dBi.But the gain of the antenna is poor because of the defects in the ground(i.e., due to back lobe radiation).The Slotted Ground Choke technique[31] can be used for increasing gain by reducing back lobes.

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