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Metamaterial microstrip slotted patch antenna for bandwidth improvement at 1.87GHz

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***Abstract*— This paper presents a proposed Rectangular metamaterial microstrip slotted patch antenna is used for improving a bandwidth at 1.87 GHz. The bandwidth of the simple microstrip patch antenna is 39 MHz and the return loss is -11.8461 dB. The bandwidth of the proposed metamaterial microstrip slotted patch antenna is increased to 60 MHz and the return loss is reduced up to -17.4437 dB at 1.87 GHz.. The proposed antenna is designed at a height 3.2 from the ground plane by using HFSS(High Frequency Structure Simulator). The band width is increased from1.59% to 3.2%. This proposed design has small size, easy to fabricate and better directivity.**

***Index Terms*—microstrip patch antenna, Metamaterial,. HFSS ,Return loss.**

I. Introduction

Microstrip antennas are large applications in many wireless communication systems because of their low profile and light weight. Moreover, the microstrip patch antennas can provide circular and dual polarizations, dual-frequency operation, frequency agility, broad band-width, feed line flexibility, omnidirectional patterning.

The principle of operation of a patch antenna can be explained as follows. The electric field is zero at the centre of the patch, maximum at one side, and maximum at the opposite side. According to the instantaneous phase of the applied signal, the sign of field on the sides of patch changes continuously. The electric fields extend the outer periphery of the patch which is called as fringing fields and cause the patch to radiate. The fundamental mode in a rectangular patch is TM10 mode. Ground plane size ,resonant length, , metal (copper) thickness, patch (impedance) width, and dielectric constant are the several parameters which makes a change in the resonant frequency. The rectangular and circular patches are the basic and most commonly used microstrip antennas.

Typically a patch consists of thin conducting sheet mounted on Substrate. Radiation from the patch is like radiation from two slots, at the right and left edges of the patch. The “slot” is the narrow gap between the patch and the ground plane. Advantage of patch antenna than several antenna is lightweight and inexpensive. The main disadvantage of the patch antenna is narrow bandwidth and low gain. The use of meta material is helpful to improve the band width. Here the MPA (Microstrip Patch Antenna) is

using the meta material to improve the band width with higher return loss. Higher return loss is good for the communication field.

II. Design Specification

Width of the antenna is .

$$W = \frac{c}{2f0}\sqrt{2/\varepsilon_{r+1}}$$

Where c is the speed of the light

ε_r is the effective dielectric constant

Effective dielectric constant of the micro strip patch antenna.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Calculation of length extension

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

The patch effective length is

$$L_{eff} = \frac{c}{2f0\sqrt{\varepsilon_{reff}}} - 2\Delta L$$

III. Design Specifications

The design parameters for both simple and proposed antenna are listed in table I below.

TABLE I: Antenna Parameters

Parameter	Values For The Normal Antenna(mm)	Value For The Proposed Antenna
Resonant frequency, fr	2.4	1.881GHz
Dielectric constant, εr	4.4	4.4
Substrate thickness, h	1.6	3.6 mm
Width of patch, W	46.07	46.06 mm
Length of patch, L	33.58	36.8 mm
Width of feed line, Wf	3.05	3.05 mm
Length of feed line, Lf	33.58	33.58 mm
Metal thickness, t	0.2	0.2 mm
Depth of inset feed, Fi	10	10.00 mm
Gap between feed line and patch, g	0.975	0.975 mm

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The diagram for proposed antenna is as shown below in fig .1 with parameter length and width.

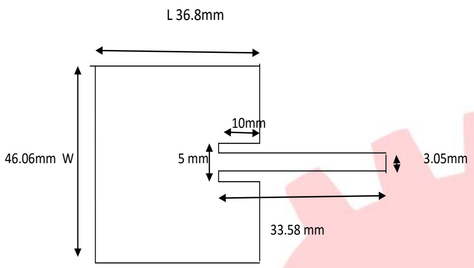

Fig. 1. Rectangular MPA at 1.88 GHz

The figure 2 shows the design of metamaterial structure loaded on the antenna

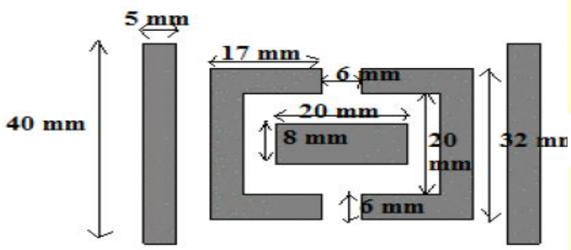

Fig.2.design of proposed metamaterial structure.

IV. SIMULATION RESULTS AND DISCUSSION

The simple and the proposed antennas are designed and analyzed their performance.

The figure 3 shows the return los parameter graph for the simple antenna with out loading metamaterial.

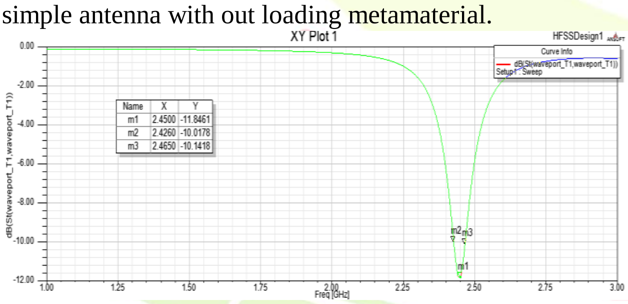

Fig. 3. Return loss of the simple antenna

The return loss of antenna designed with 2.4 GHz is shown in the fig.2.The return loss is -11.8461 dB. Here the point m2 and m3 indicated point on the graph having return loss below -10 dB. The band width is calculated as the difference between these two points shows 39 MHz bandwidth.

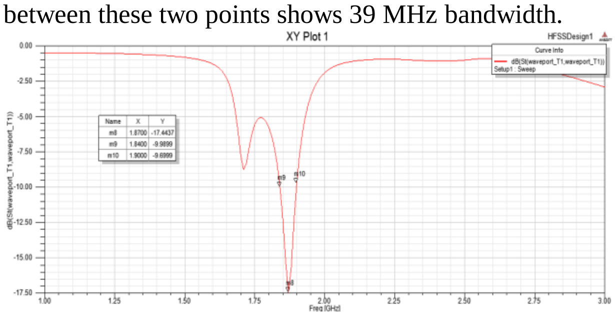

Fig. 3. Return loss plot of designed antenna

The antenna is designed with a resonant frequency of 1.881 GHz. Return loss plot shows that the antenna resonates at the desired frequency. It gives a return loss of -17.4437 dB at this frequency. Bandwidth of an antenna can be found from the return loss plot. It is difference in the frequencies resonating below -10dB. In the fig.4, m9 and m10 are -10dB points corresponding to different frequencies. Its difference gives the bandwidth of the antenna. The bandwidth of antenna is observed to be 60 MHz.

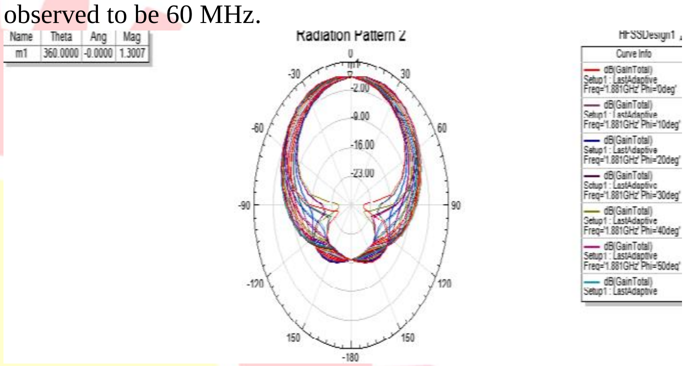

Fig. 5. Gain plot of simple antenna

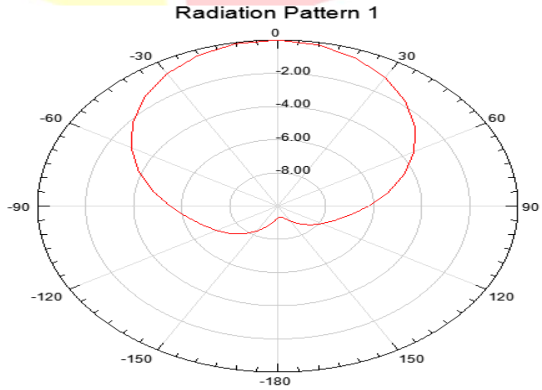

Fig. 6. Gain plot of the proposed antenna

V. COMPARISON OF SIMPLE ANTENNA AND PROPOSED ANTENNA

TABLE II: COMPARISON OF THE ANTENNAS

parameter	Simple antenna	Proposed antenna
Resonance frequency (GHz)	2.45	1.87
Return loss (dB)	-11.8461	-17.4437
Band width (MHz)	39	60
Gain (dB)	1.889e+000	8.2921e-001 dB

Comparing the results obtained from simple and proposed antenna reveals that the proposed metamaterial antenna shows high band width improvement and good increase in return loss while its gain is reduced.

VI. PARAMETRIC STUDY

There are so many parameters influencing the antenna performance like width and length of the patch, height of the substrate, width of the slot in proposed antenna.

A. Width Variation

The width of the patch is changed and analyzed change.

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The figure 7 shown below is the result of variation of width of patch on return loss parameter.

The measurements of return loss for different value of width are listed below in table III.

TABLE III: WIDTH VARIATION OF THE ANTENNA

Width (mm)	Resonance frequency(GHz)	Return loss(dB)	Band width(MHz)	Gain (dB)
46.06	1.87	-17.4437	60	0.8772
48.06	1.88	-15.35	63	1.1572
50.06	1.88	-14.3497	60	1.804
52.06	1.87	-13.9191	19	1.3788
54.06	1.87	-13.4325	70	1.4784
56.06	1.85	-14.13	132	1.4362

Based on the result got by analysing,the below figure 7 shows the returnloss graph for different values of width of patch

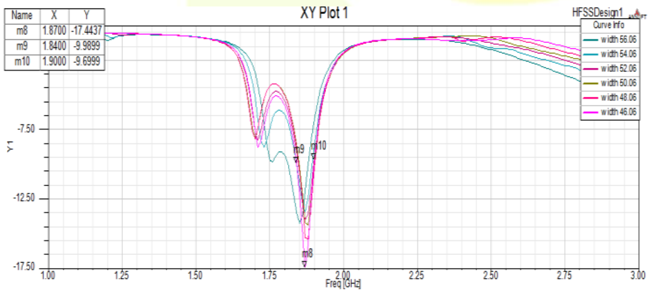

Fig. 7. Return loss graph for width variation in patch.

As the width varies, the resonance frequency is not changing a lot, but the return loss .It decreases as the width of the patch is increasing. Same way the band width of the antenna is increasing by the way. Gain is increasing due to the increase in the width

B. Length of the patch variation

Length of the patch is varied and studied the corresponding changes in antenna performance.

TABLE III: LENGTH VARIATION OF THE PATCH

Length (mm)	Resonance frequency (GHz)	Return loss (dB)	Band width(MHz)	Gain (dB)
36.8	1.87	-17.4437	60	0.8772
38.8	1.62	-17.3848	26.9	0.9168
40.8	1.49	21.3386	18	-.24194
42.8	1.42	-35	43.4	-0.824
44.8	1.33	-23.8805	43.8	-.24

From the table, the length of the antenna influences the resonance frequency. As length increases, the resonance frequency is decreasing. But the return loss increases. Corresponding band width is decreasing.

Figure below explains how the return loss responds to the variation of length

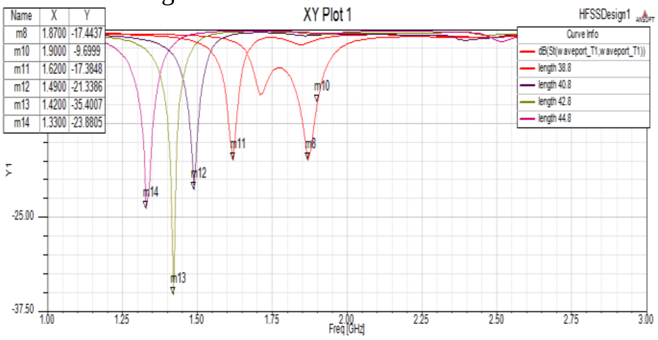

Fig. 8. Returnloss graph for length variation in patch.

C. Size Variation Of Slot

There is a slot on the patch of propose antenna. Change in slot width and length also effects the antenna performance. The size of the slotted patch size ids varied and studied the corresponding changes. T he antenna parameters for different slot size are listed below in table IV.

TABLE IV: SLOT WIDTH VARIATION

Size of the slot(mm×mm)	Resonance frequency(GHz)	Return loss(dB)	Bandwidth(MHz)	Gain(dB)
1×5	1.87	-17.4437	60	0.8772
3×5	1.84	-17.4925	61.7	0.9438
4×5	1.83	-17.6569	63.4	0.9771
5×5	1.81	-17.4671	66.2	0.9661
3×3	1.84	-17.3114	62.1	0.9615
2×2	1.86	-17.5740	51.7	0.9656

By analyzing the table the resonant frequency gradually decreases as we increase the slot length because of lengthening the current path due to the slot which means the half wave length along the radiating edge increases gradually. But due to increase of slot length we actually remove the material from the radiating edge of the microstrip patch antenna which causes the increase in as band width.

D. Height Variation O f The Substrate.

Height of the substrate has a role on performance of the antenna. Here the substrate used is FR-4. Height of the substrate (FR-4) is varied and studied the antenna parameter changes. The various height and the performance parameters are listed in table.

TABLE III: LENGTH VARIATION OF THE PATCH

Height(mm)	Resonance frequency(GHz)	Return loss(dB)	Band width(MHz)
1.6	2.45	-11.8461	39
2	2.35	-14.7384	56
2.6	2.25	-18.0281	65
3	2.23	-25.4155	70
3.6	2.18	-26.1125.	72

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With the increase in height , the fringing fields from the edges increase, which increases the extension in length ΔL and hence the effective length, decreases the resonance frequency. But the W/h ratio reduces, which decreases εreff and hence increases the resonance frequency. However, the effect of the increase in ΔL is dominant over the decrease in εreff. The return loss also increasing as the height of the substrate increases. The BW of the antenna increases from 39 MHz to 72 MHz

The figure shows return loss graph for height variation of substrate.

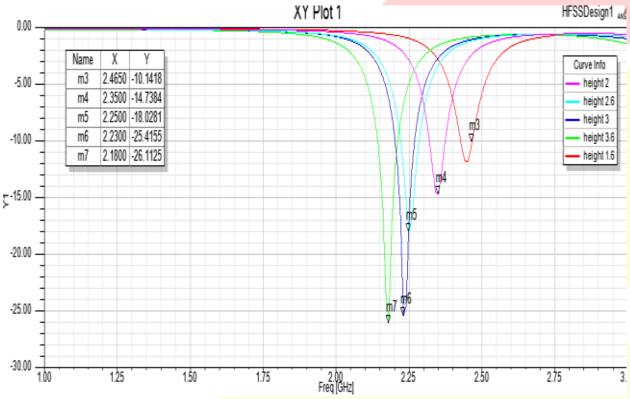

Fig. 8. Return loss for different height variation of the substrate

VII. Conclusion

The proposed antenna with metamaterial is achieving a good performance compared to the simple antenna. The band width of the proposed antenna is increased compared to the simple one. The proposed one has around 60 MHz bandwidth and that for simple antenna has 39 MHz, While gain is reduced.

On parametric study, as the width increase return loss, bandwidth and directivity are increasing while resonance frequency is not changing so far. When length of the antenna patch causes decrease in resonance frequency. And the band width and gain also decrease. As the slot width of the proposed antenna increases reduces the resonance frequency decreases, but return loss, band width and gain increases. Height of the substrate plays a role in performance. As it increases, the resonance frequency is reduced, while the return loss and gain increases.

So patch antenna with metamaterial structure has good performance compared to the simple patch antenna .the propose antenna increases the band width at 1.87 GHz to 60 MHz.

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