Design, Analysis and Fabrication of a Microstrip Slot Antenna

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Abstract: ***Antenna technology has come a long way in modern day electronics and communication world: from being a wire to printed technology. Most of the communication advancement is due to the rapid advancement in the field of antenna. High frequency electromagnetic signals are being used for communication and telemetry purposes. In this paper a antenna is designed for working in microwave frequencies The objective of this work is to design and simulate modern day advanced antenna and to obtain a better insight towards the working of an antenna and its characteristics .To keep design minimalistic and fabrication easy,a microstrip slot antenna is chosen.It is low profile simple to design and fabricate. Since microwave frequencies are being used nowadays,it would be apt to learn and analyse how an antenna works in those frequencies .Hence the idea is to design a mcirostrip slot antenna of resonant frequency 2.4 GHz,on a glass/FR4 substrate of 100mm,having a slot length 43mm and a slot width 1mm,with a microstrip line feed and stub matching,analyse and study about its characteristics,fabricate the design and test to see its conformance.***

Key Words: Microstrip antenna, slot antenna, complementary antenna,patch antenna

I. INTRODUCTION

The slot antenna is just an opening created in conductor with a particular dimension such that it radiates electromagnetic waves or receives EM waves .Normally a conductor if it is fed with electric signals and surrounded by air or vacuum radiates EM waves.The complement is also true if a slot is made filled with air and surrounding the slot if we fill it with conductor the slot will radiate EM waves.according to Babinets principle. A narrow rectangular in an infinite conducting sheet will radiate like an antenna if fed with Rf signal between the opposite sides of a slot.such an antenna is called slot antenna.The radiating properties of such a slot can be deduced by the application of Babinetstheorem.Bybabinets theorem the field distribution around this slotand the radiation from it can be shown to be the same as for an electric dipole which would just fill the slot with the following modifications. [1]. As compared with the electric dipole the electric and magnetic vectors are interchanged .the electric field from the slot is related to the magnetic field from the dipole by the impedance of free space.Thus at any point

$E_{slot} = \eta H_{dipole}$ (1) similarly $H_{slot} = E_{dipole}/\eta$ (2)

The electric field in the equatorial plane of the slot changes sign from one set of the conducting sheet to the other.the impedance at the feed point of half wave slot can

be deduced from the known dipole impedance of 73Ω. From Babinets principle [4] and Booker's extension of it ,it can be shown that if a screen and its compliment are immersed in a medium with an intrinsic impedance η andhave terminal impedance of Z_{slot} and Z_{dipole} respectively ,the impedances are related by

$Z_{slot} Z_{dipole} = \eta^2/4$ (3)

The impedance of the slot can be deduced by using folded slot. Microstrip slot antennas are used in broad range of applications from wireless and satellite communication system to medical system, primarily due to their miniaturization,simplicity, inexpensive, conformability, light weight, low profile, reproducibility and ease of integration with solid state device [1-4].

A mcirostrip antenna consist of a radiating patch on one side of a dielectric substrate with a ground on the other sied.This antenna is also referred to as patch antenna .Microstrip slot antenna is simple in structure. It consists of microstrip feed that couples electromagnetic waves through the slot above and slot radiates them. slot antennas are an about λ/2 elongated slot, cut in a conductive plate and excited in the centre. [10] U shaped slot on a rectangular patch are used for broad banding[7].By using high permittivity substrate and by different shape of slot we can enhance the gain of antenna The slot antennas can be fed by microstrip line ,slot line and coplanar wave guides. Fractal patch antennas finds application for wide band of frequency transmission and reception.[8].Decoupling slots are used for dual band of operation and finds applications in WLAN.[9].

II. ANTENNA DESIGN

The design of proposed mcirostrip slot [7] antenna requires certain fundamental parameters. Basic parameters required For an antenna design are its resonant frequency(fr),dielectric constant(ε_r) and the height of the substrate material(h).From these three parameters the width of the slot (W) can be calculated.The parameter can be calculated from the following equation.

$$W = \frac{1}{2 f_r \sqrt{\mu_o \varepsilon_o}} \sqrt{\frac{2}{\varepsilon_r + 1}} metre (4)$$

Where W= width of the slot f_r = resonant frequency.ε_o=permittivity of free space,μ_o= permeability of free space,ε_r = dielectric constant of the substrate. After finding the width of the slot ,effective dielectric constant of the substrate has to be calculated.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1 + 12\, h/w]^{-1/2} \qquad (5)$$

ε_{reff} = effective dielectric constant of the substrate
ε_r = dielectric constant of the

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substrate

h=height of the substrate material

W= width of the slot

Once the effective dielectric constant of the substrate is calculated the extended increment length of the slot(ΔL) can be calculated from the following expression.

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

ΔL = Extended increment length of the slot

h=height of the substrate material

W=width of the slot

ε_{reff} =effective dielectric constant of the substrate

Once ΔL is known ,the actual length of the slot (L) can be determined from the following expression

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_o\varepsilon_o}} - 2\Delta L \text{ metre} \qquad (7)$$

L = Length of the slot

fr = resonant frequency

One more important parameter in the design of the antenna will be position of the inset feed point(y_o) where the input impedance will be 50Ω.This can be determined from the following expression in which R_{in} will be the input impedance of the antenna designed.

$$R_{in}(y=0) = \cos^2\left(\frac{\pi}{L}y_o\right) \qquad (8)$$

The proposed antenna was designed using the following parameters

Resonant frequency (f_r)= 2.5GHz

Height of the material(h)=100mm

Dielectric constant of the substrate(ε_r) = 3.83

From the calculations the width of the slot (W) was found to be as 0.782 mm and the effective dielectric constant was found to be(ε_{reff}) 2.455.The extended increment length of the slot was calculated to be 17.76mm(18)mm respectively. Length of the slot (L) was calculated to be L=42mm.The diagram of the designed antenna is shown below.

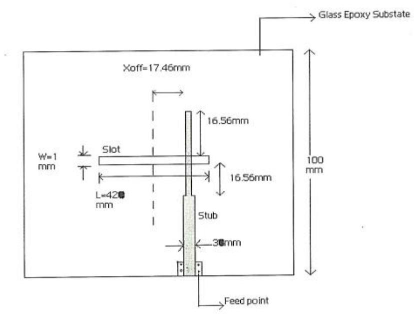

Fig. 1. sketch of the designed antenna

A. Simulation and Out Parameters

The softwares used to design and simulate the microstrip slot antenna are SUPERNEC AND 4NEC2X.[5]SuperNEC is a Method of Moments electromagnetic (EM) simulation package for windows platform.The easy to use 3D input GUI ,making use of multilevel assemblies ,provides the easiest structure input and model creation tool[6].the output viewer provides the design engineer with all necessary information for proper antenna analysis including features such as 3D and 2D pattern plots,smith chart plot with network analyzer style marker, coupling plots ,efficiency plots etc.

From Babinet’s principle a microstip slot was designed in the software and simulated for the output parameter values and its radiation pattern

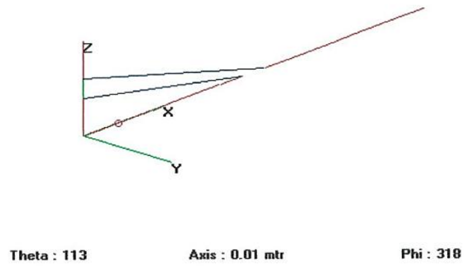

Figure2 Antenna designed in 4nec2

Further the antenna is simulated using the same software and the current and radiation pattern is obtained.

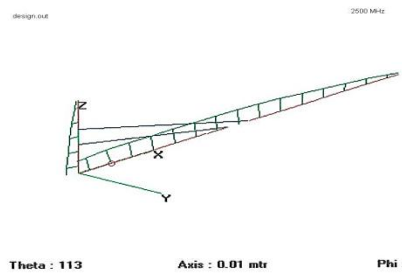

Figure3 Currents and phase over the designed antenna

The far field pattern of the designed antenna is obtained as shown in figure 4

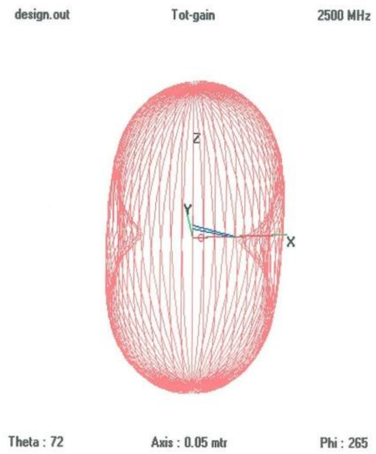

Figure4 Radiation Pattern of the designed antenna

The output parameters are shown in the main window of the software interface. All the ouput parameters are measured when a source of 1 volt is given to the antenna as input voltage. All the required output parameters are obtained from the software by simulation of the design.

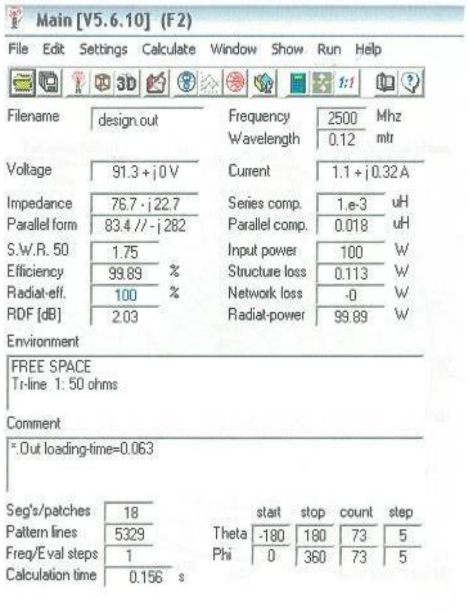

Figure5 Output parameters shown in 4nec2 after simulation

These are output parameters obtained for the designed antenna when it was simulated to radiate in free space using software as given figure 5.Further the radiation pattern was obtained in a polar plot as if figure 6 and also the smith chart of the impedance patterns are obtained.

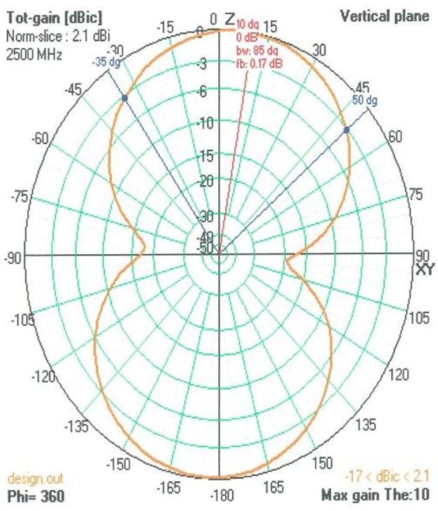

Figure6 Radiation pattern of the designed antenna in polar plot

The smith chart pattern of the impedances and SWR of the slot antenna is obtained.and shown in figure7

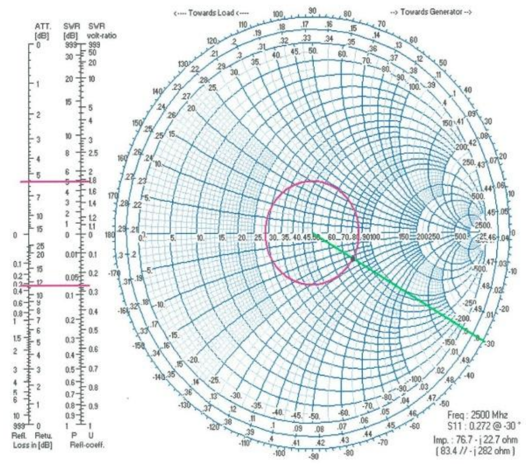

Figure7 Smith chart showing impedances and SWR

The stub matching is done using a software called TX line. Here are the simulated results from the software interface shown Figure

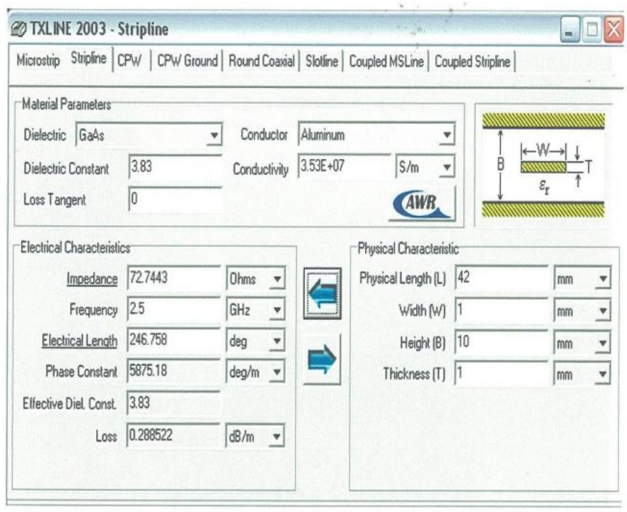

Figure8 Stub matching using TX Line software

B. Fabrication of the Antenna

The designed antenna was fabricated to the specified dimensions on a Glass epoxy dielectric substrate with a dielectric constant of 3.83.The Microstrip feed line is used as a feed line and also as a transformer with stub matching. It is etched on to the substrate with aluminiummaterial. The impedances of the stub were brought down to almost the same value of simulations but with a slight deviation. The feed point has proper connector terminals for the antenna to get connected to equipments such as a microwave source or a vector network analyzer. The fabrication was carried out with help of an industry.

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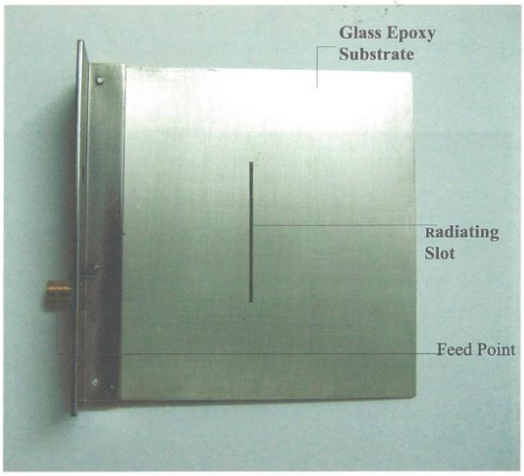

Figure9 Front view of the fabricated slot antenna

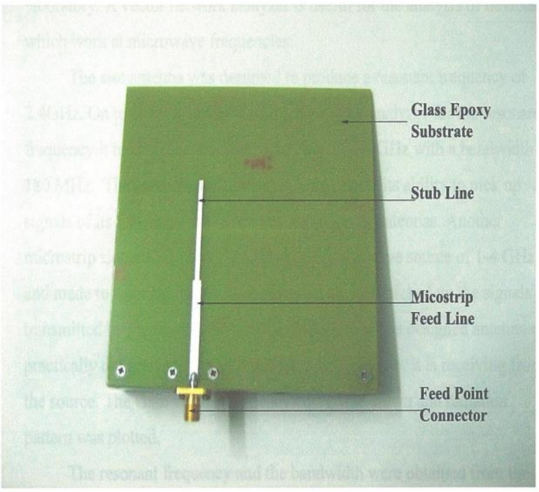

Figure 10 View of the fabricated slot antenna from behind

C. Testing the Antenna

The fabricated antenna was further tested in the aboratory to check for its conformance with the simulation results.The antenna was connected to an agilent Technologies Ltd vector network analyzer in the laboratory. A vector network analyzer is useful for the analysis of devices which work at microwave frequencies. The slot antenna was designed to produce a resonant frequency of 2.4GHz.On testing the antenna with the network analyser for the resonant frequency it returned a value approximately to 2.4 GHz with the Bandwidth of 180 MHz.The antenna was further tested to check its ability to pick up signals of its frequency range transmitted by other antennas .Another microstrip antenna was connected to a Microwave source of 1-4GHz and made to transmit energy.The designed antenna picked up the signals transmitted and a radiation pattern was practically obtained by measuring the amount of power it is receiving receiving from the source.The gain versus frequency curve was drawn and radiation pattern was plotted.The resonant frequency and the bandwidth were obtained from the network analyzer.the gain of the antennaat resonant frequency was measured using a power meter as 5.13 dB.

Figure 11Resonant frequency of the antenna on Network analyzer

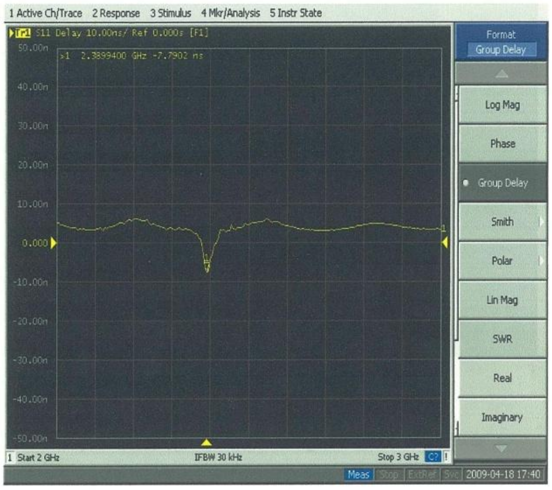

Figure 12 Group delay of output frequencies of the antenna –Network analyzer

Figure 13 SWR pattern of the antenna designed – Network analyzer

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III. ANTENNA OUTPUT

The gain of the antenna at resonant is measured from the frequency vs gain Plot as shown Table 1

Frequency (GHz)	Gain (dB)
2.0	-0.35
2.1	-0.9
2.2	-0.75
2.3	0.4
2.4	5.13
2.5	4.8
2.6	2.3
2.7	-0.32
2.8	-0.71

Table 1 Frequency versus Gain of the designed antenna

The Radiation pattern of the designed antenna was measured using power meter and Gain(dBm) vs angle(degrees) direction plot as shown Table II

Angle (degrees)	Gain(dBm)
0	5.12
90	-0.82
180	4.85
270	-0.88
360	5.13

Table 2 Radiation pattern measurements.

IV. RESULTS

Thus finally a microstrip slot antenna was designed ,simulated fabricated and tested .It was analyzed ,studied and experimentally verified successfully conforming to all the theories behind it,looking into possible applications in which these antennas can actually used.

V. CONCLUSION

In the current work the designing and manufacturing of microstrip slot antenna has been accomplished.The antenna parameters were simulated using 4nec2 software and measurements were developed with a vector Network analyser . It is observed that resonant frequency of proposed antenna is 2.4GHz ,directive gain at 360° or 0° is 5.13(dBm).,Group delay 8 n seconds and Voltage standing wave ratio (VSWR)at the feed point input is 1.3.All these parameters at the resonant frequency of 2.4 GHz.

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