Bandwidth Enhancement of Arrow- Head Microstrip Patch Antenna

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Abstract : **The Microstrip Patch Antenna are widely used in Mobile and Satellite communication, Global Position System Applications, handheld devices etc. Microstrip patch antennas have advantages like light in weight, less volume, inexpensive, small size and ease of fabrication and conformity. Also, the microstrip patch antennas are also capable to provide dual and circular polarizations, dual-frequency operation, broad bandwidth range, etc. In this paper, an optimised design of Microstrip Arrow-head Triangular shaped slot antenna is proposed. Double slot is introduced in Micrstrip Arrow-head Triangular shaped slot antenna. The dimensions of the Triangular shape is also modified. The compared results demonstrates better performance of the proposed antenna.**

Keywords: Triangle slot, Coaxial Feed, Bandwidth, Gain, Directivity, VSWR.

1. INTRODUCTION:

Antenna is a device, designed to transmit or receive electromagnetic waves, also known as transducer. Microstrip antennas have marked several advantages over conventional microwave antenna and thus are widely used in many practical applications (1). A schematic Microstrip Patch Antenna is shown in Fig1.1. The antenna consists of a dielectric substrate of some thickness, having a radiating patch on the top and a conducting ground plane at the bottom of the dielectric substrate.

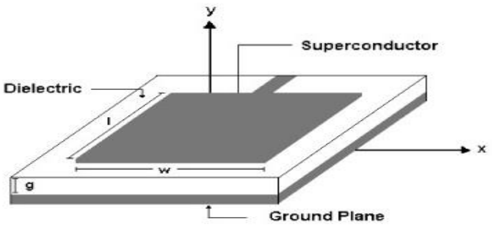

Fig 1.1 Microstrip Patch Antenna

Microstrip Patch Antenna:

A Microstrip Patch Antenna consists of a conducting and radiating patch, which can be of any planar or nonplanar geometry on top side of a dielectric substrate with a ground plane on its bottom side (1). Since the Microstrip Patch Antenna has planar configuration and ease of integration, it has been studied in detail and is heavily researched by scientists and is often incorporated as elements for an array. The rectangular and circular shaped radiating patches are most commonly incorporated in microstrip antennas. These shaped patches are used for the simple designed and the most demanding applications.

There are two types of feeding techniques in Microstrip antenna (1) :-

(A) Contacting type feeding technique : In this technique, the power is feed to patch directly by contact. Example to this type of technique are Micro strip line feed and coaxial probe feed.

(B) Non contacting type feeding technique : In this technique, the power is feed to the patch, with no physical contact being made with the patch. The power is feed by electromagnetic coupling. Example to this technique is Aperture Coupling feed.

Microstrip Patch Antenna design parameters:

The Microstrip Patch Antenna's dimensions are determined, by considering the operating frequency range of the antenna, and the effective dielectric constant of the substrate (2).

An effective dielectric constant (ε_{re}) is a necessary parameter to account for the fringing effect and the wave propagation in the antenna. The value of effective dielectric constant (ε_{re}) is slightly less than the dielectric constant (ε_r) because the fringing fields acting around the boundary sides of the patch are not limited in the dielectric substrate but also spreads in the air (2).

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} \quad ......(1)$$

Where ε_{reff} = Effective dielectric constant, ε_r = Dielectric constant of substrate, h = Height of dielectric substrate, W =Width of the patch.

A). The effective patch length :

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon_{reff} + 0.3)(\frac{w}{h} + 0.8)} \quad ...... (2)$$

Then the effective length will be given as,

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad ..... (3)$$

Where f_0 stands for Operating Frequency.

Now, the Actual Length of the patch can be calculated,

$$L_{actual} = L_{eff} - \Delta L \quad ..... (4)$$

B). The width of the patch :

$$w = \frac{c}{2 f_0 \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad .... (5)$$

2. LITERATURE SURVEY:

World scientists are constantly trying to improve the performance of the Microstrip antenna, from last few decades. The area of research includes geometrical change of shape of patch, pa- rameters variation of substrate being used, use of multilayer are name to few.

Given below is the list of few research papers along with the method applied.

Junho Yeo, and Jong-Ig Lee proposed Modified Series- Fed Two- Dipole-Array Antenna With Reduced Size (3), with a purpose of to reduce the Antenna size, favouring its application in Mobile Telephony, which was done by employing rectangular Patch for two dipole elements and adding patch at both ends of the ground. Thus the Antenna size is reduced, with improved gain and impedence matching.

Youn-Kwon Jung and Bomson Lee proposed Dual-Band Circularly Polarized Microstrip RFID Reader Antenna with separate Tx and Rx ports is connected by meta - material (MTM) branch-line coupler (4). A single rectangular patch is fed by the two output lines of the designed meta-structured branch-line coupler through the near orthogonally positioned slots. The antenna gave an isolation of 25 dB at UHF frequency and isolation of 38 dB at ISM frequency.

Horng-Dean Chen, Chow-Yen-Desmond Sim and Shang-Huang Kuo proposed Compact Broadband Dual Coupling-Feed Circularly Polarized RFID Microstrip Tag Antenna Moun-table on Metallic Surface (5). The purpose is to enhance the bandwidth of the antenna having dual offset coupling feed point. By selecting appro-priate dimensions, and incorporating the dual-offset feed technique, the bandwidth of the circularly polarized (CP) operation and impedence matching can be enhanced. The measured 6-dB return-loss bandwidth of the tag antenna is 25MHz (902–927 MHz), and its corresponding 3-dB axial-ratio (AR) bandwidth is 20 MHz (903–923 MHz).

Stefano Maddio, Alessandro Cidronali, and Gianfranco Manes proposed a new design method for Single-Feed Circular Polarization Microstrip Antenna With an Arbitrary Impedance Matching Condition (6). The two conditions are enforced by an analytical method derived from an equivalent circuit model of a quasi-symmetrical patch antenna, and manipulated to control the modal detuning. The proposed method enables the tuning of the circular polarization condition and the matching condition consistently.

On the basis of the above reviews, the main highlight obtained from them are that the overall performance of the antenna can be improved by incorporating circularly polarization, by employing different Patch structures, different feeding techniques, dual feed points, antenna dimensions variations are few of them. So the changes to the antenna dimensions are taken as the proposed work in this paper.

3. MOTIVATION:

The areas of further improvement and development includes the geometrical shape variations of patch [12][13][14] and ground plane being used, uses of parasitic elements and dipole substrate. Also, it is observed that if the number of slot on the radiating patch are increased [15], then it results in generation of more radiations, thus increasing the power of the radiated signal. Another technique to enhance the performance of the antenna is by changing the coaxial feed point location of the antenna [16], doing so will result in good impedence matching, and thus will increase the bandwidth of the antenna. Apart from this, it is also learnt that if the vertices of the slot are smoothened, then the emission of extraneous radiations can be reduced, which will also account to increased bandwidth. These are the main points observed from the Literature survey, which will be applied in this paper, for the better performance of the antenna.

4. ARROW-HEAD SLOT ANTENNA:

The Arrow-head Slot Antenna is taken as the Reference antenna in this paper, based on which the comparative studies are carried out, to bring an enhanced performance from it. The Reference antenna is shown in Fig 4.1.

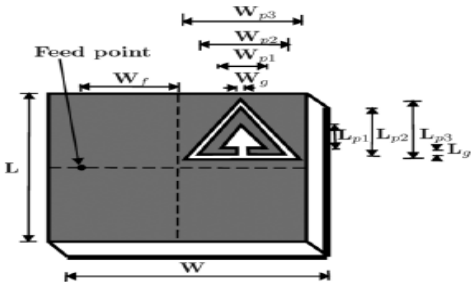

Fig 4.1 Schematic Reference Antenna

Thus the arrowhead slot square antenna as shown in Fig 4.2, have a substrate of 87mm * 87mm * 4.5 mm dimensions, a ground plane of 87mm * 87mm, and a radiating patch of 81mm * 81mm,operating at a frequency of 911 MHz (11). Here, in the Fig 4.2., the heights of the outer triangle to the inner most triangle are represented by L_{P3}, L_{P2} and L_{P1} respectively. Similarly, the base of the outermost triangle to the innermost triangle are represented as W_{P3}, W_{P2} and W_{P1} respectively. L_G and W_G represents the length and width of the square attached in the bottom of the smallest triangle, which makes the slot look like arrow-head triangular shaped slot.

TABLE 4.1

Parameters	L_{P1}	L_{P2}	L_{P3}	L_G	W_{P1}	W_{P2}	W_{P3}	W_G
Unit(mm)	15	27	32	2.5	12	25	32	4

ROGER RO4003C is the material chosen for the antenna substrate, having a thickness (h) of 4.572 mm, dielectric constant (ε_r) of 3.48, and loss tangent of 0.0027. The antenna is designed in ANSOFT HFSS Software, as shown in Fig 4.2.

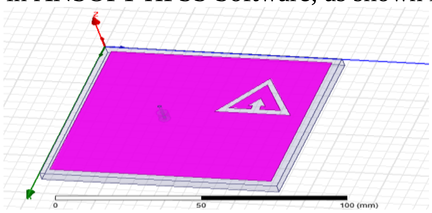

Fig 4.2 Simulated Reference Antenna.

The coaxial feed point location is fixed 10mm left to the centre of the patch.

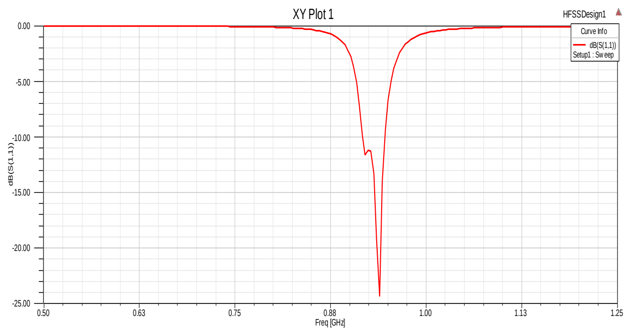

Fig 4.3 Return loss of Reference Antenna

The antenna is analysed and the Return loss graph is plotted against the frequency range, as shown in Fig 4.3. The Return loss value obtained is -24.3 dB, and the bandwidth obtained is 29.2 MHz.

5. PROPOSED WORK:

In this paper, the following modifications are proposed.

- Dimensions of the Arrow-head slot are varied.
- Vertices of the Arrow-head slot are smoothened.
- Coaxial feed point location is varied.
- Addition of another slot to the Arrow-head slot.

The simulation of the antenna is done in ANSOFT HFSS Software. The design parameters are taken same as the design parameters of the Reference Antenna, i.e., dimensions of the substrate is 87mm * 87 mm * 4.5 mm, and that of the dimensions of the patch is 81mm * 81 mm.

The substrate material is same as that of the reference antenna, i.e., ROGER RO3004C. Now, the antenna is being applied to two types of variations, which are stated below.

A). Dimension variation of the slot :

Here, the triangular slot dimensions are varied, and values are altered with respect to the reference antenna. The set of changed values with respect to the reference antenna are given below :

L_{P1} - 31.4 mm (size as in reference antenna - 15 mm)
L_{P2} - 35.6 mm (size as in reference antenna - 27 mm)
L_{P3} - 38.7 mm (size as in reference antenna - 32 mm)
L_G - 2 mm (size as in reference antenna - 2.5 mm)

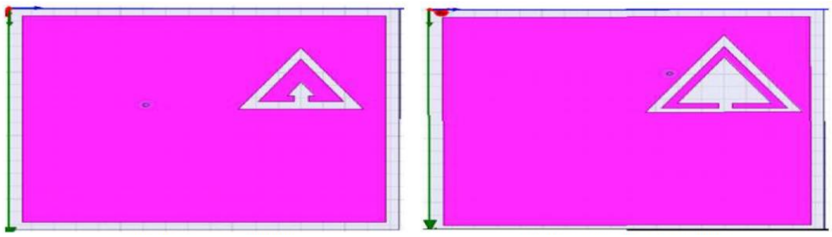

Fig 5.1 a) Reference Antenna   Fig 5.1. b) Optimised Antenna

Along with the changing slot dimensions, the position of the coaxial input feed location was also changed from the reference point given in the paper (38.5, 30, -4.5) to a new position near to the triangular slot (25, 53, -4.5). The Reference antenna is shown in Fig 5.1 a). Bandwidth, Gain, Directivity, Return loss can be improved through changes in dimensions, plane, etc of the antenna. Applying this all variations to the reference antenna, an optimised antenna is made, with its operating frequency same as the reference antenna, ie., 911 Hz, as shown in Fig. 5.1 b).

B). Slot Addition :

Here, the triangular slot dimensions are kept constant, but two concentric triangles are added more on it, and thus increasing the number of slots by a count of 2. Two new antennas are added with a height of 41.5 mm and 42.5 mm, and thus, they create a double triangular slot, as shown in Figure.

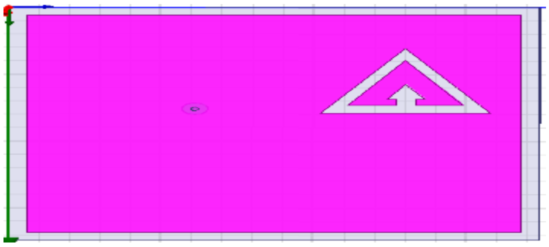

Fig 5.2 a). Reference Antenna

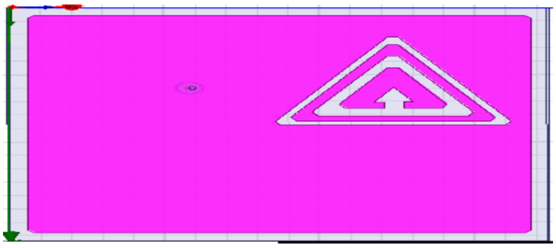

Fig 5.2 b). Optimised antenna

Also, the reference position of the Coaxial input feed was changed, compared to the position in the reference antenna, ie., from reference point (38.5, 30, -4.5) to new position (30, 29.5, -4.5). Applying all above variations, an optimised antenna is made, operating at centre frequency of 911 MHz. The Reference antenna and the Optimised antenna is shown in Fig 5.2 a) and b).

6. SIMULATION RESULTS:

The changes brought to the reference antenna, have resulted in better performance. The respective results are shown below.

A). Dimension variation simulation results:

- Bandwidth and Return loss :

To analyse the antenna in terms of Bandwidth and the Return loss parameters, the Rectangular Plot is plotted, with the Return loss against the frequency range.

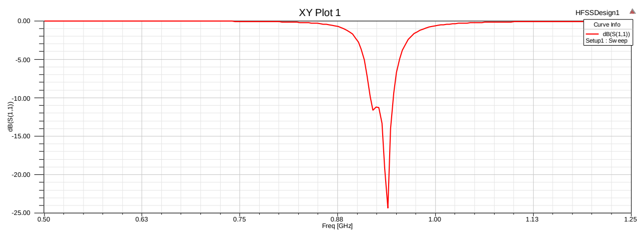

Fig. 6.1 Return loss plot of Reference Antenna

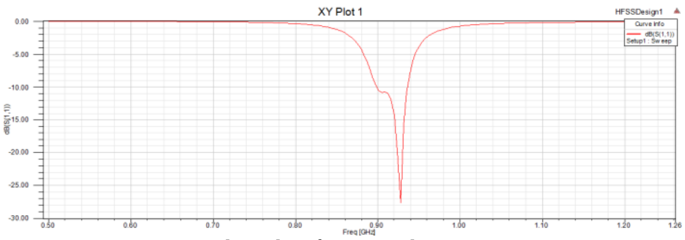

Fig. 6.2 Return loss Plot of Optimised Antenna

The reference antenna Bandwidth is 35.MHz, as shown in Fig.6.1. On analysing the optimised antenna as shown in Fig. 6.2 we obtain a Bandwidth of 37.3MHz. The optimised antenna shows an increase of 2.7MHz. bandwidth. Thus optimised antenna enhanced the bandwidth.

The desired value of return loss is lesser than -10.db. The reference antenna's is -30db as shown in Fig. 6.1. The optimised antenna is providing -27.6db return loss as shown in Fig. 6.2. The optimised antenna is getting return loss lesser than -10db. So the return loss of optimised antenna is good.

Gain plot:

To analyse the antenna based on the Gain plot, the Rectangular plot is plotted in Far Field Analysis, against frequency range. The Gain plot so obtained is shown in Fig. 6.3 and 6.4. for reference and optimised antenna respectively.

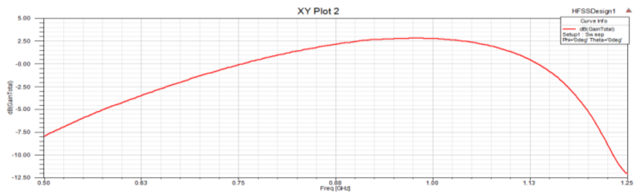

Fig. 6.3 Gain plot for Reference Antenna

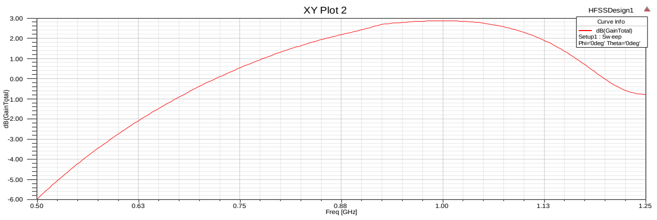

Fig. 6.4 Gain plot for Optimised Antenna

On the basis of the Gain plot of the optimised antenna, as shown in Fig 6.4, it is realized that the Gain of the antenna is about 2.57 dB, which is a point to mark the better performance of the antenna, when compared with the Gain plot of the Reference antenna as shown in Fig 6.3. whose gain is 2.56db.

- ***Radiation plot :***

To analyse the antenna based on the radiation pattern, the radiation plot is plotted with respect to directivity at frequency 911 MHz, at phi values of 0^0 and 90^0, using far field analysis. The obtained radiation plots are shown below.

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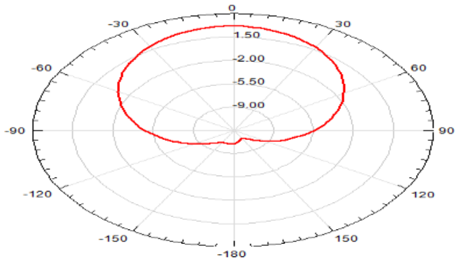

Fig. 6.5 Radiation pattern of Reference Antenna at phi=0

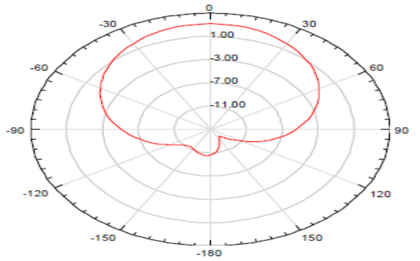

Fig 6.6. Radiation pattern of Optimised antenna at phi = 0^0

The Fig 6.6 shows the radiation plot of the antenna when the value of phi is kept 0°, and the Fig 6.8 shows the radiation plot of the antenna when the value of phi is kept 90°, they are compared with the radiation plot of the Reference Antenna as shown in Fig 6.5 and 6.7. When the antenna is at ϕ = 0°, the radiation area of optimised antenna is large as compared to reference antenna, as shown in Fig 6.6 and 6.5 respectively. Similarly, when the antenna is at ϕ = 90°, the radiation area of the Optimised antenna is large compared to the Reference antenna as shown in Fig 6.8 and 6.7 respectively.

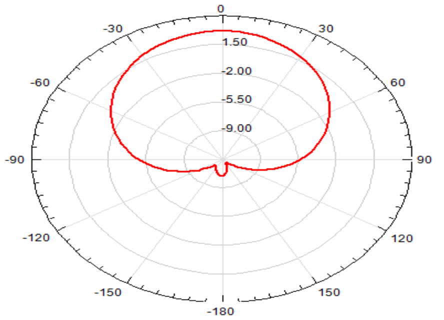

Fig 6.7 Radiation plot of Reference Antenna at phi = 90^0

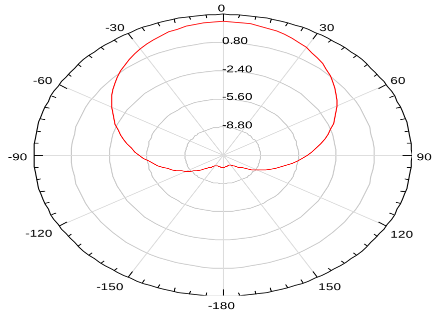

Fig 6.8 Radiation plot of Optimised Antenna at phi = 90^0

- ***Directivity plot :***

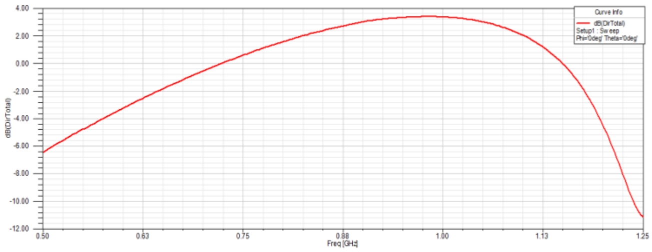

Fig 6.9 Directivity plot for Reference antenna

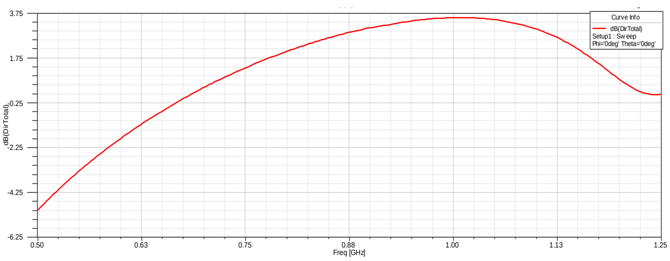

Fig 6.10 Directivity plot for Optimised antenna

The Directivity plot of the antenna is plotted, in Fig 6.9 and 6.10. The result obtained from it shows that the directivity of the optimised antenna is 3.21dB, is compared with the Directivity value of the Reference antenna, i.e., 3.10 dB, as shown in Fig 6.9. This shows better directivity of Optimised antenna.

- ***3 – D Polar plot:***

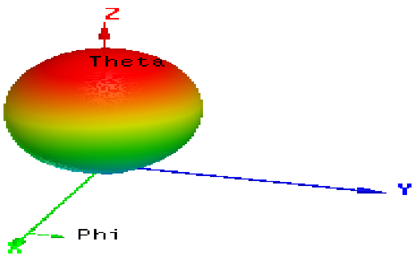

Fig. 6.11 – D polar plot of Reference Antenna

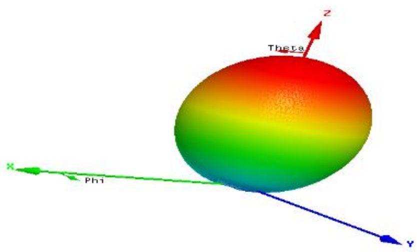

Fig. 6.12 – D polar plot of Optimised Antenna

The radiation pattern is also shown in 3-D view as shown in Fig 6.11 and 6.12. The 3 – dimensional polar plot of the Optimised antenna is plotted with respect to the phi and theta values, at the operating frequency of 911 MHz, as shown in Fig 6.12, which is shown in comparison to the 3 – D plot of the Reference antenna as shown in Fig 6.11.

- ***VSWR :***

VSWR stands for Voltage Standing Wave Ratio, which is used to study the Reflection Coefficient of the Antenna. It describes the power reflected by the antenna during its operation.

$$VSWR = \frac{1+\Gamma}{1-\Gamma} \quad ....(9)$$

Here, Γ stands for Reflection Coefficient. It is determined from the Voltage being measured along the transmission line leading towards the antenna. VSWR is the ratio of peak amplitude of a standing wave to the minimum amplitude of a standing wave. The VSWR Plot for the Optimised Antenna is shown in Fig 6.14, in comparison to the VSWR plot of the Reference antenna, as shown in Fig 6.13.:

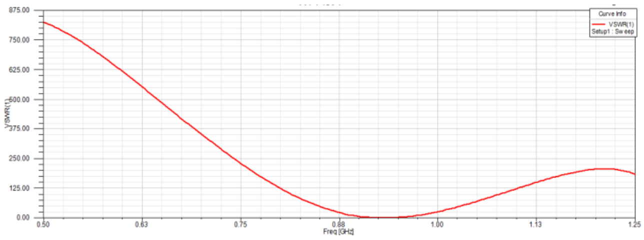

Fig. 6.13 VSWR Plot of Reference Antenna

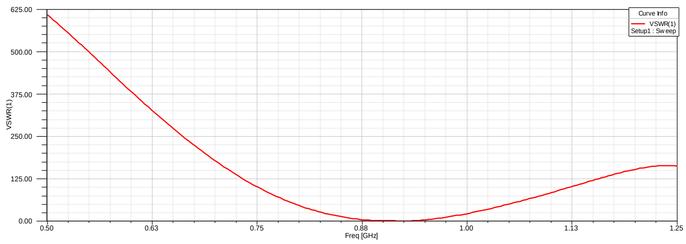

Fig. 6.14 VSWR Plot of Optimised Antenna

Here, the VSWR value depicted from the Fig 6.14 is about 1.8, which is a good value for the antenna. These all results are with respect to the variations brought in the dimensions of the triangular slot patch of the antenna, and which are better in performance when compared to the reference antenna's performance.

B). Slot Addition simulation results :

- Bandwidth and Return loss :

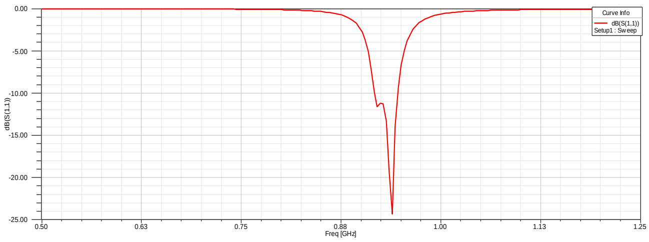

Fig. 6.15 Return loss plot of Reference Antenna

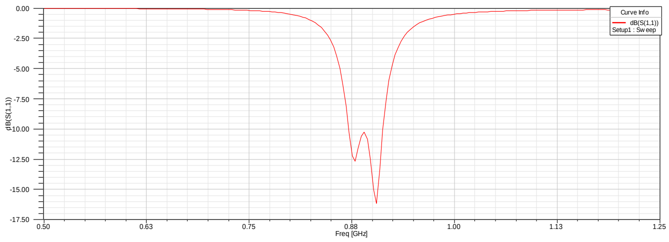

Fig. 6.16 Return loss plot of Optimised Antenna

The Return loss graph is plotted for the antenna, as shown in the Fig 6.16. The antenna gave a Return loss of -12.80 dB and -16.07 dB, at the two frequency dips, and produced a bandwidth of 41.3 MHz, which is far better when compared to the Return loss plot of the Reference antenna, as shown in Fig 6.15.

- ***Gain :***

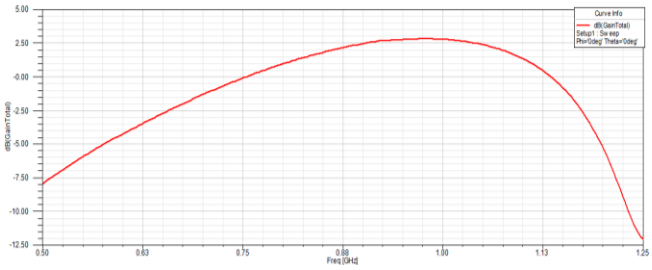

Fig.6.17 Gain plot of Reference Antenna

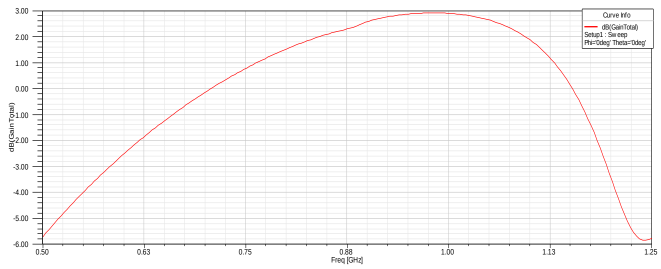

Fig.6.18 Gain plot of Optimised Antenna

The Gain plot of the Optimised antenna is plotted in far field analysis, as shown in Fig 6.18. The gain of 2.67 Db is received in the antenna, which is a high value compared to the reference antenna's Gain value, as shown in Fig 6.17.

- ***Radiation Pattern :***

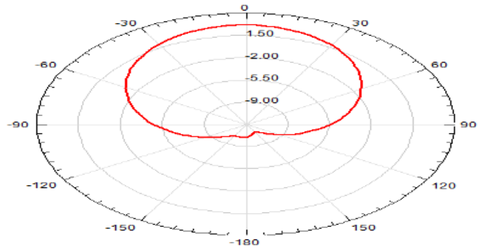

Fig. 6.19 Radiation pattern of Reference antenna at phi = 0^0

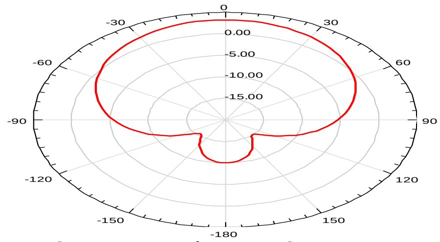

Fig. 6.20 Radiation pattern of Optimised antenna at phi = 0^0

The Radiation Pattern is plotted at frequency 911 MHz, at phi values of 0^0 and 90^0, which gives an account of the directivity of the radiation of the antenna, as shown in Fig 6.20 and 6.21 respectively, and they are shown in comparison with the Radiation pattern of the Reference antenna, at phi values of 0^0 and 90^0, as shown in Fig 6.19 and 6.21 respectively.

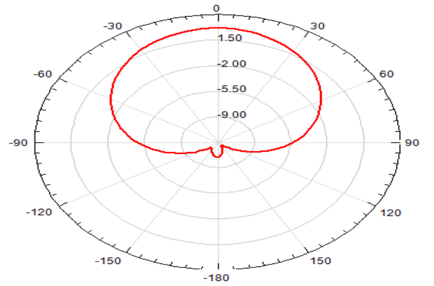

Fig. 6.21 Radiation Pattern of Reference antenna at phi = 90^0

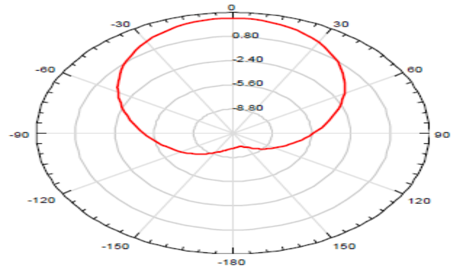

Fig. 6.22 Radiation Pattern Optimised antenna at phi = 90^0

- ***Directivity :***

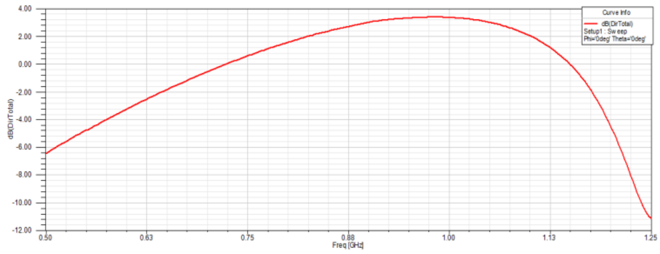
Fig. 6.23 Directivity Plot of Reference antenna

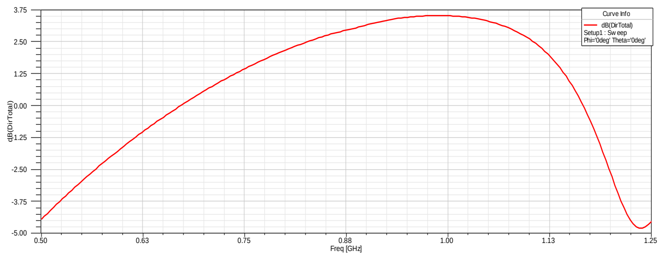
Fig. 6.24 Directivity Plot of Optimised antenna

The Directivity Plot of the antenna is plotted in 3-D Rectangular plot, under Far Field Analysis, in terms of Directivity Gain against the frequency range. Here, from the Fig 6.24, the Directivity value is found to be around 3.28 dB at operating frequency of 911 MHz, when compared to the Directivity value of 3.10 dB of the Reference antenna, as shown in Fig 6.23.

- ***3 – D Polar Plot :***

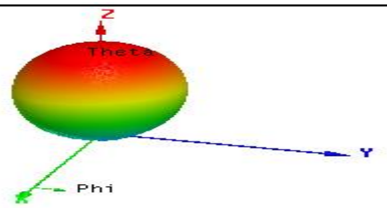

Fig. 6.25) 3 – D Polar plot of Reference antenna

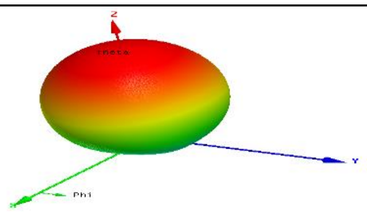
Fig. 6.26) 3 – D Polar plot of Optimised antenna

The 3 – dimensional polar plot of the Optimised antenna is plotted with respect to the phi and theta values, at the operating frequency of 911 MHz, as shown in Fig 6.26, which is shown in comparison with the 3 – D polar plot of the Reference antenna, as shown in Fig 6.25.

- ***VSWR :***

VSWR stands for Voltage Standing Wave Ratio, which is used to study the Reflection Coefficient of the Antenna. The VSWR Plot for the Optimised Antenna is shown in Fig 6.28.

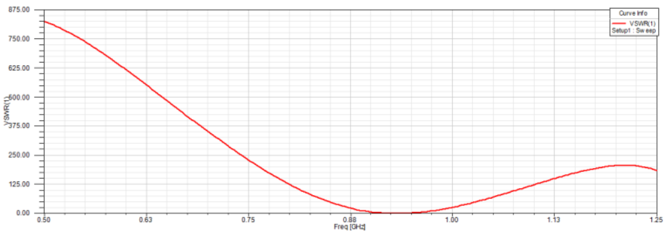

Fig. 6.27 VSWR Plot of Reference antenna

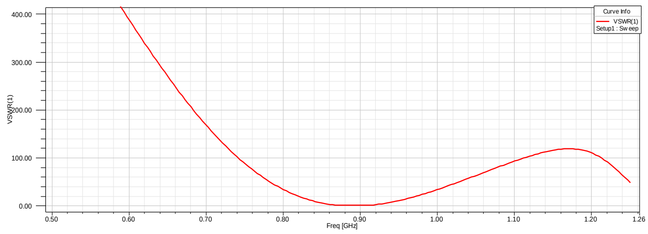

Fig. 6.28 VSWR Plot of Optimised antenna

Here, the VSWR value is found to be 1.6, which is a good value, when compared to the VSWR plot of the Reference antenna, as shown in Fig 6.27.
These all results are with respect to the variations brought on the triangular slot patch of the antenna, that is addition of another two triangles, thus making double triangle slot patches and which are better in performance when compared to the reference antenna's performance.

7. CONCLUSIONS:

The Microstrip Patch antenna faces huge limitations as low bandwidth range operation and low gain. The Microstrip Arrow-head shape Patch antenna is taken as the Reference antenna. Dimensions of the reference antenna has been varied. Double slots are also made through addition of two triangles to design an optimised antenna. The Optimised antenna are simulated on HFSS simulator. The optimised antenna demonstrates better performance than reference antenna.

TABLE – 6.1

Parameters	Reference Antenna	Antenna With Varied Size Of The Triangular Shape Slot	Antenna With Double Triangular Slot
BANDWIDTH	29.2 MHz	37.3 MHz	41.3 MHz
GAIN	2.56	2.57 Db	2.67 dB
DIRECTIVITY	3.10	3.21dB	3.28 dB
VSWR	3.20	1.8	1.6
RETURN LOSS	-24.3 dB	-27.6 dB	-16.7 dB

On the basis of the above results, it can be said that the changes made to the dimensions of the triangular slot patch and the addition of double slot have effectively improved the performance of the reference antenna, like Bandwidth, Gain, Directivity, VSWR. The values obtained are better than the corresponding values of the reference antenna.

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