Compact Microstrip Antenna for Bandwidth Enhancement

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Abstract— In this paper compact microstrip antenna for bandwidth enhancement has been proposed.In this microstrip antenna rectangular shaped slots have been cut on the patch for bandwidth enhancement .Rogers RO 4003 has been used as a substrate.The proposed antenna resonates at 3.1Ghz,4Ghz,4.9Ghz and 6.3Ghz VSWR≤2 in 4.8-5.10Ghz frequency band. Efficiency of this antenna is 97.97%.This antenna works for multiband and wideband applications. In this paper return loss, radiation pattern, VSWR, gain have been studied. Ansoft HFSS tool has been used for designing and simulation. It works for Wimax, satellite, Wireless applications (WLAN) and radar applications, medical applications.

Key words: Wireless, satellite.

I. INTRODUCTION

An antenna is usually metallic device (as a rod or wire) for radiating or receiving radio waves. Energy transitional structure between free space and a guiding device. Microstrip patch antenna became very popular in the 1970s primarily for spaceborne application. A microstrip patch antenna consists of a dielectric substrate, with a ground plane on the other side. Due to the growing of wireless communication market, future communication systems are expected to provide multimedia, high data rate as well as communication services. Many applications such as; imaging,vehicular radar, communication and measurement systems require integrated antennas of small size, low cost and low profile [1] .

So that the demand of microstrip antennas still persists due to its light weight, low profile, low cost and ease of integration with microwave circuit and no other antenna still could replace its features and hence it is being widely used in the wireless and other applications. However standard rectangular microstrip antenna has the drawback of narrow bandwidth and low gain.

The bandwidth of microstrip antenna may be increased using number of techniques such as use of a thick or foam substrate , cutting slots or notches like U slot , E shaped , H shaped patch antenna, introducing the parasitic elements either in coplanar or stack configuration, and modifying the shape of the radiator patch by introducing the slots[2].

There are some other methods which are used to increase the bandwidth of microstrip antenna such as increase the substrate thickness, use of a low dielectric constant substrate, use of various feeding techniques and impedance matching use of slot antenna geometry and multiple resonators.The microstrip patch antenna is very well suited for applications such as wireless communications system cellular phones, pagers, radar and satellite communication system[9]. The advantages of microstrip antenna have made them a perfect candidate for use in the wireless local area network (WLAN) applications. Though bound by certain disadvantages microstrip patch antenna can be tailored so they can be used in the new high speed broadband WLAN system.

Commonly, the operation BW depends on the requirement of the wireless communication system, which needs various BWs. Unfortunately, it may be wastes a lot of time for antenna designers to find a suitable slot antenna structure according to a required operation BW. Thus, the investigation on the relationship between the antenna structure and the BW becomes very useful. For this purpose, this paper presents a deep study on the Microstrip antennas . While in this paper, the antenna BW is greatly affected by various cut slots. In , the bandwidth of an aperture coupled microstrip patch antenna has been improved by using an appropriate impedance-matching network using filter design techniques. The use of two triangular structures for microstrip patch antennas to improve the bandwidth has been studied . Unbalanced structures have also been used to design patch antennas to improve bandwidth

The 74.5% bandwidth can be obtained by adding impedance matching network, but the design is inconvenient and the production is complexity, which restrict the further development of this technology. The design technique of wideband microstrip antenna is analyzed detailedly. The wideband operation is achieved by combining two technologies: special material substrate and add matching network. The S11 parameter of the antenna has been simulated by the HFSS, and the bandwidth of antenna is 74.5% , which is wider than commonly microstrip antenna[3-8].

II. ANTNNA GEOMETRY

It is well known that microstrip-fed antennas have the advantage of a relatively large bandwidth, good impedance matching, and capability for full integration with active or passive components.

The structure of proposed antenna shown in the fig.1

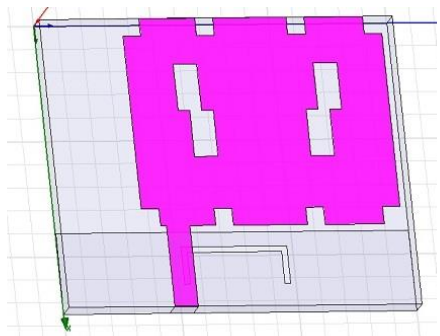

Fig.1: proposed microstrip antenna

To reduce costs, the substrate was selected as Rogers , which has a relative permittivity of r=3.55, loss tangent of 0.0027 and a thickness of 1.6 mm . The ground plane is chosen to be rectangular.

In this FR-4 Epoxy substrate has been taken having thicknesss of 1.6mm.In this dimension of patch are 18mm by 22mm. Figure 1 shows the schematic of the conventional planar slot antenna based on the Rogers substrate and a 50ohm microstrip feed-line used to excite the antenna. For the design of 50ohm microstrip feed-line to be compatible with standard measurement systems. In this, four rectangles of 1.5 by 1.5 have been removed from the patch in the first iteration. In this by applying different iterations self similar structures are obtained

Parameter	Value
Length of substrate	25mm
Width of substrate	30mm
Length of patch	18mm
Width of patch	22mm
Thickness of substrate	1.6mm
Dielectric constant of substrate	3.55
Loss tangent of substrate	0.0027
Feed to patch	Microstrip feed line

Table 1: Antenna Dimension

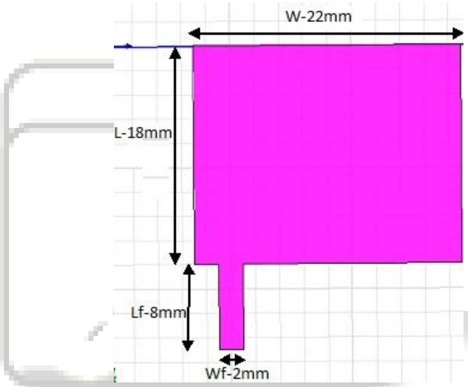

Fig. 2: simple patch antenna zeroth iteration

This is the simple rectangular microstrip patch.Length of patch L-18mm ,W-22mm,Lf-8mm, Wf-2mm. Figure 3 shows the simulated return loss curve of the simple Microstrip patch antenna against frequency. The return losses of simple Microstrip patch antenna is -22 dB around 6.4GHz and -19.3dB around 3.4GHz .The simple Microstrip patch antenna operates in the frequency range of 3.2GHz to 6.95GHz. Patch Waveform

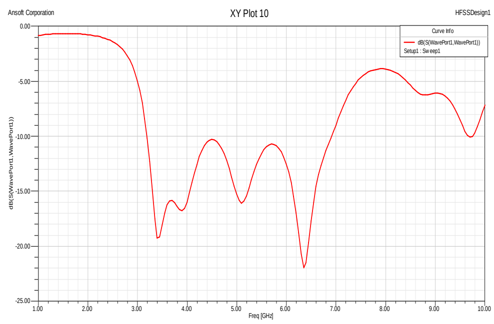

Fig. 3: Simulated results of return losses versus frequency

Now rectangular slots are cut into this patch. In the first iteration four rectangles of dimensions 1.5mm by 1.5mm have been cut from the patch as shown in figure4.In this, all slots having same length and width .If we change L and W results are not improved.

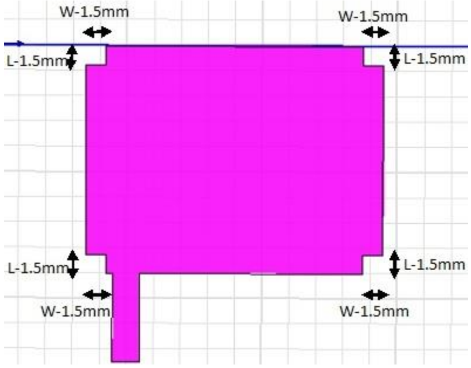

Fig.4: first iteration Microstrip antenna

In first iteration four slot cut reduces the size of antenna.

Size reduction in first iteration is less.Various parameters of antenna are improved and antenna resonates at multiple freq. The return losses of first iteration -30dB around 5.1GHz -26.5dB around 6.4GHz ,-22.8dB around 3.4GHz and -20dB around 4GHz.

First iteration result

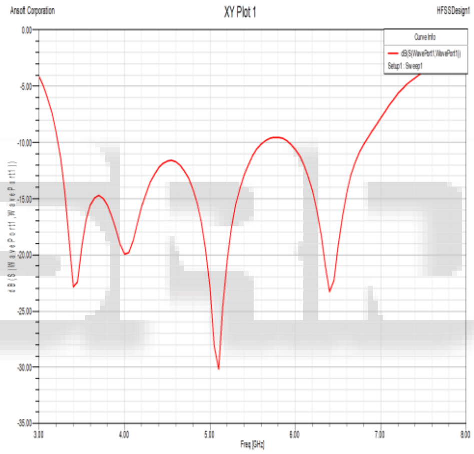

Fig.5: Simulated results of return losses versus frequency

After it,on the same side four small slot having dimension 1.5 by 1.5 are cut from the patch shown in figure.

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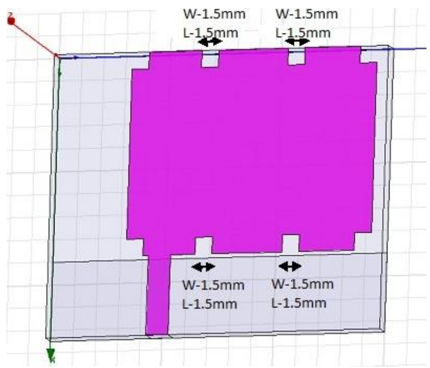

Fig. 6: Second iteration microstrip antenna

In second iteration size of antenna is reduced .The return losses of 2nd iteration -31dB around 6.35GHz, -26dB around 5GHz,26.5dB around 3.35GHz.

Second iteration result

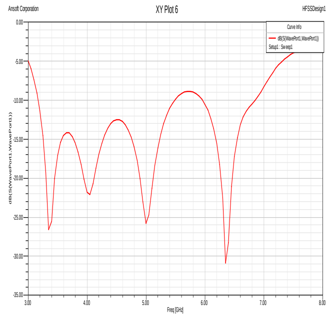

Fig.7: Simulated results of return losses versus frequency

This is the third iteration further rectangular cuts into patch. By cut slot from patch impedance matching is high . If impedance matching of any circuit is proper / good than Reflection of signal is very less from receiver to transmitter so that complete signal is received at receiver side.The length of 50ohm microstrip feed line is adjusted to achive an excellent input matching. In third iteration,symmetric four slots in width and length are cut from patch. The design of antenna after third iteration shown in fig. 8

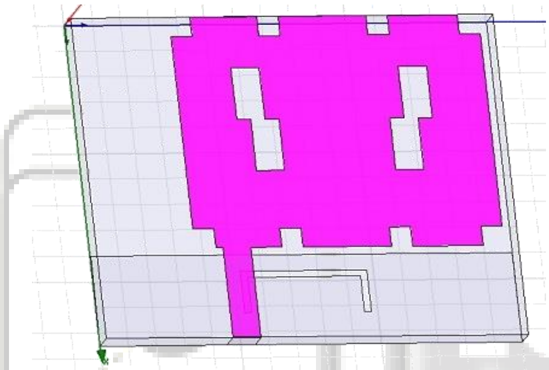

Fig. 8: third iteration Microstrip antenna

In third iteration area of the patch has been reduced .Return loss that obtained is very good as compare to first and second iteration. Bandwidth of proposed antenna is 74.8%. The basic antenna consist of feed ,and a ground plane with a modified slot.

Third iteration result

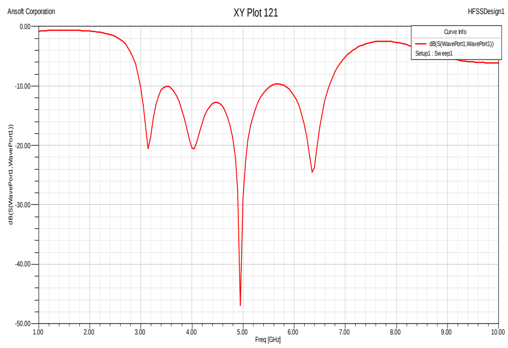

Fig.9: Simulated results of return losses versus frequency

Efficiency of this antenna is 97.97%. Size reduction in third iteration is maximum..Various parameters of antenna are improve and antenna resonates at multiple frequencies.

The return losses of third iteration -47dB around 4.95GHz, -24.5dB around 6.35GHz ,-20.5dB around 3.15GHz and –20.5dB around 4GHz. Return losses are maximum in third iteration.

A. Defected ground structure on proposed antenna:

After third iteration in the proposed antenna design we cut a thin u slot in the ground and we get improvement in antenna parameters.

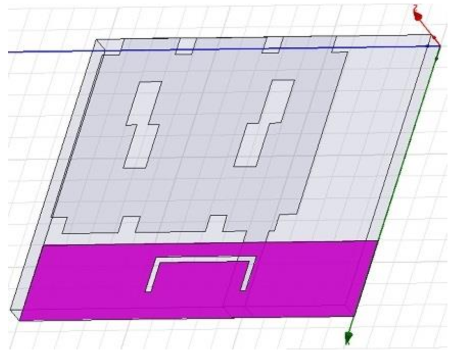

Fig.10: Proposed antenna with DGS

DGS result

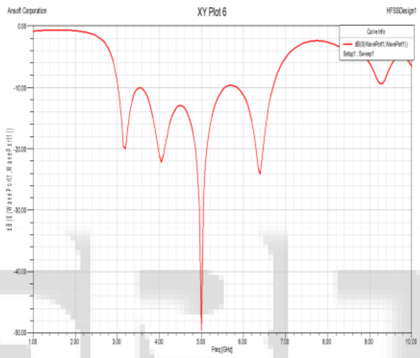

Fig.11: Simulated result of retun losses versus frequency

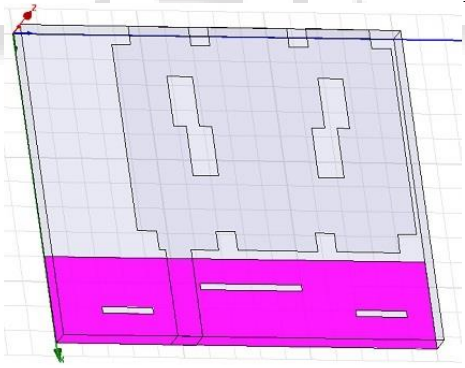

Fig.12: Ground Structure 1

Ground Structure Result

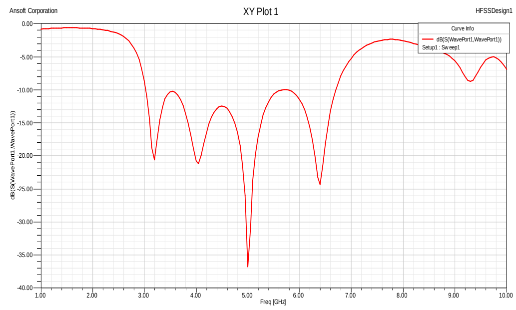

Fig.13: Simulated result of retun losses versus frequency

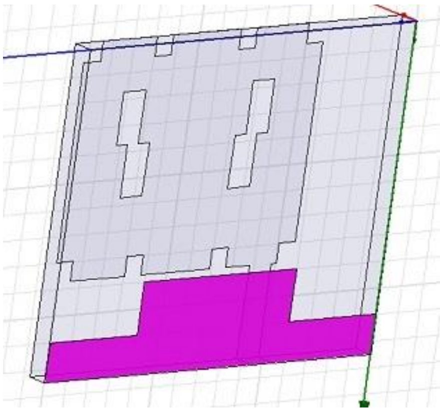

Fig.14: Ground Structure

III. DESIGN REQUIREMENTS

There are three essential parameters for the designing of a microstrip antenna. Firstly, the resonant frequency(f_0) of the antenna must be selected.

Secondly,the dielectric material of the substrate (ε_r) selected for this design is Rogers(RO) 4003 which has a dielectric constant of 3.55 and loss tangent is 0.0027.The dielectric constant is important design parameter.

Lastly, substrate thickness is important design parameter. Thick substrate increase the fringing field at the periphery or the radiating patch.

IV. PHYSICAL PARAMETERS

The antenna parameters of this antenna can be calculated as :

Width of the patch

$W=c/2f_0(\sqrt{(\varepsilon_r+1)/2})$

Effective Permittivity

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

Calculate the extended length of patch

$\Delta L=0.421h(\varepsilon_{reff}+0.3)(w/h+0.264)/(\varepsilon_{reff}-0.258)(w/h+0.8)$

Calculate the Patch Length

$L=\lambda_0/2-2\Delta L$

Calculate effective length of the Patch

$L_{eff}=L+\Delta L$

Calculations of dimensions

When solution frequency(fo)=6.5Ghz

h = 1.6mm

ε_r = 3.55

$W=3\times108/(2\times 6.5\sqrt{(3.55+1)} \div 2)$=22.6mm

L=Leff-2ΔL

V. SIMULATION AND RESULTS

A. *Return losses:*

The proposed antenna was constructed and studied. The return losses of the antenna are measured using an ansoft HFSS tool. Figure 15 shows the simulated results of return losses in different iterations. In this, return losses in the zeroth iteration are – is -22 dB around 6.35GHz and -19.3dB around 3.4GHz .In the first iterartion return losses are -30.2.dB around 5.1GHz ,-23.3dB around 6.4GHz. The return losses of 2nd iteration -31dB around 6.35GHz, -26dB around 5GHz,26.5dB around 3.35GHz. The return losses of third iteration -47dB around 4.95GHz, -24.5dB around 6.35GHz ,-20.5dB around 3.15GHz and -20.5dB around 4GHz. Return losses are maximum in third iteration.

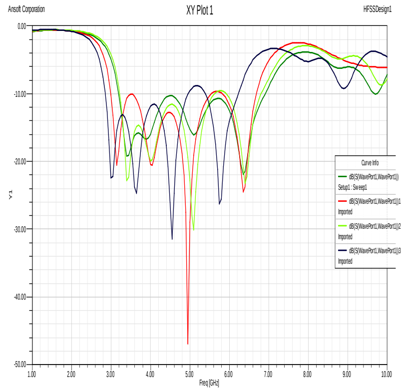

Fig. 15: Simulated results of return losses versus frequency

Table of return losses at different iterations

Iteration Number	Resonant Frequency(Ghz)	Return Loss(db)
0th Iteration	6.35	-22
	3.4	19.3
	5.1	-16
1st Iteration	5.1	-30.2
	6.4	-23.3
	3.4	-22.8
	4	-20
2ndIteration	6.35	-31
	3.35	-26.5
	5	-26
	4	-22
3rd Iteration	4.9	-47
	6.35	-24.5
	4	-20.5
	3.15	-20.5

Table 2: Return losses

B. *Radiation Pattern:*

An antenna radiation pattern or antenna pattern is defined as “a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization.

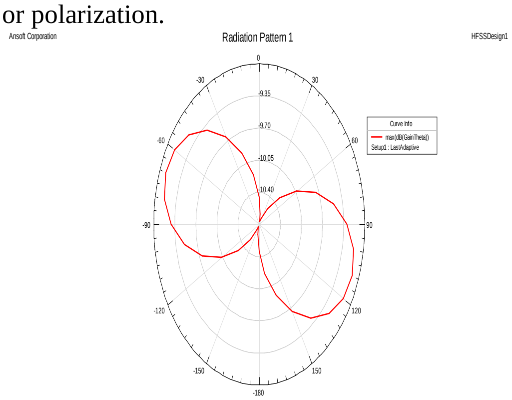

Fig. 16: Radiation Pattern at ‘0deg’

The radiation property of most concern is the two- or three dimensional spatial distribution of radiated energy as a function of the observer's position along a path or surface of constant radius .In this paper, radiation pattern is taken in terms of gain(dB).Figure7 shows the simulated results of radiation pattern at 0db and figure 8 shows the simulation result at 90 deg.

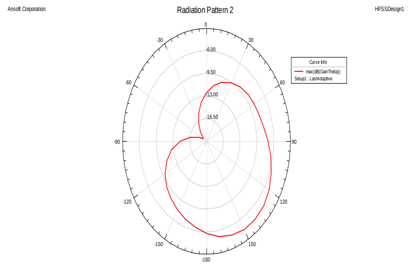

Fig. 17: Radiation Pattern at '90 deg'

C. 3D polar plot:

Fig.10 shows the 3D polar plort in terms of gain theta.This plot indicate the radiation intensity an gain of the antenna in different directions.

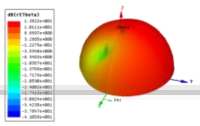

Fig. 18: 3D Polar plot

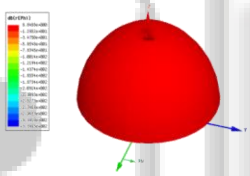

Fig. 19: 3D Polar plot in terms of gain total.

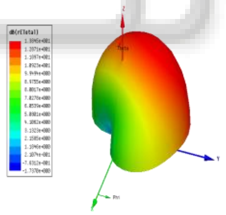

Fig. 20: 3D Polar Plot

D. VSWR:

VSWR(voltage standing wave ratio) should be ≤2. In this design,VSWR ≤2 in 4.8-5.10 Ghz frequency band.

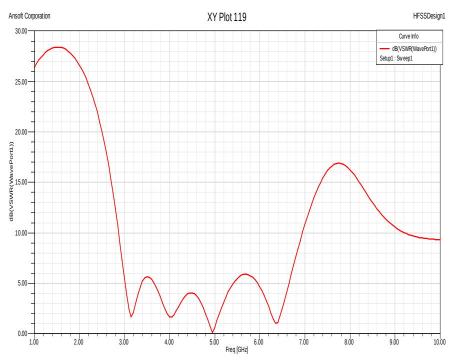

Fig. 20: VSWR versus frequency

In this design, VSWR ≤2 in 6.3-6.45 GHz and 3.95-4.10GHz frequency band. VSWR is 0.61 around 5 GHz, 0.07 around 4.95 GHz, 1.02 around 6.35 GHz and 1.62 around 4.05GHz.

VI. CONCLUSION

In this paper microstrip antenna has been studied for bandwidth enhancement. In this microstrip feed line is used to excite the antenna .In this microstrip antenna rectangular shaped slots have been cut on patch for bandwidth enhancement. Bandwidth of this antenna is 74.8 %.The proposed antenna resonates at 3.1Ghz,4Ghz,4.9Ghz and 6.3Ghz VSWR≤2 in 4.8-5.10Ghz frequency band. Efficiency of this antenna is 97.97%.This antenna works for multiband and wideband applications. In this paper return loss, radiation pattern, VSWR, gain have been studied. Ansoft HFSS tool has been used for designing and simulation. It works for Wimax, satellite(6.1-7.1Ghz), Wireless applications (WLAN) and radar applications, medical applications.

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