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Article

Design and Parametric Analysis of Multiband Microstrip Patch Antenna

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A B S T R A C T

In this paper a rectangular shaped, low cost compact size microstrip patch antenna is designed which can be used at high frequencies. Parametric analysis of proposed antenna design is done for four different feeding methods. Different parameters like return loss, VSWR, radiation pattern, directivity, resonant frequency are simulated and analyzed using Ansoft HFSS 13. A prototype antenna is fabricated and tested in order to validate the suggested method.

Keywords: Microstrip Patch Antenna, Stripline-Feed, Inset-feed, Edge-feed, Probe-feed, Resonant frequency, VSWR, Return Loss, Directivity

Introduction

TODAY owing to an increase in multimedia applications demand for antennas that would cover joint bands has arisen. These antennas are useful for such a number of applications where several bandwidths are required along with directivity and a modest level of gain. They sometimes used over the HF portion of the spectrum where operation is required on a number of frequencies to enable communication to be maintained. They are also used at VHF and UHF, for a variety of applications.

Patch antennas play a very significant role in today's world of wireless communication systems. A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration. Other configurations are complex to analyze and require heavy numerical computations. A microstrip antenna is characterized by its length, width, input impedance and gain and radiation patterns. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals for the last ten years, on these antennas shows the importance gained by them. Microstrip antennas are the present day antenna designer's choice.[2]

Various types of multiband patch antennas are being proposed by researchers with different feeding techniques. Paper[3] presents edge-fed patch antennas with reduced spurious radiation. In[4] compact multiresonator-loaded planar antenna is presented for multiband operation. Paper[5] describes a compact high gain microstrip antenna for wireless applications.

This paper describes design, comparative parametric analysis of stripline feed, inset feed, coaxial feed and edge feed rectangular shaped patch antenna with their simulated results. It has been demonstrated by HFSS simulation software that proposed design is suitable for multiband operation. The proposed antenna geometry generates six resonant modes at 1.34, 1.99, 2.98, 3.27, 3.56 and 3.86 GHz. The properties of antenna such as bandwidth, S-parameter, VSWR, directivity are analyzed for proposed antenna geometry. The simulated antenna is fabricated and tested using ZVL VNA for various parameters. The proposed antenna design is highly suitable for L and S band application.

Proposed Geometry

A 1.6 mm FR4 epoxy substrate with dielectric constant 4.4 is chosen. The proposed antenna consists of a radiating patch; ground plane and 50 ohms feed line. Dimensions of patch are L= 36.3 mm and W= 46.8 mm. The width of the feed line (input port) can be varied to obtain impedance matching.

To achieve the multiband operation, four narrow slits are taken out from the main radiating patch. Fig.1 shows the geometry of the resonant antenna under consideration. In this case, the proposed design consists of patch elements on one side of the dielectric substrate and planar ground on the other side. Contrary to this function, use of the FR4 substrate would have a strong influence on the antenna performance, as it changes the effective dielectric constant under the patch. For example, increasing the thickness of the substrate causes operating frequencies to lower. At the same time increasing the dielectric constant of the substrate has the same effect.

A parametric study of the proposed patch antenna is carried out to achieve multiband performance. The effects of different iterations of the design have been investigated based on the antenna performance. The first iteration is done by subtracting a narrow slit from the main rectangle patch; second iteration is done by subtracting the second slit from the previous design. Similarly, third and fourth iterations are performed by subtracting third and fourth slits respectively.

It has been demonstrated that by adding narrow slits close to the radiating edge, as shown in Fig. 1, multiple frequency operation can be obtained. A suitable operating frequency is given by the minimum in the return loss, as shown in Fig. 2.

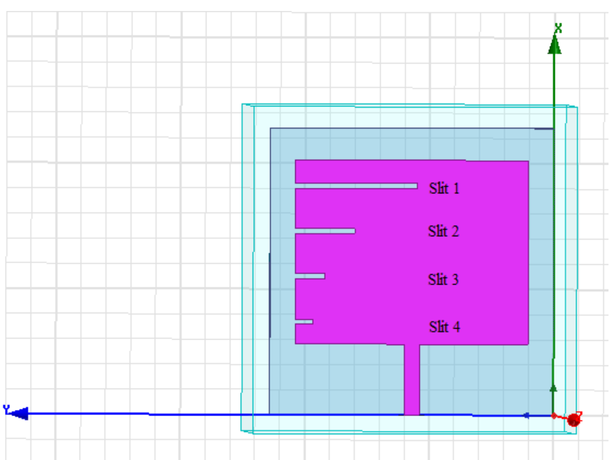

Figure 1.Proposed Multiband Antenna

Simulation Results & Discussion

The basic parameters that are analyzed here are given in briefly.

Return loss

For an efficient transfer of energy, the impedance of the radio, antenna and transmission cable connecting them must be the same. Transceivers and their transmission lines are typically designed for 50Ω impedance. If the antenna has impedance different than 50Ω, then there is a mismatch and an impedance matching circuit is required. When any of these components are mismatched, transmission efficiency suffers. Return loss is another way of expressing mismatch.

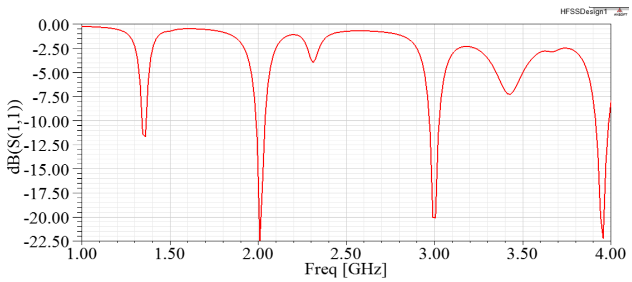

Figure 2.Return loss Vs Frequency plot

By introducing slit 1and 2, the surface current distribution at the center of the radiating patch is greatly enhanced, covering four bands of operation, can be seen in Fig.2. The slit appears to produce return loss of -11.68dB, -22.42dB, -20.06dB and -22.22dB at frequencies 1.36GHz, 2.01GHz, 3.00GHz and 3.95 GHz respectively, however the bandwidths are very narrow.

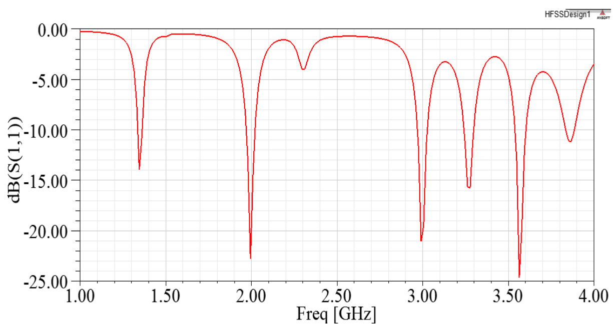

Figure 3.Return loss Vs Frequency plot for final design

By introducing slit 3and 4, the surface current distribution of the radiating patch is changed again and this change offers two more bands between 3 and 4 GHz frequency.

From the above return loss plot, Fig. 3, it is clear that the designed antenna is having six bands of operations. S11 parameter obtained at all these frequencies has values less than -10dB. The value of return loss are -13.94dB,-22.78dB, -21.02dB, -15.70dB, -24.64dB and -11.17dB at 1.34GHz, 1.99GHz, 2.98GHz, 3.27GHz, 3.56GHz and 3.86GHz frequency respectively.

VSWR

The VSWR is always a real and positive number for antennas .For small VSWR, the antenna is better matched to the transmission line and more power is delivered to the antenna. The minimum VSWR is 1.0.[6] In this case, no power is reflected from the antenna, which is ideal.

VSWR curve (Fig. 4) indicates that the designed antenna is having six bands of operations. The value of VSWR at all these six frequency bands is between 1 and 2.

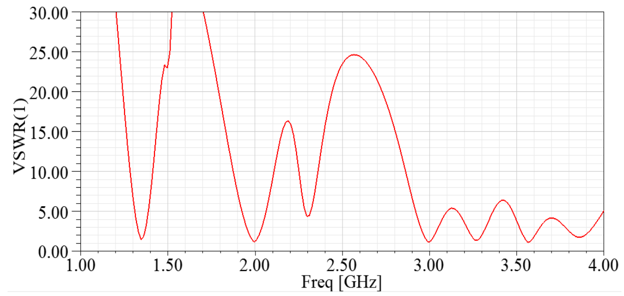

Figure 4.VSWR Vs Frequency plot

Resonant Frequency

The resonant frequency and electrical resonance is related to the electrical length of an antenna. Typically an antenna is tuned for a specific frequency and is effective for a range of frequencies that are usually centered on that resonant frequency. Some antenna design has multiple resonant frequencies. Here a conventional rectangular shaped patch antenna design is proposed. Above results show the proposed antenna can operate at six-resonant frequencies.

Directivity

Directivity of an antenna is a measure of the concentration of the radiated power in a particular direction. Fig.5 shows directivity plot of proposed design. Maximum achieved directivity of the proposed antenna is 3.5597dB.

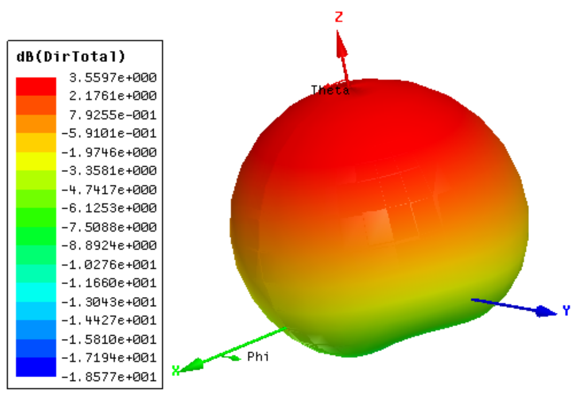

Figure 5.Directivity plot of proposed design

Radiation Pattern

Radiation pattern is graphical representation of the relative field strength transmitted from or received by the antenna. Antenna radiation patterns are taken at one frequency, one polarization and one plane cut.[4] The patterns are usually presented in polar or rectilinear form with a dB strength scale. Fig. 6 shows elevation pattern for ϕ= 0º, 90º, 180 º, 270 º and 360º.

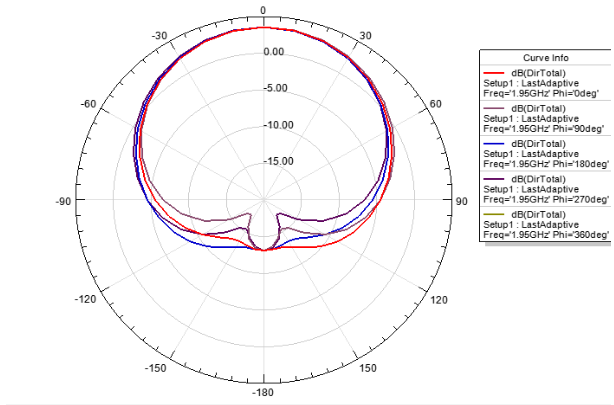

Figure 6.Elevation pattern at φ = 0o, 90 o, 180 o, 270 o and 360o

Half Power Beam width

The Half Power Beamwidth (HPBW) is the angular separation in which the magnitude of the radiation pattern decreases by 50% (or -3 dB) from the peak of the main beam.[9] Fig. 7 shows elevation pattern for ϕ= 0º, 90º, 180 º, 270 º and 360º. From this figure it is clear that HPBW is 100 degrees.

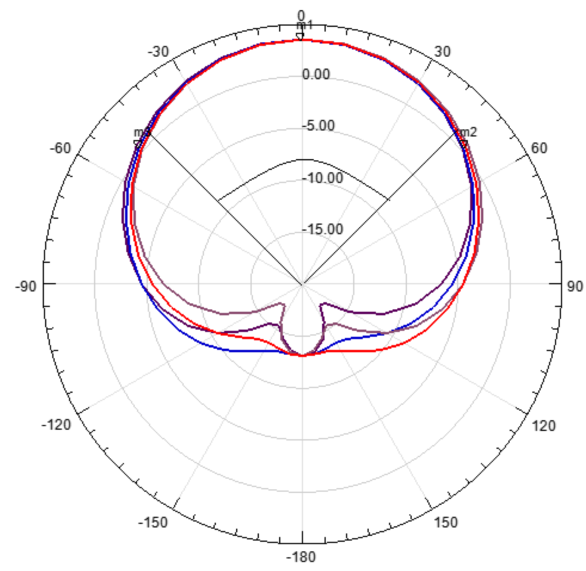

Figure 7.Beam width

Bandwidth

Most antennas are operated around the resonant point. This means that there is only a limited bandwidth over which it can operate efficiently. Outside this, the levels of reactance rise to levels that may be too high for satisfactory operation. Bandwidth is defined as the range between upper cut of frequency at 10 dB and lower cut of frequency at 10 dB.

$BW=f_H-f_L$

Proposed design has six bands of operations with narrow bandwidths. Table 1, summarizes values of Return Loss (S11 parameter), their VSWR and bandwidths at six different frequencies.

Figure 7.Beam width

Frequency	Return loss	VSWR	Bandwidth
1.34GHz	-13.94dB	1.50	26MHz
1.99GHz	-22.78dB	1.16	52MHz
2.98GHz	-21.02dB	1.19	58MHz
3.27GHz	-15.70dB	1.39	58MHz
3.56GHz	-24.64dB	1.12	62MHz
3.86GHz	-11.17dB	1.78	48MHz

From the above results we can say that the designed antenna is having six bands of operations. Return loss parameter obtained at all these frequencies has values less than -10dB. The value of VSWR at all these resonating frequency bands is also between 1 and 2. Hence we can say that designed antenna, which is resonating at six different resonating frequencies, is a multiband antenna.

Proposed Antenna Design with Various Feeding Methods

The functional characteristics and output parameters of microstrip antennas affect by choosing different feeding (excitation) techniques. This sub-section presents effect of feeding techniques such as inset feed, coaxial feed and edge feed on the radiation parameters of proposed multiband microstrip patch antenna with their simulated performance parameters.

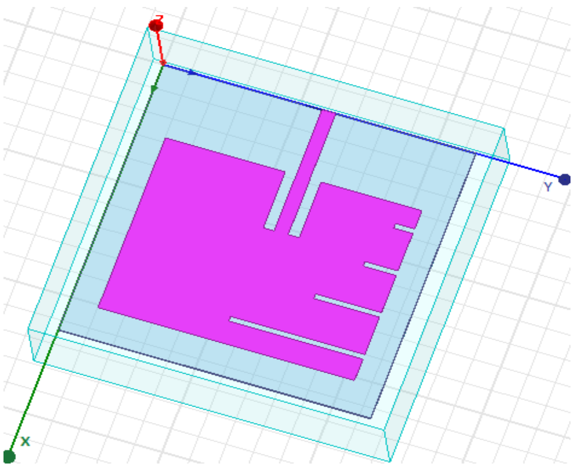

Figure 8.Inset Fed Rectangular Patch antenna

Inset Feeding

Inset feed comes under strip line feeding method. In this inset fed patch antenna 12 mm long inset is cut out from the radiating edge. The purpose of this inset cut is to match the impedance of the feed line to the patch without the need of any additional matching element. This is achieved by properly controlling the inset position. Inset fed proposed antenna is shown in Fig. 8. Following graphs show simulated results of inset fed patch antenna.

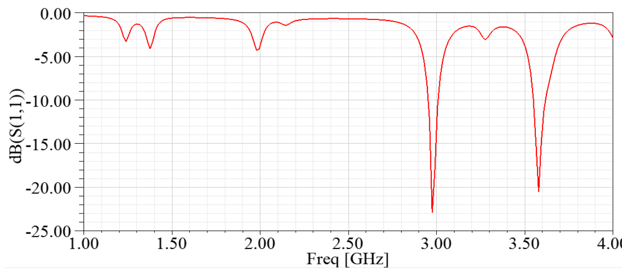

Figure 9.Return Loss (S11) of inset fed antenna

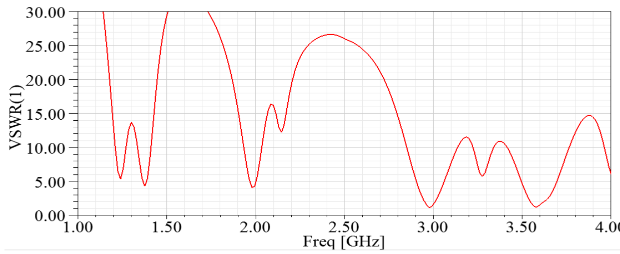

Figure 10.VSWR parameter of inset fed antenna

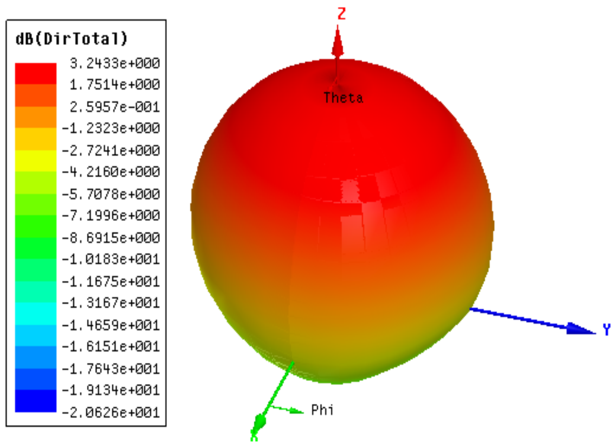

Figure 11.Directivity plot of inset fed patch

Above results indicate that proposed design with inset fed scheme provides two bands of operation which have the return loss parameter less than -10dB. At these two frequencies VSWR is optimum. Maximum return loss is -23 dB. Total directivity of inset fed patch antenna is 3.2433dB.

Edge Feeding

Edge feed type also comes under strip line feeding method. In this edge fed patch antenna the feed line is connected with edge strip line and the width of this edge strip line is less than the width of the feed line as shown in Fig. 12. Graphs (Fig. 13-15) show simulated results of edge fed patch antenna.

Above graphs show that proposed patch antenna with edge feed technique gives five resonating frequencies and the maximum value of S parameter is -21dB. At all these five frequencies VSWR parameter is between 1 and 2. Maximum directivity of antenna is 1.5481dB.

Coaxial Feeding

Fig.16 shows coaxial probe fed proposed microstrip patch antenna. In coaxial probe feeding scheme, the feed can be placed at any desired location inside the patch in order to match with its input impedance.[9] The antenna has been fed using 50 Ω coaxial probes to main stem. Simulated results are shown below (Fig. 17-19).

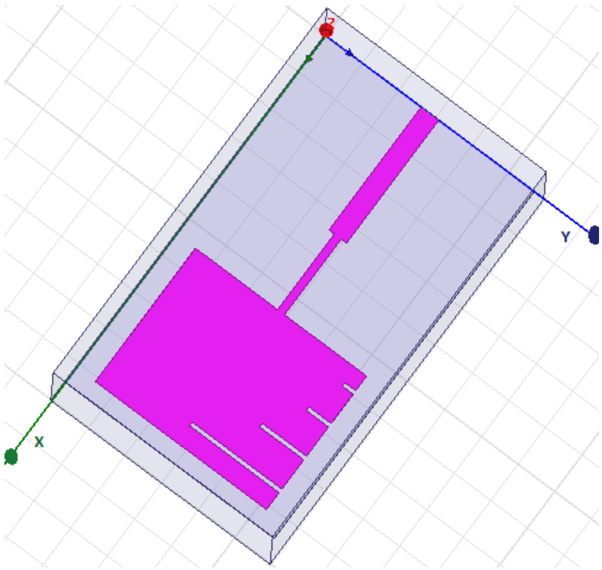

Figure 12.Edge fed rectangular patch antenna

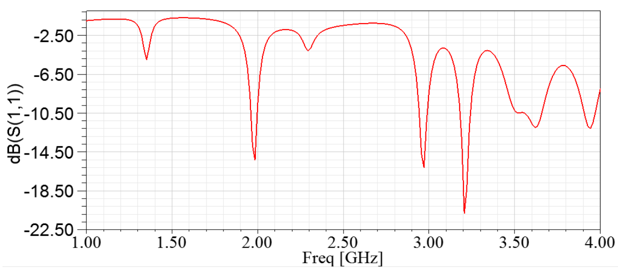

Figure 13.Return Loss (S11) of edge fed antenna

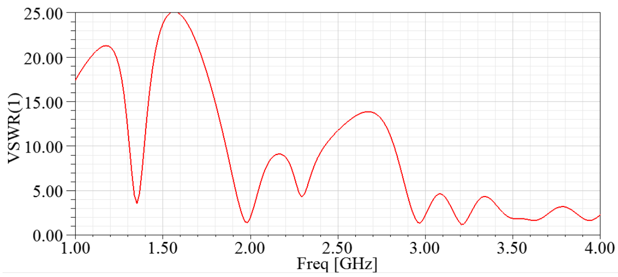

Figure 14.VSWR parameter of edge fed antenna

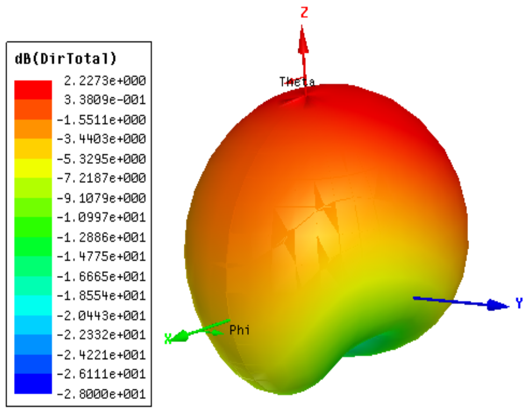

Figure 15.Directivity plot of edge fed antenna

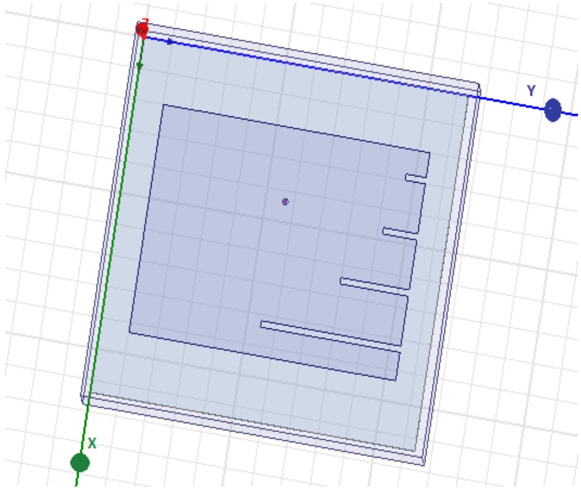

Figure 16.Coaxial probe fed rectangular patch antenna

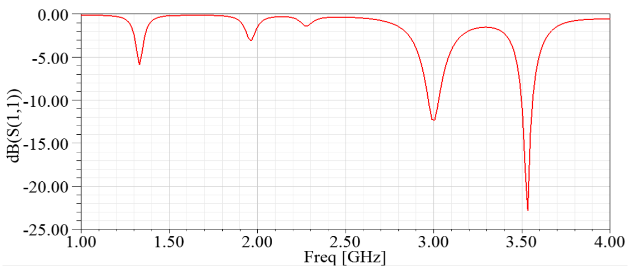

Figure 17.Return Loss (S11) of probe fed antenna

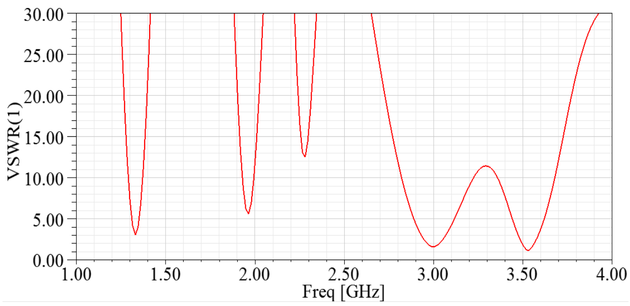

Figure 18.VSWR parameter of probe fed antenna

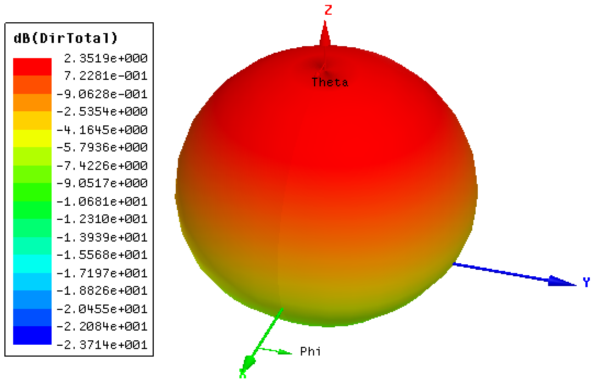

Figure 19.Directivity plot of probe fed patch

The return loss plot presents two bands of operations. Maximum achieved return loss is -23dB. Probe fed patch antenna have two frequencies at which VSWR has optimum values. Total directivity of probe fed patch antenna is 2.3519dB.

Table 2, summarizes simulated parameters of proposed antenna with comparison of various feeding techniques.

Table 2.Results of various feeding techniques

Feeding technique	No. of bands	Maximum return loss	Directivity	VSWR range
Stripline feed	6	-24.64dB	3.5597dB	1-2
Inset feed	2	-22.88dB	3.2433dB	1-2
Edge feed	5	-20.82dB	2.2273dB	1-2
Probe feed	2	-22.83dB	2.3519dB	1-2

From the comparative analysis it is clear that various feeding techniques affect the performance of proposed multiband patch antenna design. After observing the results and antenna parameters, we can say that out of these four feeding techniques i.e. strip line feed, inset feed, edge feed and probe feed, the stripline fed proposed patch antenna provides efficient results. The return loss and directivity is higher in stripline feeding technique on comparing with other methods. This stripline fed patch antenna operates between 1.0 to 4.0 GHz at six different frequency bands and VSWR for all these bands are between 1 and 2.

Experimental Results & Discussion

Testing of antenna is done by using R & S ZVL Vector Network Analyzer. It is the instrument to combine the functions of a network analyzer, spectrum analyzer and power meter in a single box.

The proposed antenna with optimal design, as shown in Fig. 20, is built and tested. The following figure (Fig. 20-21) shows the tested results of the fabricated antenna.

(a) Return Loss

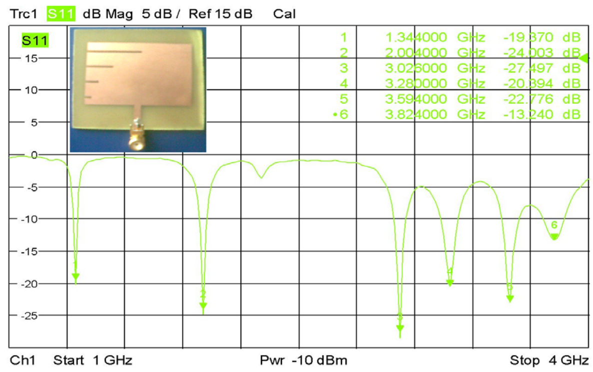

Figure 20.Tested S parameter Vs Frequency plot

(b) VSWR

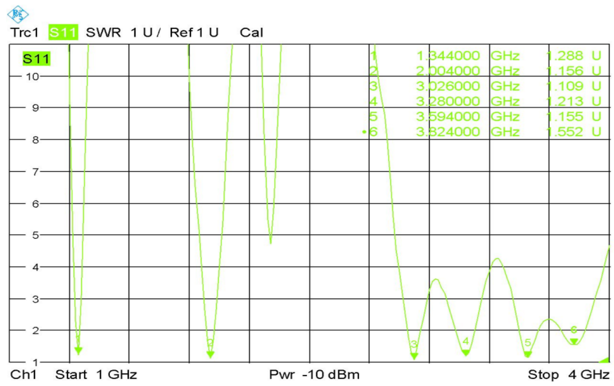

Figure 21.Tested VSWR Vs Frequency plot

Table 3, Summarizes values of Return loss and VSWR for both simulated and tested results. From this table it is clear that proposed antenna has six resonating frequencies. Simulated and Tested results are nearly same.

Table 3.Comparison between Simulated and Tested Results

Frequ-ency	Return loss (in dB)		VSWR	
	Simulated	Tested	Simul-ated	Tested
1.34GHz	-13.94dB	-19.37 dB	1.50	1.28
1.99GHz	-22.78dB	-24.0 dB	1.16	1.15
2.98GHz	-21.02dB	-27.49 dB	1.19	1.10
3.27GHz	-15.70dB	-20.89 dB	1.39	1.21
3.56GHz	-24.64dB	-22.77 dB	1.12	1.15
3.86GHz	-11.17dB	-13.24 dB	1.78	1.55

Conclusion & Future Work

This paper presented the design and parametric analysis of compact six-band printed antenna for multiband applications. The comparative study of excitation techniques describes that various feeding techniques affect the performance of proposed multiband patch antenna design. After observing the results and antenna parameters, we can say that out of these four feeding techniques i.e. strip line feed, inset feed, edge feed and probe feed, the stripline fed proposed patch antenna provides efficient results. The stripline fed proposed antenna can operate between 1.0 to 4.0 GHz at six different frequency bands i.e. 1.34, 1.99, 2.98, 3.27, 3.56, and 3.86 GHz. The value of VSWR at all these resonating frequency bands is also between 1 and 1.8. Return loss parameter obtained at all these six frequencies has values less than -10dB Total directivity of the proposed multiband antenna is 3.5597dB.

This proposed antenna design is highly suitable for L and S band applications. It can be used for WLAN, Wi-Max and other wireless applications.

The simulation tool Ansoft HFSS has given enough good results to satisfy our requirements to fabricate the antenna on hardware which can be used wherever needed. The measured and simulated results are in good agreement.

Though an exhaustive study on multiband antenna design has been carried out in this work, still there is enough scope for improvement and further research, using switches and diodes reconfigurable antenna can be designed. Array can be configured for proposed design.

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