Gain Enhancement of Elliptical Monopole Antenna using Defected Ground Structure and Slot

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***Abstract* - The aim of this paper is to present the elliptical monopole Antenna which covers the Ultra Wide Band 3.1 to 10.6 GHz. This is a simulation based study .The design and simulation of the antenna is carried out using High Frequency Structure Simulator (HFSS 13.0) software. It is widely used technology in many fields such as communication, satellite communication. Our antenna supports resonating frequency 4.32 GHz and 4 GHz for WLAN (wireless local area network), 3.5 GHz for WIMAX (worldwide interoperability for microwave access). The proposed antenna is designed on FR4 PCB having size 30 mm x 30 mm x 1.6 mm. The antenna exhibits a good VSWR and Return Loss over the entire frequency range. The antenna has been designed according to some suggested and known formulae.**

Keyword- ultra wideband, elliptical monopole antenna, defected ground structure.

I. INTRODUCTION

Antennas have fundamental importance in the field of wireless communication. With the rapid development and advancement of wireless broadband technologies we require light weight, low cost, and small size antennas. Therefore the demand for smaller low-cost antenna has been increased to a great extent. In order to support high mobility, a compact and light weighted antenna is needed. In antenna various size reduction and broad banding techniques using shorted pins or shaped slots, post-gap , or parasitic elements were came in existence.

An antenna is an electrical device which converts electric power into radio waves and vice versa. Any conductor, through which an RF current is flowing, can be an antenna.

This paper presents the design equations for lower band-edge frequency for all the regular shapes of printed monopole antennas with various feed positions. The length of the feed transmission line is a critical design parameter of these monopole antennas. Design curves for the length of the feed transmission line for various lower band-edge frequencies for all these regular shaped monopoles have been generated. A systematic study has been presented to explain the ultra-wide bandwidth obtained from these antennas with an example of elliptical monopole antenna. Multi resonance printed monopole antennas are being used increasingly for applications of UWB technology because of their attractive features [1].

Printed elliptical monopole antenna PEMA has been designed to cover the UWB frequency range. Simulation results showed that this orientation of the impedance locus leads to very wide operating frequency range 2.83~13.7 GHz, which exceeds the UWB requirements, as well as good gain and efficiency. This paper focus on bandwidth enhancement of microstrip circular patch antenna by introducing a narrow rectangular slit [3].

This paper presents the design of microstrip circular patch antenna for UWB application. This antenna was designed on Fr4 with overall size of 31.17 x 40 x 0.787 mm3 [4].

In this study, a simple and compact ultra-wideband (UWB) patch antenna with rectangular slot is presented. The fabricated antenna consists of a rectangular patch tapered from a microstrip feeding structure and a truncated ground plane [5].

A novel compact and ultrawide-band (UWB) antenna is presented in this paper. A novel CPW-fed monopole circular patch UWB antenna with c-shape slot is proposed in this article. The proposed antenna has an extremely wide frequency band range, the impedance bandwidth of which is measured as 4.2 to 10.5 GHz for return loss <_10 dB. Simulated and measured results are presented for the proposed antenna. [6].

A new multilayer microstrip antenna is introduced using Stacked Multi resonator patches. [7]**.**

The paper presents a Wideband Helical Microstrip Antenna, with particular attention to high bandwidth, size reduction and low back lobe radiation in VHF (Very High Frequency)/ lower UHF (Ultra High frequency) band. The antenna inserted with shorting post, is double probe-fed having a minimum VSWR (Voltage Standing Wave Ratio)[8].

A. Ultra Wide Band

Ultra wide band is a communication method rapidly used in wireless network. To achieve high bandwidth connections with low power utilization. It is rapidly advancing as a high data rate wireless communication technology. The Federal Communication Commission (FCC) has released a bandwidth from 3.1 GHz-10.6 GHz for UWB. It provides high data rate which may be up to several hundred Mbps which makes it difficult to track the transmitting data, which highly ensures the data security and for UWB systems power consumption is extremely small as order of 0.5mW according to FCC. An Omni directional radiation pattern is desirable because of user mobility and freedom in transmitter or receiver position. The meaning of Omni directional radiation pattern is that signal waves passing through the antenna shall be able to travel in all directions. UWB supported conical antenna, log periodic antenna, spiral antenna, monopole antenna.

The capabilities of UWB are:-

(i) Operates over an ultra-wide bandwidth.
(ii) Satisfactory radiation properties over the entire frequency range.
(iii) A good impulse response with minimal distortion.
(iv) Low power utilization.

II. DESIGN SPECIFICATION

- Frequency of operation: A circular monopole antenna operates over frequency band of 3.1GHz to 10.6GHz.
- Lower band-edge frequency f_L=3.1Ghz
- FR-4 substrate having thickness of 1.6mm
- Dielectric constant of 4.4.
- Length of 50Ω feed line P=0.3mm

III. DESIGN PROCEDURE

1) Patch Size (A)

The size of Elliptical Monopole Antenna can be calculated via the following equations

$$f_L = \frac{c}{\lambda} = \frac{7.2}{(L+r+p)*k} \text{GHz}$$

$$L = 2B$$

$$r = \frac{A}{4}$$

The approximated value of εeff is given by :

$$\varepsilon eff = \frac{\varepsilon r + 1}{2}$$

$$k = \sqrt{\varepsilon eff}$$

Effective dielectric constant=4.4. Using equation with, f_L=3.1GHz we estimated A=8mm& B=6m.

2) Microstrip Line Width (Wstrl)

The Microstrip line width has been calculated from the following equation

$$Z_0 = \frac{87}{\sqrt{\varepsilon r + 1.41}} \ln\left(\frac{5.98h}{0.8Wstrl + t}\right)$$

Z_0 - characteristic impedance of Microstrip line,
h - substrate thickness which has been taken 1.6mm,
t - metallization thickness which is 0.035mm,
Wstrl - Microstrip feed line width. Wstrl = 3mm

3) Ground Plane Length (Lg)

$$L_G = \frac{\lambda}{4} = \frac{c}{4kfl}$$

$$K = \sqrt{\varepsilon eff}$$

Where,
f_L= 3.1GHz , εeff =2.7, We calculated value Lg which is approximately equal to 20mm.

IV. SIMULATED ANTENNA DESIGN

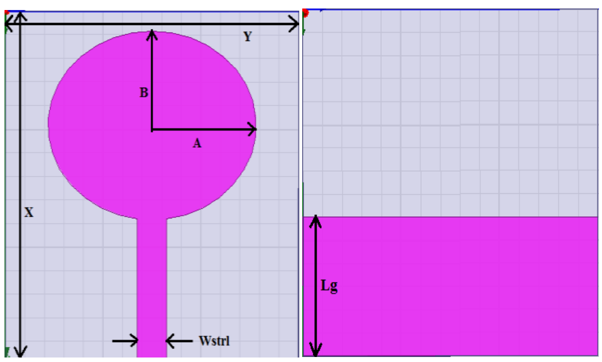
The proposed elliptical monopole antenna can be designed by using HFSS 13.0 software.

A. *Elliptical Monopole Antenna*

The elliptical monopole antenna with major radius 8 mm, a 50 Ω microstrip feed line are printed on one side of the FR4 substrate. The length and the width of the dielectric substrate are 30x30 mm. The width of the microstrip feed line is fixed at 3mm to achieve 50Ω impedance.

Table 1 Dimensions of antenna

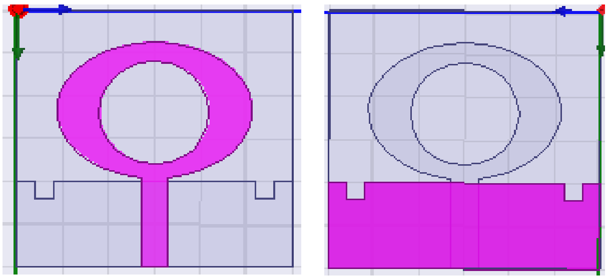
Parameters	Dimensions(mm)
L(mm)	30
W(mm)	30
W_{strl}(mm)	3
P(mm)	0.3
A(mm)	8
B(mm)	6
L_G(mm)	10



Fig(a)Front view Fig(b)Bottom view
Fig1 Elliptical monopole antenna

B. *Modified Elliptical Monopole Antenna*

This antenna is modified by incorporating DGS in ground plane and slot in patch.



Fig(a)Front view Fig(b)Bottom view
Fig2 Modified Elliptical monopole antenna

V. SIMULATION RESULT

A. Simulation Result of Elliptical Monopole Antenna

The return loss versus frequency curve with the optimized values is shown below. This shows that the proposed antenna covers the entire UWB.As seen in the plot for return loss the graph is below -10dB for the desired frequency range hence, this graph is satisfied for better performance. It is observed that the return loss curve has resonance frequency at 4.322 GHz. Antenna operates at the frequency range of 3.48GHz to 13.07GHz.

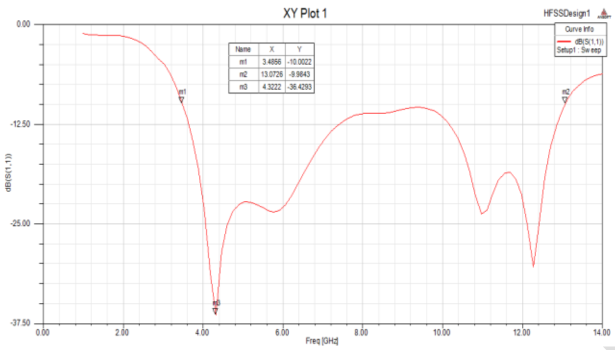


Fig 3. Reflection coefficient [dB] versus frequency [GHz]

Fig4 shows the plot for VSWR versus frequency. The plot specifies the value of VSWR between 1 and 2 which satisfies the UWB characteristics and for the same region the return loss is also less than -10 dB. The value of VSWR is 1.03 at resonant frequency of 4.322 GHz.

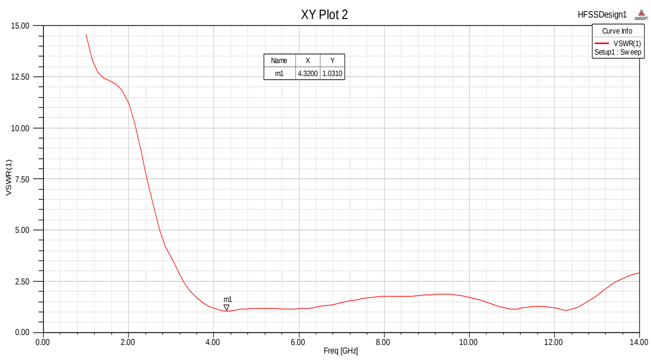


Fig 4.VSWR versus frequency [GHz]

The measured 3D radiation patterns of the antenna at resonant frequency of 4.322GHz is shown in Fig 4.1.3. The results show reasonable omnidirectional radiation pattern .The omnidirectional antenna is capable of transmitting in all the possible directions with equal intensities. The value of gain at 4.322 GHz is 8.5 dB

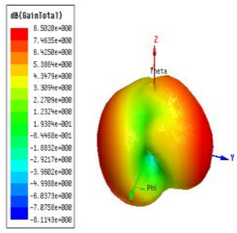


Fig.5.3D radiation pattern at 4.32 GHz

For perfect impedance matching, the reactance should be negligible and impedance should be 50 Ω. From the plot we can see the value of impedance is 49+j1.03 Ω at 4.322GHz.

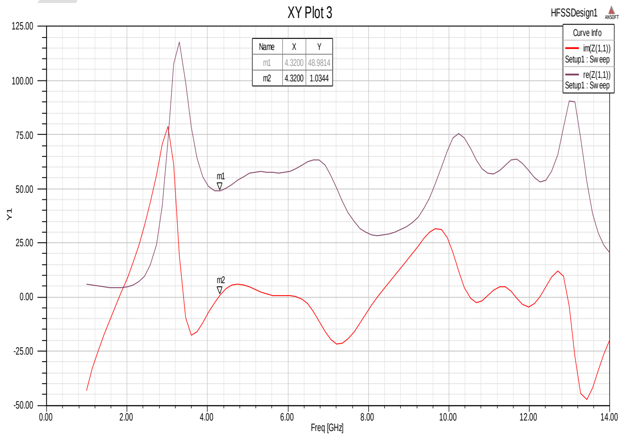


Fig 6 Real and imaginary impedance versus frequency [GHz]

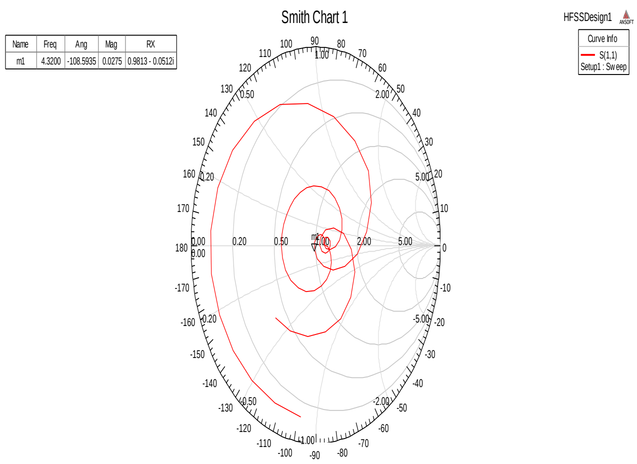


Fig.7. Smith chart

B. Simulated Result of EMA With DGS And Slot

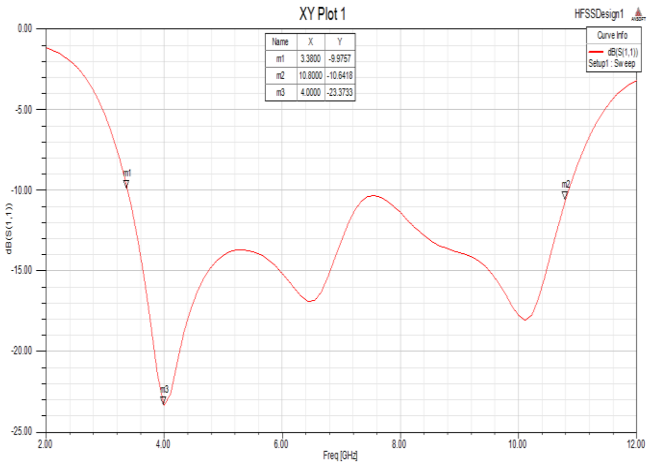


Fig 8. Reflection coefficient [dB] versus frequency [GHz]

The return loss versus frequency curve with the optimized values is shown below. This shows that the proposed antenna covers the entire UWB.As seen in the plot for return loss the graph is below -10dB for the desired frequency range hence, this graph is satisfied for better performance. Antenna operates at a frequency range of 3.38GHz to 10.8GHz. It is observed that the return loss curve has resonance frequency at 4 GHz.

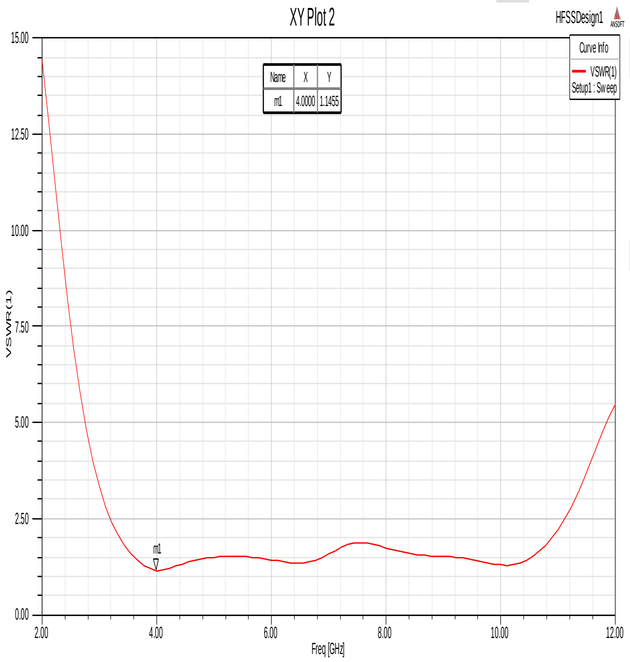


Fig 9.VSWR versus frequency [GHz]

Fig 9 shows the plot for VSWR versus frequency. The plot specifies the value of VSWR between 1 and 2 which satisfies the UWB characteristics and for the same region the return loss is also less than -10dB.The value of VSWR is 1.145 at resonant frequency of 4GHz

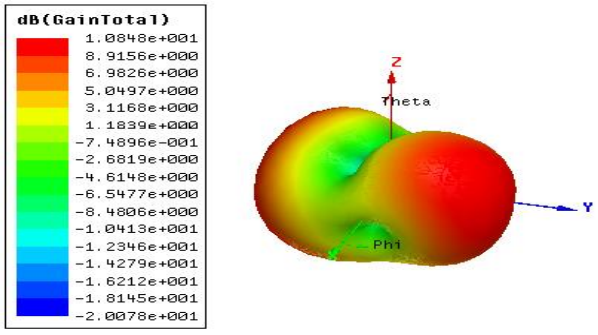


Fig10. 3D radiation pattern at 4.32 GHz

The measured radiation patterns of the antenna on the E-plane and H-plane at resonant frequencies of 4GHz is shown in Fig 10. The results show reasonable omnidirectional radiation pattern .The omnidirectional antenna is capable of transmitting in all the possible directions with equal intensities. The value of gain at resonating frequency of 4GHz is 1.0848.

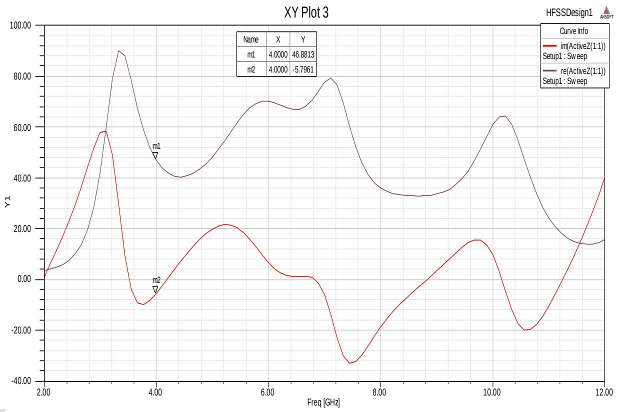


Fig 11 Real and imaginary impedance versus frequency [GHz]

For perfect impedance matching, the reactance should be negligible and impedance should be 50 Ω. From the plot we can see the impedance is approximately 50 Ω, hence it is satisfied. The value of impedance at resonating frequency of4GHz is 46.88+j5.79 Ω.

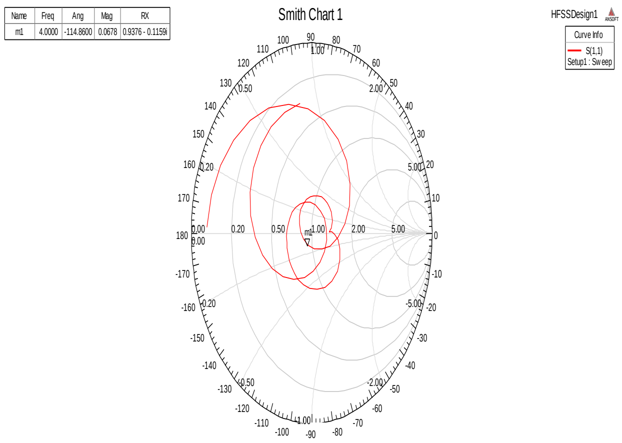


Fig.12. Smith chart

Table 2 Performance parameter of EMA

Performance Parameter	Elliptical Monopole Antenna	EMA with DGS and Slot
Resonant frequency	4.32GHz	4GHz
Frequency range	3.48GHz to 13.07GHz	3.38GHz to10.8GHz
VSWR	1.01	1.14
Impedance (Re)	48.98Ω	46Ω
Reactance	j1.03	-j5.7
Gain	8.5 dB	1.08 dB

From above table we can say that bandwidth of antenna is reduced but it satisfied the ultra wide band frequency range and gain is enhanced from 8.5 dB to 1.08 e+001.

VI. SUMMARY & FUTURE SCOPE

The simulated results are obtained for different antenna parameters like return loss, gain, impedance, voltage standing wave ratio (VSWR), radiation pattern, and directivity.

The antenna designed can be used for various Ultra Wide Band applications ranging from 3..38GHz to 10.8GHz. It is observed that we have achieved the desired specifications.

In the future, other reconfiguration techniques can be used such as electrical, mechanical. Fabrication of antenna can be done with PIN diodes, varactor diode, MEMS switches, photo conductive switches etc.

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