Design and Development of Frequency Reconfigurable Microstrip Planar Monopole Antenna

Hinduja
Department of E&CE.
SJMIT.Chitradurga.
Chitradurga.India
hinduja.cta@gmail.com

Chandrappa D N
Asso.professor,
Dept of E&CE.
EPCET.Bangalore
. Bengalore.India
karanthdc@gmail.com

Swathi N
Department of E&CE.
SJMIT.Chitradurga.
Chitradurga.India
swathin904@gmail.com

Chetan S
Scholar,Asst,professor Dept of E&CE.
SJMIT.Chitradurga.
Chitradurga.India
chetan.s@sjmit.ac.in

***Abstract*- This paper proposes and discusses frequency reconfigurable printed monopole antenna loaded with parasitic radiator. The antenna proposed is planned to cover applications for WLAN/Satellite. The structure is made of printed strip line and parasitic radiator attached to the patch using PIN diode. The proposed structure is simulated using ANSYS HFSS. PIN diode is simulated using HFSS is used as switch. The measured -10dB bandwidth for the reflection coefficient is from 5.4 to 5.6GHz and 7 to 7.8GHz which are suitable for WLAN and satellite band applications.**

I. INTRODUCTION

Nowadays, wireless communications are taking up an important role in our everyday life and to create smaller and lighter mobile terminals is one of the critical requirements for the development of future wireless communications.

Unlike electronic circuits, the size of an antenna is not technology-related, but is set by thelaws of physics. the antenna size is restricted by the wavelength of a given application. This makes antenna miniaturization an art of compromise among antenna size, operating bandwidth and radiation performance. The parameters which best characterize the performance of a small antenna are the quality factor (Q), operating bandwidth and the Voltage Standing Wave Ratio (VSWR). The lower the quality factor, the more broadband the antenna, the lower the VSWR, the easier it is to transfer power from the transmission line to the antenna.

Currently there are several wireless systems applications in a multitude of areas such as mobile and personal communications, radio-frequency (RF) identification, wireless local area networks (WLAN), remote sensing, etc. Regardless of the application, most of those systems have similar demands for increased functionality, improved performance, compact size, and most importantly lowerdevelopment cost. An objective that attracts a lot of effort is the integration of multiple functions on a single convergent system.

II. DESIGN OF MICROSTRIP MONOPOLE ANTENNA

The use of superior commercial tools for designing rectangular patches decreases the need to alter the measurements by means of a knife to remove metal or metal tape to increase the patches. Antennas can be constructed with tuning tabs with the cost of increased labor. Tuning tabs are not suitable for arrays when it is not possible to access the input port to individual antennas. A cut and try technique become highly hard as we add layers to boost bandwidth and numerical methods are a requirement.

The physical shape of the rectangular patch is acquired from transmission line. Hence, transmission line model is the apparent option for the rectangular patch inspection. Microstrip antenna is viewed as a transmission line with characteristic impedance Z_0 and propagation constant (𝛾 = 𝛼+ 𝑗𝛽). In this model, fields differ over the patch length and remain continuous over the width. Fringing fields at the open ends produce radiation.

The first stage involves selecting an appropriate dielectric substrate of thickness 'h' and loss tangent. Selection of thicker substrate to design the antennas can achieve broad bandwidth. However, there is one major difference. Dielectric substrates, whether thick or thin, produce force between top conductor and ground plane. When thick substrates are used, electric fields experience less force and attempt to move away from the patch thus increasing the radiation level. However, thick substrate lowers resonant frequency. Therefore, for efficient radiation it would be preferable to use substrates with w/h >1, where 'w' is the width of the patch.

The process for developing a rectangular patch antenna as shown in Fig.1, is explained below. The three vital parameters for the design of patch antenna are

- Operating frequency (f_0): The antenna resonant frequency must be properly chosen which is able to operate under the desired frequency range. Inthis

research antenna operating frequency is taken as 5.5GHz.

- Substrate dielectric constant: FR4 epoxy dielectric material relative permittivity of 4.4 is picked in this study.
- Substrate height: To make antenna less bulky the thickness of the substrate is selected as 1.57mm.

Using this data, the steps engaged in the calculation of dimension of the patch is described below

Step 1: a practical width that leads to good radiation efficiencies is

$$W = \frac{V_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

where, W - width of the patch,

f_r - resonant frequency,

ε_r - dielectric constant of the substrate.

V_0 - velocity of light in free space=3e8 m/s

Step 2: effective dielectric constant of the patch antenna is determined using

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{W}\right)^{-\frac{1}{2}} \quad (2)$$

application. Fig.1 shows the antenna structure with patch dimension 09mm x 09mm x 0.1mm and substrate dimension of 15mm x 17mm x 1mm. The ground plane is partial and measures 05mm x 15mm x 0.1mm.

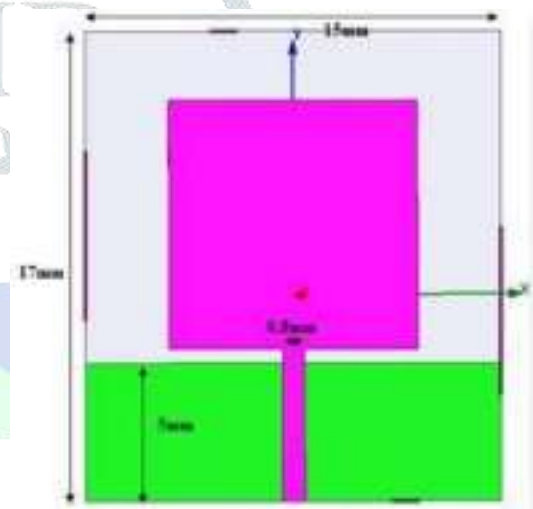


Fig. 1 Microstrip monopole antenna

A. Design of Frequency Reconfigurable monopole antenna

$$\Delta L = 0.412\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}\frac{h}{2} \quad (3)$$

where, h – height of the substrate, W – width of the patch,

ε_{reff} – effective dielectric constant of the patch, $1 < \varepsilon_{reff} < \varepsilon_r$

The frequency reconfigurable monopole antenna with microstrip line feeding is designed using ANSYS HFSS on a less expensive, widely available FR4 epoxy substrate with relative permittivity of 4.4 and dielectric loss tangent of 0.02 for wireless application. Fig. 4.4 shows the antenna structure with patch dimension 09mm x 09mm x 0.1mm and substrate dimension of

Step 3: Once width is found extension of the length of the patch (ΔL) is determined using

15mm x 17mm x 1mm. The ground plane is partial and measures 05mm x 15mm x 0.1mm. A parasitic element (radiator) is added to the top of the rectangular patch. It measures 8.8mm x 0.5mm x 0.1mm. The dimension of the parasitic element is tuned to obtain the desired frequency reconfiguration at WLAN application. PIN

diode is used as a switch to obtain frequency reconfiguration.

Step 4: The effective length of the patch can now be determined by

$$L_{eff} = \frac{V_0}{2f\sqrt{\varepsilon_r}} \quad (4)$$

where, L_{eff} – effective length of the patch antenna.

Step 5: The actual length of the patch(L) is now calculated using

$$L = L_{eff} - 2\Delta L \quad (5)$$

where, L is the length of the patch antenna.

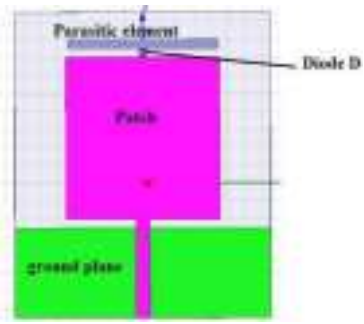


Fig.2 Frequency reconfigurable monopole antenna

III. DESIGN OF PIN DIODE

The monopole antenna with microstrip line feeding is designed using ANSYS HFSS on a less expensive, widely available FR4 epoxy substrate with relative permittivity of 4.4 and dielectric loss tangent of 0.02 for 7.9GHz

We use PIN diode as RF switch to reconfigure antenna frequency. PIN diode works as very good RF switch because Satellite of its intrinsic region which provides more charge storage in between the two junctions. Electrical equivalent circuit of pin diode and its High frequency structure simulator (HFSS) model is presented in Fig.3. HFSS model of a switch is made by using lumped RLC boundaries in switch contacts as shown in Fig.3. Electrical equivalent circuit for switch off/on is presented in Fig. 4. In switch on position it works as series combination of Rs and L. It start conducting in this position. In switch off position, it work as parallel combination of R_p and C_p. Capacitance block the current and no current flows in this position and it work as open circuit.

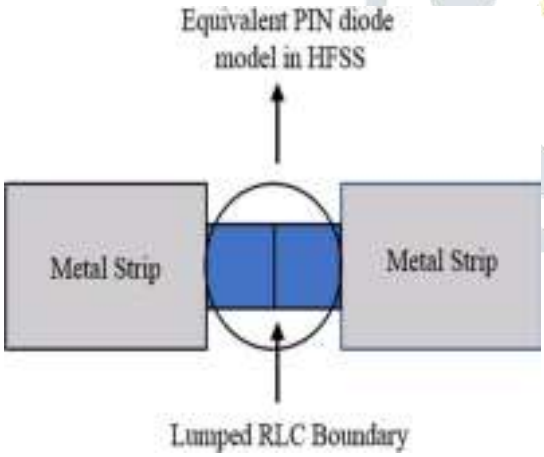


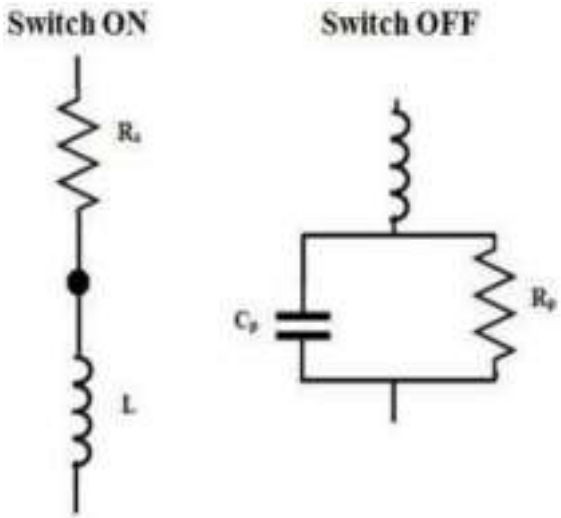
Fig.3, PIN diode : HFSS model

communication applications. The simulated return loss plot is shown in Fig. 5

Fig. 5 Return loss plot when diode is OFF

Fig. 5 reveals a low return loss of -16.03dB at 7.4GHz for the antenna. It shows that at that frequency the antenna functions more effectively. Throughout bandwidth calculation, one has to find certain frequencies where the curves break line S11=-10dB. These are 7GHz and 7.8GHz frequencies. So the antenna system's bandwidth is 0.8GHz.

Fig. 6
Fig.4 Elec



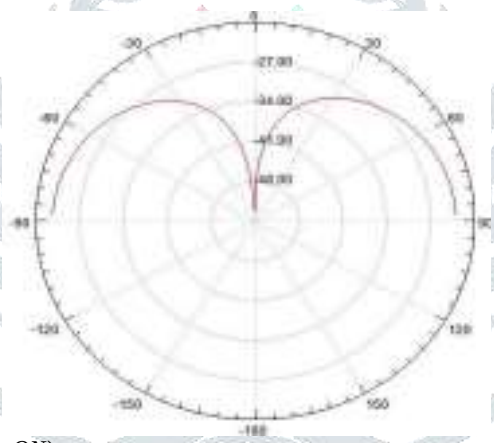
PIN diode

III. RESULTS AND DISCUSSIONS

ANSYS HFSS software is used to design and simulate proposed patch antenna models. Various antenna parameters such as return loss, VSWR, radiation pattern for different frequency reconfiguration is studied in this chapter.

A. Typical Monopole Antenna (diode is OFF)

This is similar to the condition when the diode is OFF. For antenna performance a return loss greater than - 10dB is desired over the entire operating bandwidth as is typical for



B. Typical Monopole Antenna (diode is ON)

This is similar to the condition when the diode is ON. For antenna performance a return loss greater than -10dB is desired over the entire operating bandwidth as is typical for communication applications. The simulated return loss plot is shown in Fig. 8

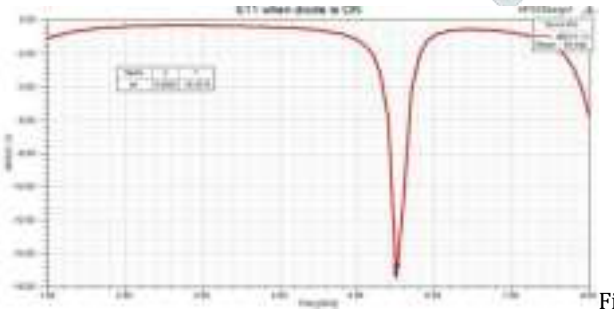


Fig. 8 Return Loss when diode is ON

Fig. 6 reveals a low return loss of -15.42dB at 5.5GHz for the antenna. It shows that at that frequency the antenna functions more effectively. Throughout bandwidth calculation, one has to find certain frequencies where the curves break line S11=-10dB. These are 5.4GHz and 5.6GHz frequencies. So the antenna system's bandwidth is 0.2 GHz.

VSWR is the
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OFF is 1.3 a
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Fig.

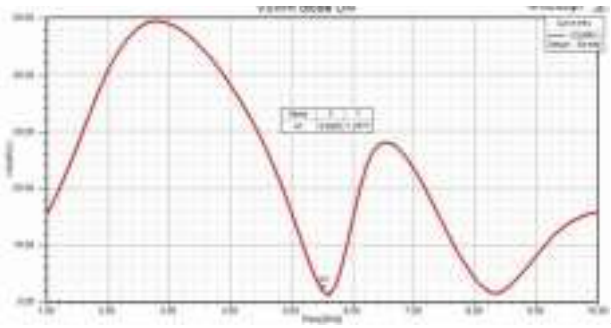

Fig. 9 VSWR when diode is ON

As seen in Fig. 9 VSWR for the antenna when diode is ON is 1.9 at 5.5GHZ. Hence, we can say that the feed line is perfectly matched to the antenna input. As seen in Fig. 10 the radiation pattern of the antenna when diode is ON is like monopole antenna. Hence there is no change in the characteristics of radiation pattern when diode is turned ON or OFF.

Fig. 10 Radiation pattern when diode is ON

C. Current plots

Fig. 11 (a) and (b) shows current plots on the monopole antenna when diode is ON and OFF respectively. It is seen that when the diode is turned ON currents flow from patch to the parasitic radiator (Fig.11a) as a result of which the overall dimension of the patch increases and frequency decreases. Hence in this case the operating frequency switches from 7.4GHz to 5.5GHz. But when diode is OFF (Fig.11b) since there is no current flow to the parasitic radiator the operating frequency remains at the original designed frequency of 7.4GHz.

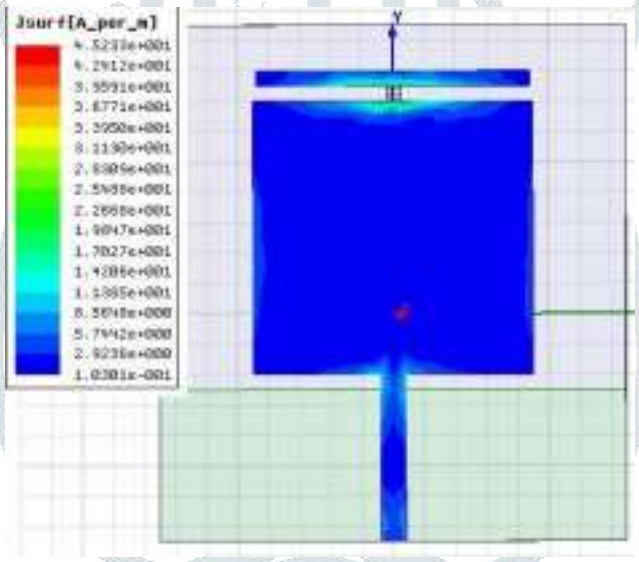

Fig. 11(a) current plot when diode is ON

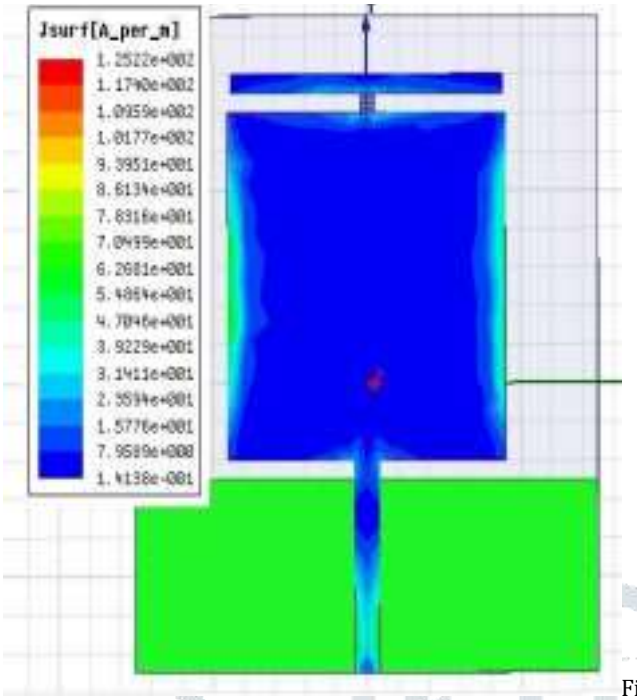

Fig. 11.(b) current plot when diode is OFF

The summary of the simulation results is presented in Table 1

TABLE 1 SUMMARY OF THE SIMULATION RESULTS

Parameters	Diode ON	Diode OFF
Operating frequency	5.5GHz WLAN Application	7.4GHz Satellite Application
Bandwidth	0.2GHz	0.8GHz
Radiation pattern	Monopole like	Monopole like
VSWR	1.9	1.3
Current	Current flows to parasitic radiator	No current flow

CONCLUSION

A frequency reconfigurable monopole antenna is presented for WLAN and satellite applications. Frequency reconfiguration is achieved using PIN diode simulated using HFSS. A parasitic radiator is attached to the patch for this purpose. By using this technique frequency reconfiguration is achieved from 7.4GHz to 5.5GHz operating frequency. It is observed from analysis that the current flowing through the parasitic element is the reason for this property. Various antenna parameters like return loss, VSWR and radiation pattern are analyzed. The antenna exhibits monopole like radiation pattern at both the frequency. The antenna is suitable for WLAN and satellite applications.

In future the designed antennas may be fabricated and tested in real time environments.

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