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Performance Enhancement of Rectangular Microstrip Patch Antenna using Multiple DGS Technique

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Abstract

The microstrip antenna is widely used in advanced wireless communication. In recent years, the microstrip patch antenna has attracted much attention. Microstrip patch antenna is an important antenna above 1GHZ in wireless communication. It is used in mobile, aircraft, satellite and medical applications. Microstrip antenna has advantage of low profile, easy fabrication, simple feeding and interfaced with other IC's. In this paper microstrip patch antenna is designed for resonating frequency of 4GHz. The antenna is designed with Glass epoxy FR-4. The reference antenna is designed with 1.6mm thickness and height of dielectric is doubled and multiple DGS is used. The bandwidth is enhanced from 105MHz to 415MHz. The increase in bandwidth is 400 % . Fractional bandwidth increased from 2.6% to 10.3%. The bandwidth enhancement of reference antenna and with proposed RMPA with multiple DGS are compared.

RMPA is simulated using HFSS software with different substrates and with multiple DGS. The RMPA is also simulated using MATLab and compared. Results show that bandwidth can be increased adopting multiple DGS technique.

Keywords: HFSS, Matlab, Multiple DGS, Wirelss communication

INTRODUCTION

Communication Engineering is a one of the most developing branch of Electronics Engineering. Communication plays an important role in advancement of human's progress. Antenna is a critical component in wireless communication. The microstrip patch antenna is becoming more and more useful in wireless communication above 1GHz.

The microstrip antenna is constructed by using layer of metal on both sides of a dielectric material. The bottom layer is called ground plane and has more area. The top layer is called patch. The patch can have different shapes [1]. Rectangular and circular patches are more commonly used. Square, rectangular, triangular, dipole and circular shapes are more used for microstrip patch. The cross polarization is less for thesese shapes Also the radiation pattern of these can be analyzed easily. The microstrip dipole is more important and useful. It has inheretent property of more bandwidth and can be easily fabricated and occupies less space. For linear polarization, a single MPA or MPA arrays are useful. MPA arrays with single or multiple feeds are used to get greater directivity or gain. Pencil beam is generated by a square MPA and fan beam is generated by rectangular MPA. For analysis, very difficult to calculate current distribution in circular patch. But fabrication of circular MPA is easy.

The microstrip antenna working can be analyzed[2] by Transmission Line Model (TLM), Resonating Cavity Model (RCM) and Full wave Analysis (FWA). Among 3 methods, the Transmission Line model is easiest of all and gives good physical insight, but less accurate and coupling modeling is more difficult. The Cavity Resonating model gives good physical insight. Resonating model is more accurate compared with TLM, but it is more complex. It is difficult to model coupling. Resonating Cavity model is explained by the cavity resonating principle[3]. The patch behaves like a cavity. In microstrip patch antenna, the top patch and bottom ground behaves like a short circuited walls. It behaves like an open circuited at the sides. At different frequencies, inside cavity only certain modes are allowed to exist. When the microstrip patch antenna is excited at resonant frequency, a strong field is set up, inside the cavity and strong current in the surface of bottom ground plane. This results in a strong radiation and behaves as a good antenna. The Full wave model are very accurate, very versatile. It is most complex model and gives less physical insight.

Microstrip Patch Antenna(MPA)[3] is low profile, compact, small in size, has less weight. The fabrication of MPA uses simple photolithography and etching process. The feeding methods of MPA are also simple such as probe feed, microstrip line feed etc. The microstrip patch antennas can be used in arrays and with other microstrip circuit devices. The major applications of MPA are aerospace, medical, satellite and mobile communications. The radiation pattern of MPA has almost hemispherical and directivity is moderate.

The bandwidth is less in microstrip patch antenna. There are many methods to enhance bandwidth[3]. MPA bandwidth enhancement is one of major research area and a number of researchers are working for enhancing the bandwidth of microstrip patch antenna. The efficiency of MPA dependent on conductor and dielectric losses. Compared to other types of

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antennas, MPA efficiency is less. Hence there is a scope for improvement and research in this area.

A number of researchers worked on characterization of various parameters for microstrip patch antenna. Few recent and current methods to enhance bandwidth of microstrip patch antennas are discussed.

The bandwidth of microstrip patch antenna can be improved by varying dimensions and shapes[4]. The most literature describes design optimization microstrip antenna bandwidth on size and shape optimization. The MPA bandwidth depends on width of patch and thickness of dielectric material used [5]. The material optimization is not carried out much. This is because inhomogeneous material fabrication problems and very less access to analysis tools. The bandwidth enhancement by using different substrates optimum topology or material design of dielectric substrate is described in [6][7] for simple MPA. The bandwidth enhancement using parasitic elements is described by author in [8]. Reducing size of antenna and increasing bandwidth using Transformation electromagnetics is explained in [9]. The method of using parallel resonant strip for increasing bandwidth of planar tablet computer antenna is described in [10].

For a Probe feed U slot MPA, Characteristics mode analysis of 3 different methods, with experimental results is described in [11]. The 3 techniques are ReSF, Dimensional invariance (DI) and DI ReSF. On critical parameters such as slot thickness, probe radius, variation of fed point Characteristic mode analysis, on characteristics of U-slot MPA are discussed. The bandwidth can be enhanced by different shapes of patch. Aperture stacked patch (ASP) antenna [12] radiation pattern improvement is implemented. In the paper patch shape is designed to reduce effective propagation constant. The higher order modes of MPA is removed. The enhancement of 8% (68 to 76) bandwidth is achieved.

Impedance bandwidth improvement by incorporating parasitic strip and also etched slots is described, for horizontally polarized omnidirectional antenna in [13]. For a MPA bandwidth and harmonic suppression is described in [14]. For a spiral MPA gain and bandwidth improvement by using circularly symmetric HIS in ground plane is explained in[15]. Enhancement of impedance bandwidth for microstrip monopole slot antenna is explained in [16]. Compared to these methods proposed antenna gives more bandwidth.

In this paper rectangular microstrip patch antenna MPA[3] is designed for 4GHz, with substrate height of 1.6mm of FR4 with dielectric constant of 4.4. Then increased the height to 3.2mm to enhance the bandwidth. The bandwidth of 1.6mm is compared with bandwidth of increased height of substrate. After this multiple DGS method implemented to further enhance the bandwidth. The bandwidth enhancement and other performance parameters are compared. The paper is organized as follows. The proposed antenna design is explained in section II. Simulation results of FR4 antenna are given in Section III. Bandwidth enhancement and performance parameters like radiation pattern of reference antenna and modified FR4 antenna results compared and discussed in section IV. Conclusion is described in section V. Acknowledgement is given in section VI.

PROPOSED ANTENNA DESIGN

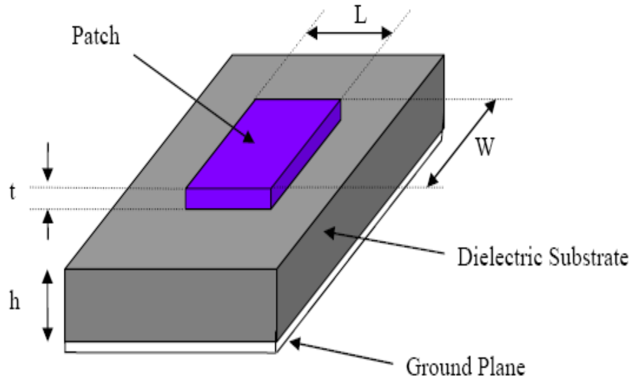

Figure 2: Basic structure of Rectangular Microstrip Antenna. (RMPA)

The rectangular patch is most widely used configuration. It is easy to analyze using both Transmission-line model and Cavity models. It is very accurate for thin substrate. The mathematical model used in this paper is described below. This model is based on assumption the resonating frequency (Fr), Dielectric constant (Er), and height or thickness (h) of substrate are specified. Figure 2 shows the basic structure of RMPA. In our research we have following design.

In microstrip patch antenna the design dimensions are the length (L), Width (W) and height (h) [3]. In MPA resonating dimension is given by Length. The width is adjusted such that it is more than Length. Generally W is designed such that it is equal to 1.5L. Length, Width and feeder dimensions are design parameters. The calculations of these design parameters are described here.

The width calculation uses the following formula.

$$W = \frac{c}{2fr}\left(\frac{\sqrt{2}}{\sqrt{Er+1}}\right) \text{------------- (1)}$$

Where C is speed of light , It is 3×10^8 m/s

fr is Resonating frequency

Er is the dielectric constant of substrate . Normal value for FR4, it is 4.4

The effective dielectric constant is calculated by

$$Eeff = \left(\frac{Er+1}{2} + \frac{Er-1}{2}\right) * (1/\sqrt{(1+(\frac{12h}{w}))} \text{----- (2)}$$

The extended length is calculated by

ΔL = 0.412*h [(Eeff +0.3) (W/h + 0.264) /

(Eeff - 0.258) (W/h + 0.8)] ----- (3)

The Length L of microstrip antenna is calculated by

$$L = \left(\frac{c}{2fr\sqrt{Er}}\right) - 2\Delta L \text{ --------------------- } (4)$$

After calculations, the dimensions of microstrip antenna with Glass and FR4 dielectric material, RMPA are tabulated in the Table 1.

Table 1: RMSA dimension with different dielectric materials.

Sl No	Description	Width - W (mm)	Length – L (mm)
1	Glass	20.8	14.77
2	FR-4	22.6	16.6

A. Feeding methods and Calculation of feed point & feeder dimensions.

The feed point and feeder dimensions depends on type of feeding technique used. The various feeding techniques used for microstrip antenna are described below.

There are 2 types of feeding. They are Contact type and Non-contact type. In contact type microstrip line feed and coaxial probe feed are widely used. In non-contact type aperture coupling and proximity coupling are popular. In our research we have used contact type of feeding.

The different feeding methods are explained briefly. The first method is microstrip line feed. In this method metal strip is connected to edge of patch directly. In microstrip feeding, the feed width is very much smaller than patch width. The strip can be fabricated by etching on the MPA substrate which provides a planar structure. There are different type of microstrip line feed. They are Centre feed, offset feed and Inset feed. The figure shows microstrip line feed technique.

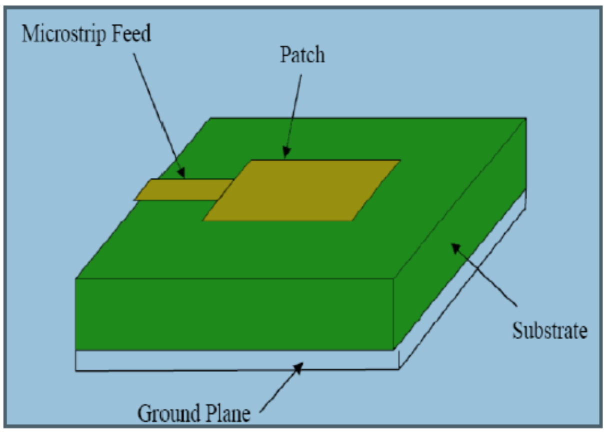

Figure 3: Microstrip Line feed for MPA.

Figure 3 shows Centre feed microstrip line feed technique. In centre feed, the microstrip line is in the center of patch. In offset feed is not at the center, there is an offset. In inset feed the patch is closer to the center to reduce high input impeda-nce. The inset cut in is provided to match the patch and feed line impedances without use of another matching device.

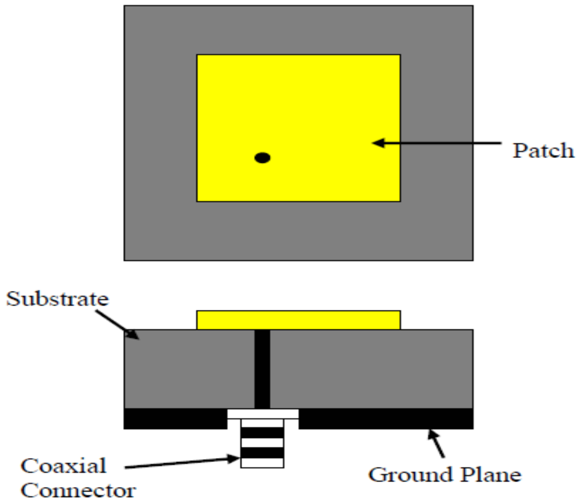

Figure 4: Coaxial Probe feed for MPA

Figure 4 shows co-axial probe feed for Microstrip Patch Antenna. This method very popular and frequently used for feeding microstrip patch antenna. The inner conductor of probe is connected to patch by soldering. The outer ground conductor is connected to bottom ground layer. In this method, the position of feed is varied to match the input impedance. It is difficult to model this method because of hole drilling. This method the impedance matching is easy. The fabrication requires drilling and soldering. The spurious radiation is more. More thickness of substrate increases probe length and input impedance becomes more inductive. Bandwidth of probe feeding is 2-5%. The reliability is less. But practically one of important method of microstrip antenna feeding because of easy connectivity.

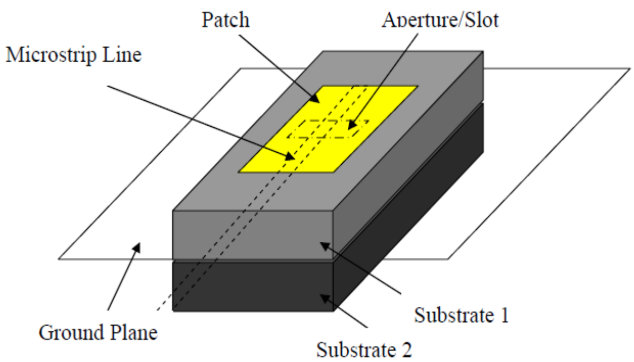

Figure 5: Aperture coupled feeding for MPA

Aperture coupled feeding method for microstrip patch antenna is shown in above figure no 5. This technique is also known as Electro-magnetic coupling. Two dielectric substrate materials are used feeding method. The feed line is present between the two dielectric substrate materials. The patch is present on upper part of top substrate material. The antenna is shielded from field circuit part. Energy is transmitted to antenna by a slot or hole or aperture. The amount of coupling between feed and patch is dependent on shape, size and location of aperture. This method has advantage of less spurious feed radiation, Good reliability, Impedance matching is easy and bandwidth is generally 2-5%. But can be increased upto 13% .

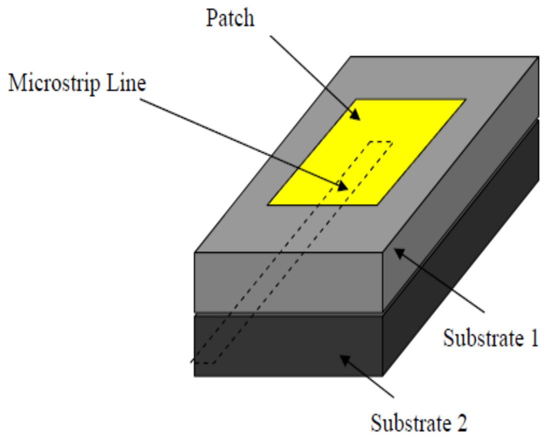

Figure 6: Proximity coupled feed for MPA

Figure 6 shows Proximity coupled feed method for microstrip antenna. If the inset feed is stopped just before the patch antenna or probe feed is modified such that it does not extend to the patch antenna, then new feeding method results in proximity coupling. The gap introduced by proximity coupling, introduces capacitance, which cancels the probe inductance, due to multiple substrate height.

Proximity coupled or indirect feed has advantage of minimum spurious feed radiation. The impedance matching is easy and reliability is good. It has bandwidth upto 13%. But fabrication is difficult and needs alignment

In proposed RMPA, microstrip line feed is used. The dimensions are calculated as per formulae given in [2]. The results of calculations are given in Table 3 .

Table 3: Feeder dimensions of RMPA with FR-4 dielectric.

Sl No	Description	Feeder length (mm)	Feeder point distance (mm)
1	FR-4	4.4	5.00584

SIMULATION & TESTING

The design & Simulation of 4GHz rectangular microstrip patch antenna (RMPA) is as shown in Figure 7.

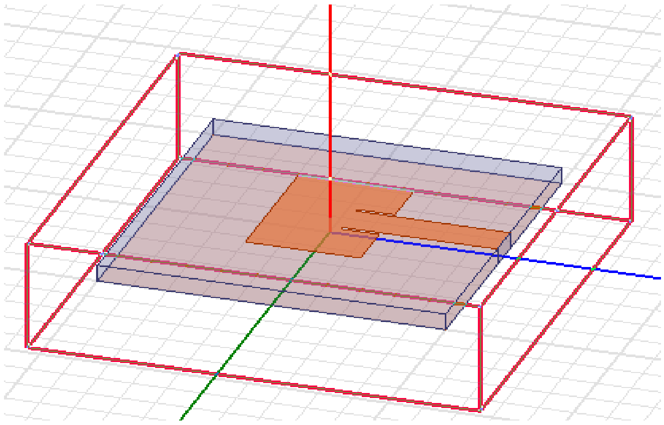

Figure 7 : RMPA design using HFSS

The rectangular microstrip patch antenna RMPA is designed and simulated using High Frequency Structural Simulation (HFSS) Tool. The RMPA is designed with first with Glass material of Er is 5.5 with thickness 1.6mm and 3.2 mm. The RMPA with 1.6mm Glass substrate is found to be resonating at 4GHz. But return loss S_{11} is found to be -6dB, less than required value of -10dB. For wireless communication application minimum required value of return loss is -9.5dB. Hence -10dB return loss impedance bandwidth is zero for 1.6mm Glass substrate. So, the substrate thickness is increased to 3.2mm and it is found to be resonating at 4.06 GHz. The S_{11} was found to -10.4dB. S11 bandwidth with 3.2mm Glass substrate RMPA is found to be 100MHZ. This bandwidth is very narrow. Then Antenna designed with Glass Epoxy FR-4 substrate with Er is 4.4 and first thickness of 1.6mm and it is found that the RMPA has resonating frequency of 4.06GHz and a narrow bandwidth of 105MHz. Then increased the FR4 substrate thickness to 3.2mm. The RMPA is simulated and with bandwidth of 200MHz. The gain is found to be 4.984 dB.

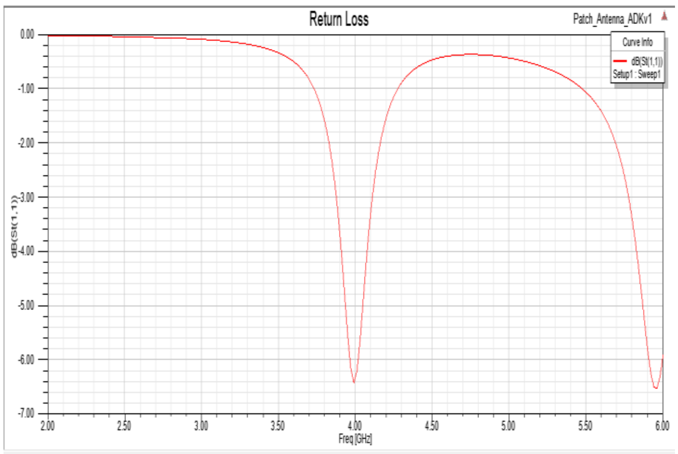

Figure 8: S_{11} characteristics with frequency for 1.6mm Glass substrate RMPA

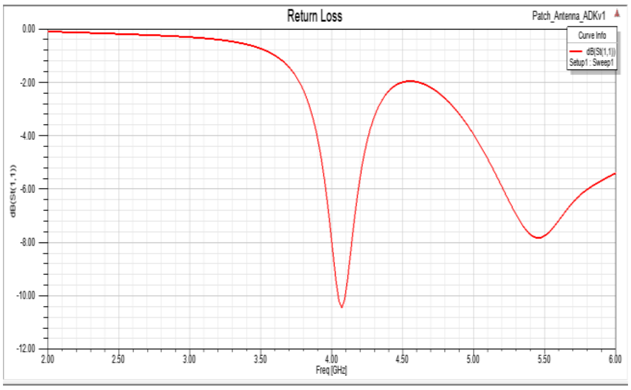

Figure 9: S_{11} characteristics with frequency for3.2 mm Glass substrate RMPA

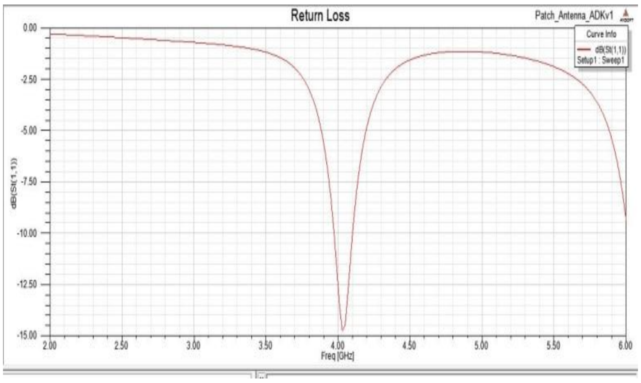

Figure 10: S_{11} characteristics with frequency for 1.6mm FR-4 substrate RMSA

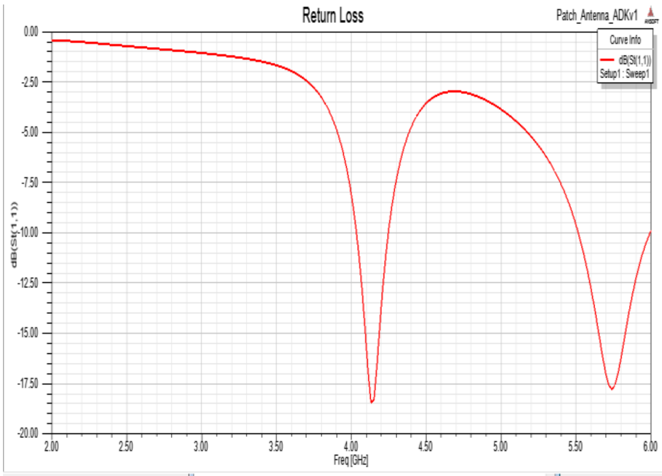

Figure 11: S_{11} characteristics with frequency for 3.2 mm FR-4 substrate RMSA

Return loss or S_{11} is the reflection of power of signal, when it is entered in a transmission line. If T is the voltage reflection co-efficient of input terminal of antenna. S_{11} return loss can be found by

S_{11} = -20 log |T|---------------(5)

Reflection co-efficient T is defined as ratio of incident wave Vi to the reflected wave Vr.

The simulation S_{11} characteristics with frequency for 1.6 mm and 3.2mm Glass substrate are shown in figure 8 and figure 9. The most commonly used antenna parameter is return loss S_{11}. S_{11} represents amount of power reflected from the antenna, also known as reflection co-efficient. S_{11} = 0dB, implies that 100% power is reflected and 0% power is radiated. In figure 8, the value of s11 is -6.4dB, for 1.6mm thickness Glass substrate RMSA. This value is below -10dB. Hence bandwidth for -10dB is 0. Bandwidth of an antenna is defined as the band of frequencies over which it can function as per specifications. If highest frequency is FH, lowest frequency is FL and the center frequency of band is Fc , then bandwidth is defined as

Bandwidth = 100X (FH – FL) / FC ---------- (6)

Figure 9 shows S_{11} characteristics of 3.2mm thickness Glass RMSA. The value of S_{11} is found to be -10.4. It satisfies the S_{11} value above -10dB. The bandwidth is found to be 100MHz for S_{11} of -10dB.

The simulation of S_{11} characteristics with frequency for 1.6 mm and 3.2mm FR4 substrates are shown in figure 10 and 11. The value of s_{11} is above -10dB for both 1.6 mm and 3.2 mm thickness FR4 substrate RMSA. In figure 10, the value of S_{11} is found to be -14dB for 1.6mm thickness FR4 substrate RMSA. The S_{11} -10dB bandwidth is found to be 105MHz. In figure 11, the value of S_{11} is found to be -19dB for 3.2mm thickness FR4 substrate RMPA. The S_{11} -10dB bandwidth is found to be 200MHz.

The comparison of results are given in Table 5.

Table 5: Comparison of Glass and FR-4 substrate 1.6 & 3.2mm thickness RMPA results

Sl No	Description	Glass 1.6 mm	Glass 3.2 mm	FR-4 1.6 mm	FR-4 3.2 mm
1	Resonance Frequency	4GHZ	4.06GHZ	4.04GHZ	4.15GHZ
2	S_{11}	-6.4dB	-10.4dB	-14dB	-19dB
3	Bandwidth for S_{11} -10dB	-	100MHz	105MHz	200MHz
4	Gain	6.6 dB	6.92dB	4.12 dB	4.98 dB

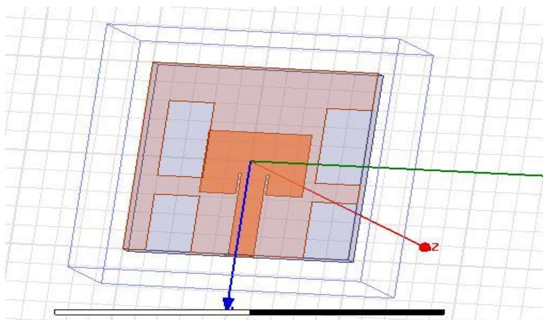

Figure 12: RMPA with multiple DGS design using HFSS

The simulation of RMPA with multiple DGS using HFSS is shown in figure 12. DGS is a technique to enhance bandwidth with defect in ground structure. The simulation of S_{11} characteristics with frequency for 4GHz, 3.2mm FR4 substrates without DGS and with multiple are shown in Figure 13 and 14. The value of S_{11} is above -10dB for both without and with multiple DGS of 4GHz 3.2 mm thickness FR4 substrate RMPA. In Figure 13, the value of S_{11} is found to be -17dB for 3.2mm thickness without DGS. FR4 substrate RMSA of 4GHz resonating frequency. The S_{11} -10dB bandwidth is found to be 200MHz. In Figure 14, the value of S_{11} is also found to be -17.39dB . The S_{11} -10dB bandwidth is found to be 415.7 MHz for 4GHz antenna with multiple DGS. The bandwidth of 1.6mm reference antenna is found to be 105MHz. The total bandwidth enhancement achieved w.r.t reference antenna is nearly 400%.

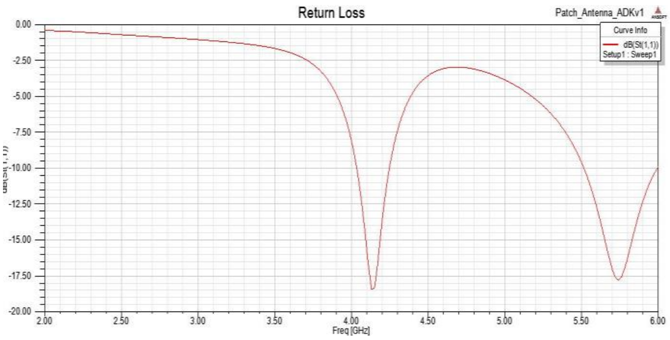

Figure 13: S_{11} characteristics with frequency for 3.2mm FR4 substrate RMPA

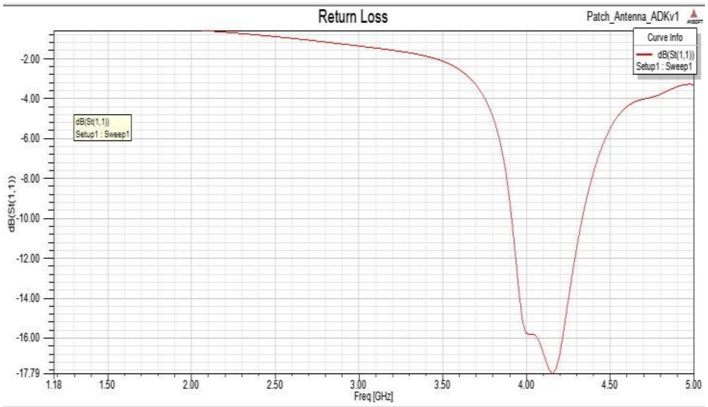

Figure 14: S_{11} characteristics with frequency for 3.2mm FR4 substrate RMPA with multiple DGS

The simulation of S_{11} characteristics with frequency for 1.6 mm reference antenna without DGS and 3.2mm FR4 substrates with multiple DGS are shown in Figure 13 and 14. The value of S_{11} is above -10dB for both 1.6 mm and 3.2 mm thickness FR4 substrate RMPA. In Figure 13 , the value of S_{11} is found to be -17dB for 1.6mm thickness FR4 substrate RMSA. The S_{11} -10dB bandwidth is found to be 105MHz. In Figure 14, the value of S_{11} is found to be -17.39 dB for multiple DGS 3.2mm thickness FR4 substrate RMPA.. The S_{11} -10dB bandwidth is found to be 415.7MHz

The comparison of results are given in Table 6.

Table 6: Comparison of FR-4 substrate 3.2mm thickness 4GHz RMPA and 4GHz RMPA with multiple DGS results

Sl No	Description	1..6 mm RMPA without DGS	3.2 mm RMPA without DGS	3.2mm RMPA with multiple DGS	3.2 mm RMPA with DGS
1	Resonance Frequency	4.04 GHz	4.15GHz	4.1658GHz	4.1206 GHz
2	S_{11}	-14dB	-19dB	-17.39dB	17.6dB
3	Bandwidth for S_{11} -10dB	105MHz	200MHz	415.7MHz	226.1 MHZ
4	Gain	4.12 dB	4.948dB	3.93dB	4.9 dB

Reflection co-effient S_{11} can be measuredusing RF network analyser[17]. The three different types of network analysers are Scalar network analyser(SNA), Vector network analyser (VNA) an large signal network analyzer(LSNA). SNA is used for measuring only amplitude responses of DUT. VNA is able to measure parameters like amplitude response, phase response, scattering parameters , transmission and reflection co-efficients. The LSNA is a specialized form of SNA and measures characterstics of devices under large signal conditions.The Voltage standing wave ratio (VSWR) is also related to S_{11}. For a good antenna VSWR should be less and below 2.

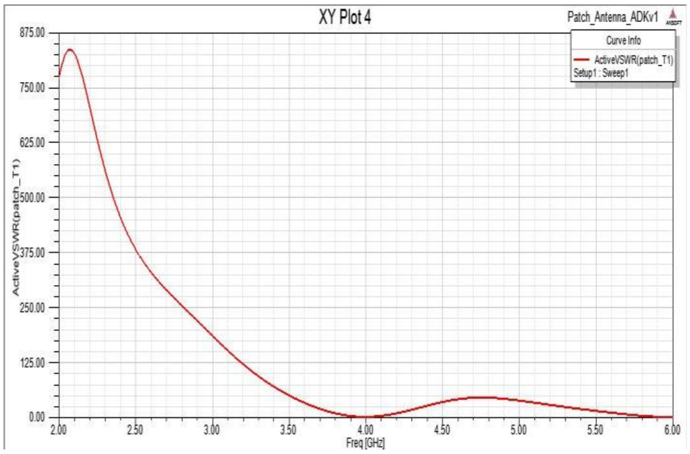

Figure 15: VSWR characteristics w.r.t frequency for 1.6mm Glass substrate RMPA

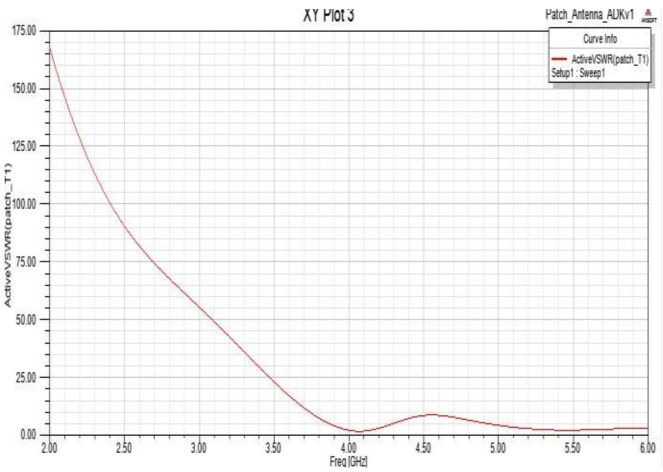

Figure 16: VSWR characteristics.r.t frequency for 3.2mm Glass substrate RMPA

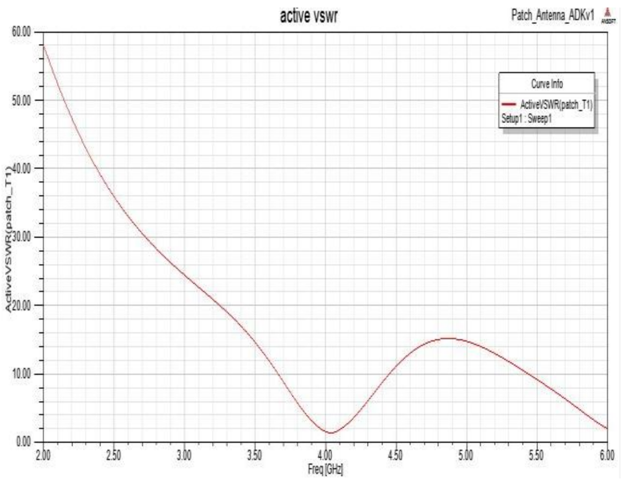

Figure 17: VSWR char. for FR4, 1.6mm RMPA

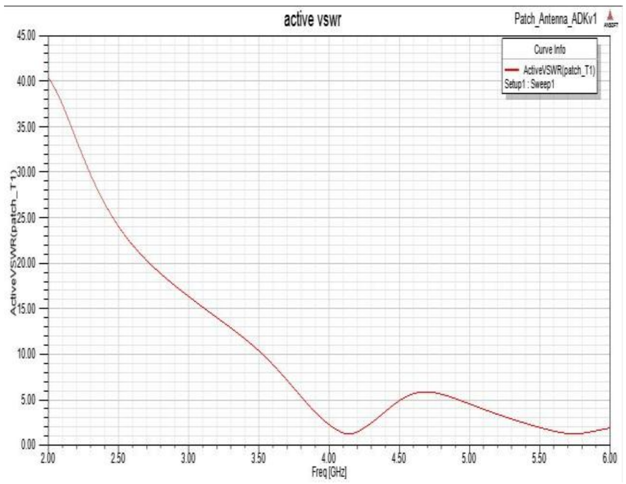

Figure 18: VSWR char. for FR4 3.2mm RMPA

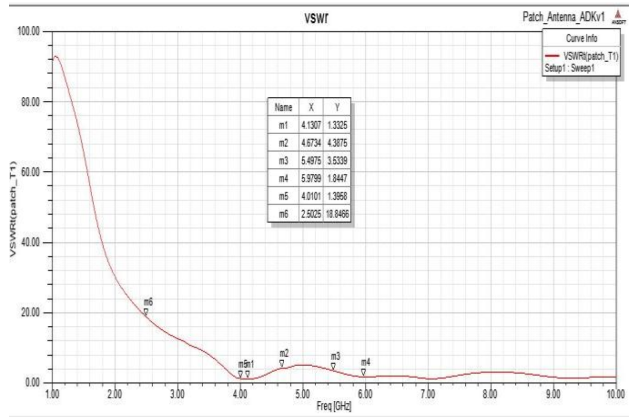

Figure 19: VSWR char. for FR4, 3.2mm RMPA

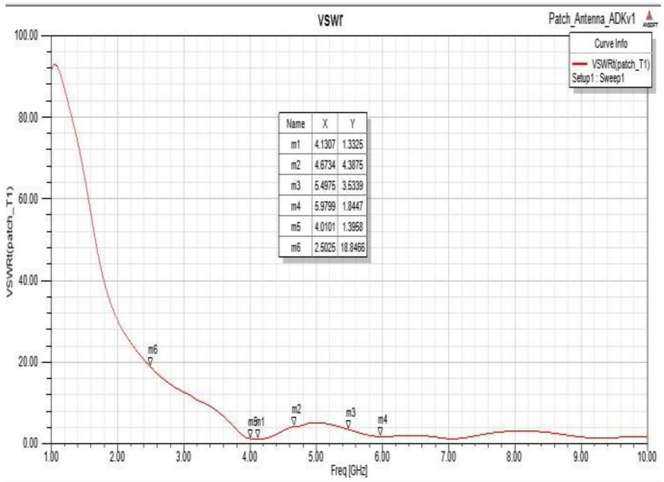

Figure 20: VSWR char. For FR4, 3.2mm RMPA with multiple DGS

Figure 15 and 16 shows the VSWR characterstics with respect to frequency for 1.6mm ,and 3.2mm Glass substrate RMSA. Fgure 17 and 18 shows the VSWR characterstics with respect to frequency for 1.6mm and 3.2mm FR-4 substrate RMSA. From figures it is observed that initial VSWR is more for Glass and is less compared to glass for FR4. Among 1.6 mm and 3.2 mm the initial VSWR is more for less thickness substrate. The VSWR decreases with increase in frequency and becomes sligtly above 1 and below 2 at resonant frequency. The value of VSWR at resonance is also more for Glass substrate than FR-4. The details are shown in figures. The VSWR characterstics of reference antenna is shown in Figure 19 and VSWR characterstics of antenna with multiple DGS is shown in Figure 20. The VSWR comparison is tabulated in Table 7.

Table 7: The comparison of VSWR of 1.6mm and 3.2mm thickness Glass & FR-4 substrate RMSA.

Sl. No	Parameter	Glass 1.6mm	Glass 3.2 mm	FR-4 1.6mm	FR-4 3.2mm
1	VSWR Highest	875	175	58	40
2	VSWR Lowest	2	2	2	1

The VSWR is defined as ratio of Vmin / Vmax. From the graphs it is observed that VSWR high is observed at frequency below resonant frequency.VSWR Lowest value observed at resonance frequency. The highest value of VSWR is more for Glass than FR-4. As the thickness inreases, the high value of VSWR decreases. At resonance VSWR minimum is observed. It has a value between 1 and 2. For FR-4, 3.2 mm thickness RMSA VSWR value is 1. This is a good acceptable perfect value.

The VSWR of reference antenna without DGS is 1.5 and propsed antenna with multiple DGS is 1.1. Hence there is a performance enhancement in VSWR also with multiple DGS.

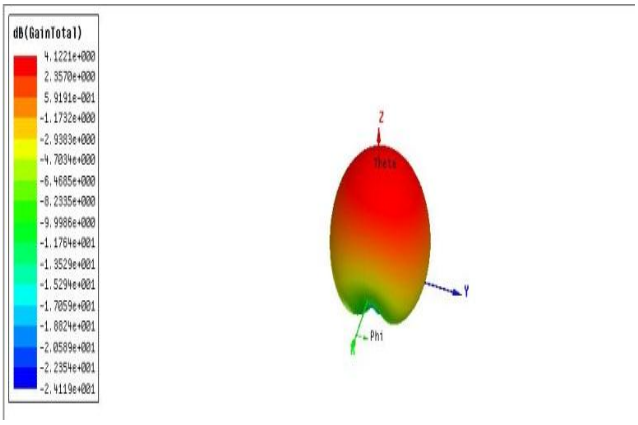

Figure 21: Gain characteristics w.r.t frequency for 1.6mm FR-4 substrate RMPA

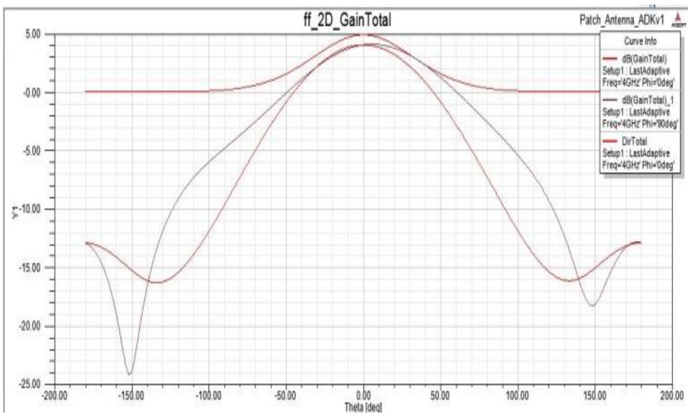

Figure 22: Total Gain characteristics w.r.t frequency for 1.6mm FR-4 substrate RMPA

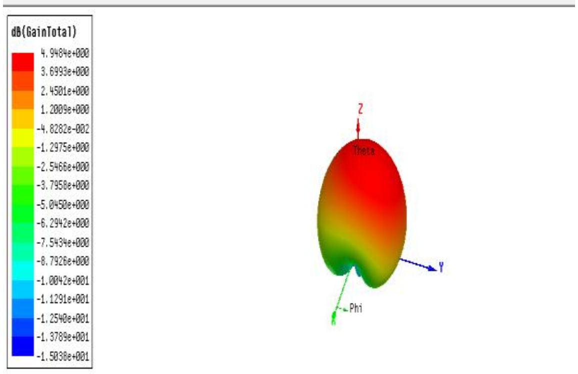

Figure 23: Gain characteristics w.r.t frequency for 3.2mm FR-4 substrate RMPA

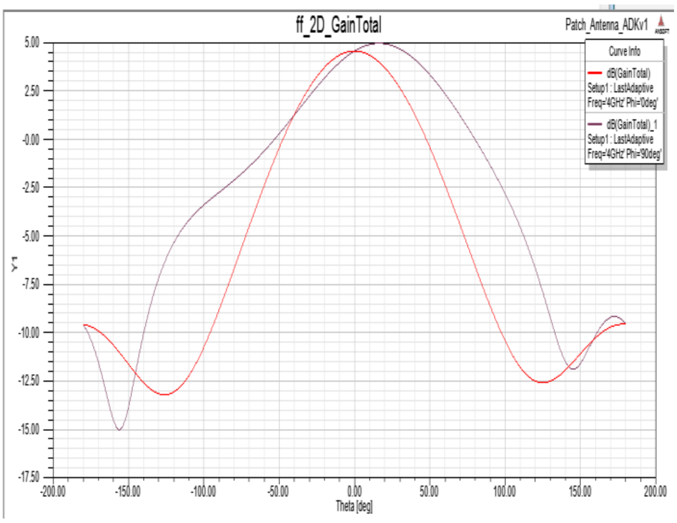

Figure 24: Total Gain characteristics w.r.t frequency for 3.2 mm FR-4 substrate RMPA

The gain characteristics of an antenna plays an important role for selecting an antenna for particular application. Figure 21 and figure 22 shows gain characteristics and total gain characteristics of FR-4substrate 1.6mm thickness RMPA.

Figure 23 and 24 shows gain characteristics and total gain characteristics of FR-4 substrate 3.2 mm thickness RMSA. The maximum gain of 1.6mm thickness RMSA is 4.12 dB and 4.98dB for 3.2mm thickness RMSA. The total gain characteristics shows that for both 1.6mm and 3.2mm thickness RMSA, the total gain increase with Theta value attains maximum value at 0 Degree. It decreases with further increase of angle in opposite direction.

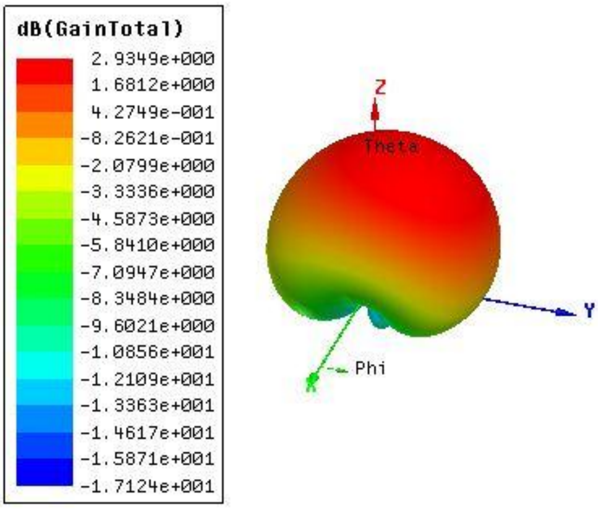

Figure 25: Gain characteristics for FR-4 substrate reference RMPA.

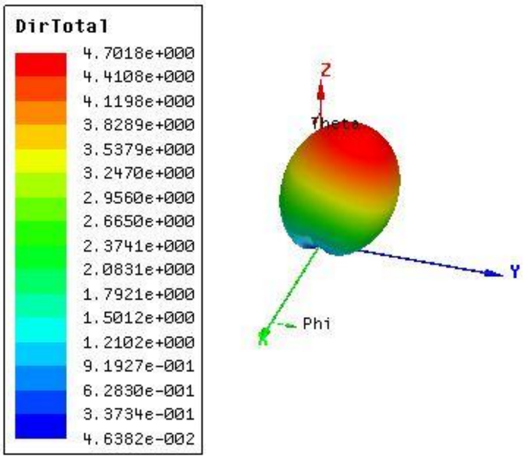

Figure 26: Directivity characteristics for reference FR-4 substrate RMPA

Figure 25 and 26 shows gain, directivity characteristics and total gain characteristics of FR-4 substrate 1.6 mm thickness reference RMPA. The gain and directivity characteristics of RMPA with multiple DGS are shown in Figure 27 and Figure 28. The maximum gain of 1.6mm thickness RMPA is 2.93 dB and directivity is 4.7dB. For 3.2mm thickness RMSA with multiple DGS the total gain is 3.9dB and directivity is 3.4dB . The total gain characteristics shows that for both 1.6mm and 3.2mm thickness RMSA, the total gain increase with Theta value attains maximum value at 0 Degree. It decreases with further increase of angle in opposite direction.

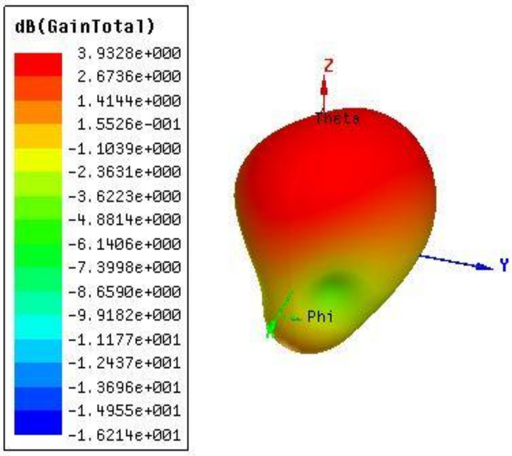

Figure 27: Gain characteristics for FR-4 substrate RMPA with multiple DGS

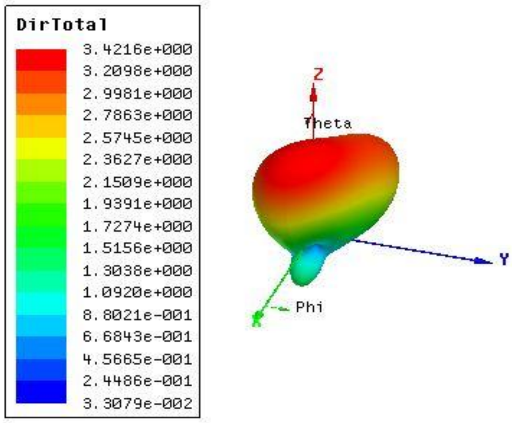

Figure 28: Directivity characteristics for FR-4 substrate RMPA with multiple DGS

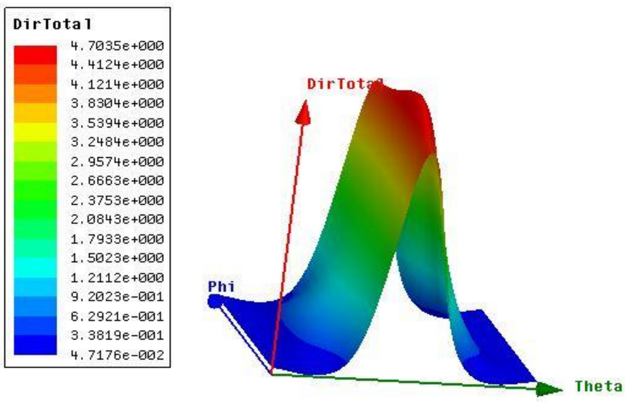

Figure 29: Total Directivity characteristics w.r.t Theta for 1.6mm FR-4 substrate RMPA

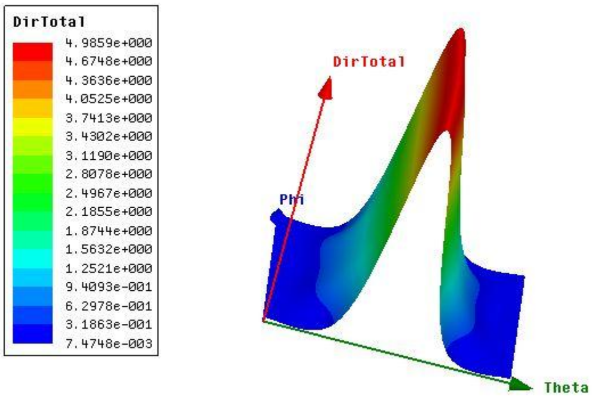

Figure 30: Total Directivity characteristics w.r.t Theta for 3.2mm FR-4 substrate RMPA

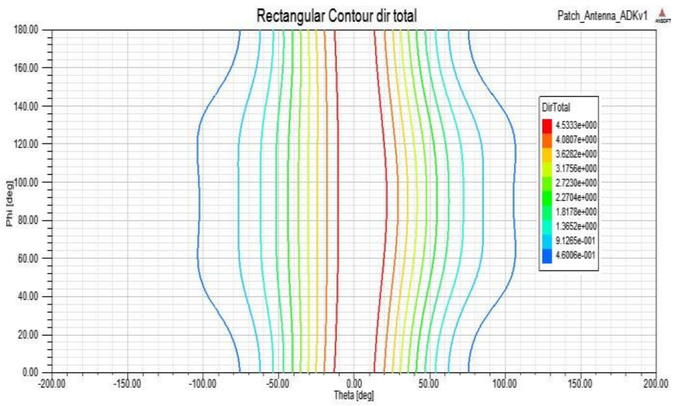

Figure 31 : Rectangular contour total directivity characteristics w.r.t angle for 1.6mm FR-4 substrate RMPA

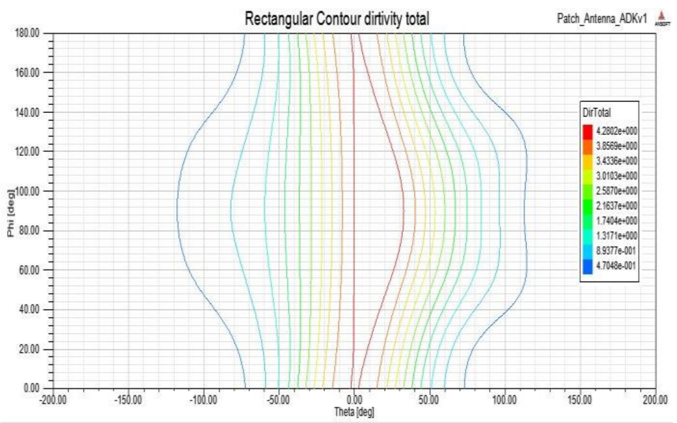

Figure 32 : Rectangular contour total directivity characteristics w.r.t angle for 3.2mm FR-4 substrate RMPA.

Figure 29 and 30, shows the total directivity characteristics for 1.6mm and 3.2mm FR4 substrate RMPA. The total directivity appears like a resonance curve. Directivity increases with theta, becomes maximum and then it reduces. From the figure it is found that maximum value the total directivity increase with thickness of substrate because it reduces losses. Figure 31 and 32 represents the rectangular contour total directivity of 1.6mm and 3.2mm FR4 substrate RMPA. The maximum value is at center. Directivity is dependent on value of thickness of substrate, width and length of patch. In our results we find the value of directivity is more for higher thickness RMPA.

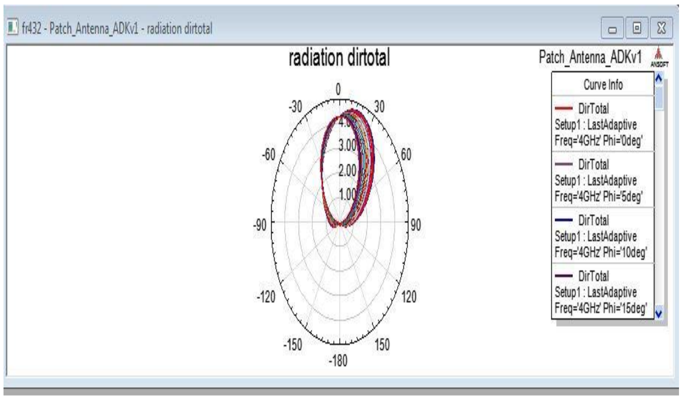

Figure 33: Directivity Radiation pattern for 3.2mm FR4 substrate RMPA

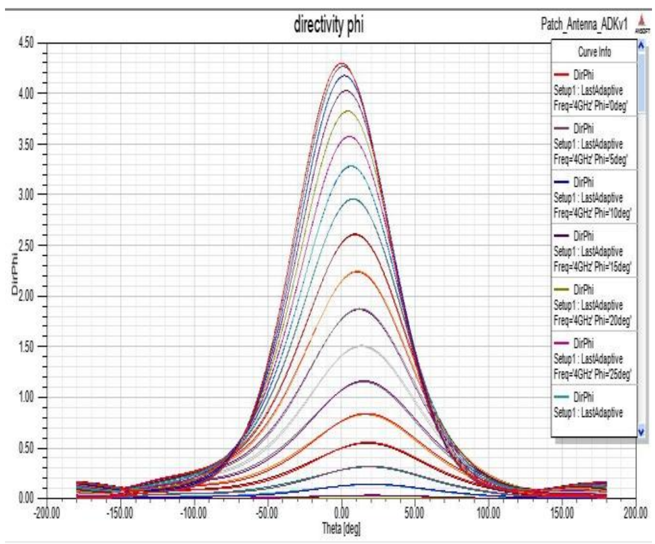

Figure 34 : Directivity Phi Radiation pattern for 3.2mm FR4 substrate RMPA for different values of angles.

Figure 34, 35 and 36 shows the Directivity, Directivity Phi radiation pattern and Directivity Theta radia tion pattern for different values of Phi and theta. It follows a normal distribution or resonance curve. Figure 36 directivity total with theta value in 2D for 3.2mm thickness FR4 material RMPA while Figure 38 shows 3D total directivity pattern for 3.2mm thickness FR4 material RMPA.

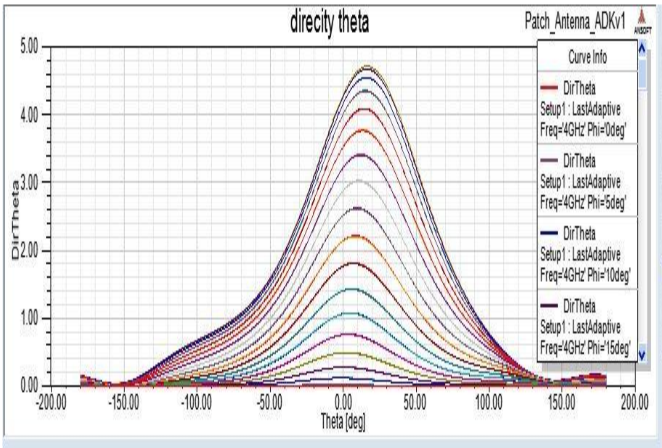

Figure 35 : Directivity Theta Radiation pattern for 3.2mm FR4 substrate RMPA at different angles

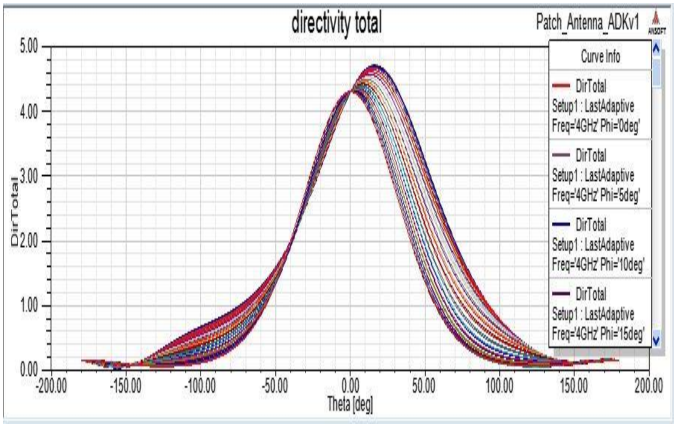

Figure 36: Directivity Total Radiation pattern for 3.2mm FR4 substrate RMPA at different angles

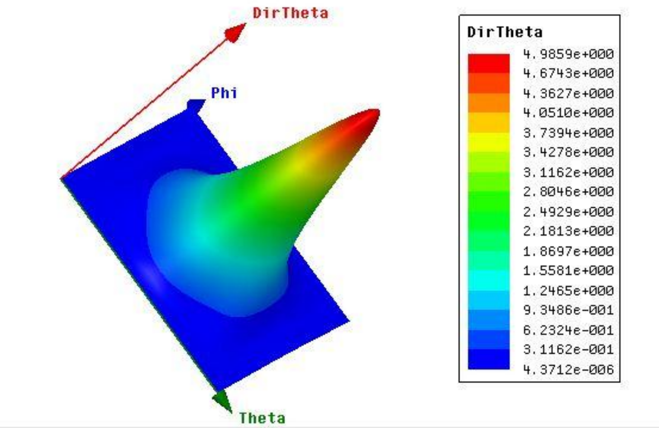

Figure 37: Directivity Theta Radiation pattern for 3.2mm FR4 substrate RMPA at different angles

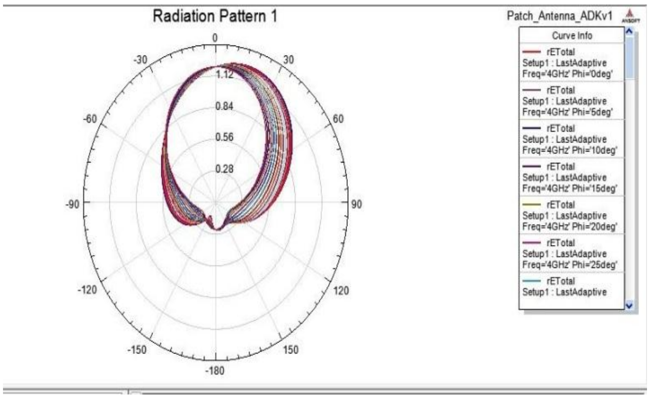

Figure 38: Radiation pattern for 1.6 mm FR-4 substrate RMPA

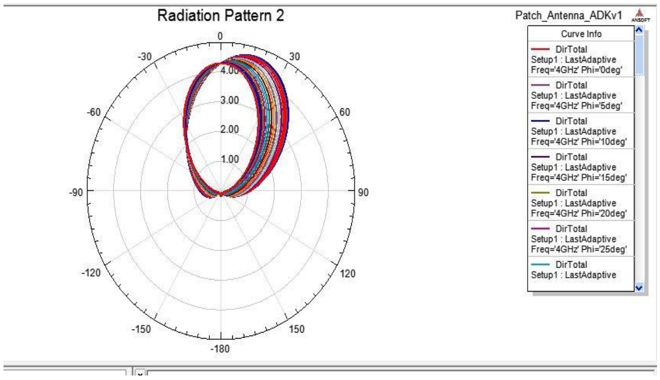

Figure 39: Radiation pattern for 3.2mm FR-4 substrate RMPA

The radiation pattern is an important characteristic of antenna. The shape of radiation pattern depends on type of antenna. Generally it's shape is Figure of 8. For microstrip antenna it has shape of hemisphere. Figure 38 and 39 shows radiation pattern of FR-4 substrate material thickness of 1.6 mm and 3.2mm. In figure 38 and 39 the radiation pattern is hemisphere.

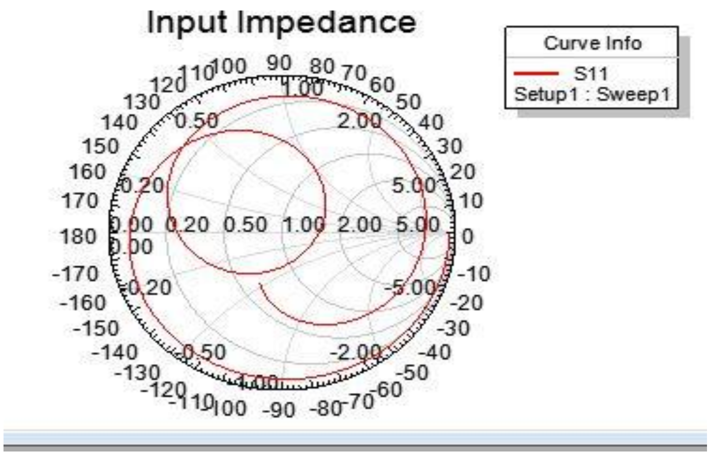

Figure 40 : Input impedance characteristics w.r.t frequency for 1.6 mm FR-4 substrate RMPA

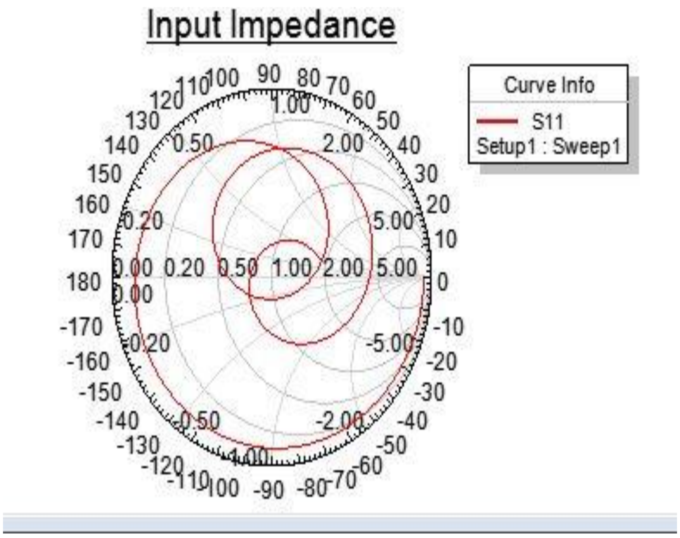

Figure 41: Input impedance characteristics w.r.t frequency for 3.2 mm FR-4 substrate RMPA

The impedance of antenna plays important role in determining characteristics, efficiency of antenna. The resistance patch of designed 4GHz, RMSA varies from 0 to 217 ohms from one end of patch to another end. The impedance of RMSA contains both resistance and reactance. For maximum power transfer to antenna, impedance matching should be done. The two port network impedance is assumed to be 50 ohms and matched with patch. A very good designed antenna works inefficiently if impedance matching is not designed properly. Figure 40 and Figure 41 shows the input impedance of 1.6 and 3.2mm thickness FR-4 substrate RMSA. From figure it is observed that impedance is matched and it is 50 ohms.

The comparison of input impedance and radiation pattern are given in Table 8.

Table 8 : Comparison of impedance & Radiation pattern of 1.6mm & 3.2 mm FR-4 antenna

Sl No	Description	1.6mm Antenna	3.2mm antenna
1	Input impedance	50 ohm	50 ohm
2	Radiation Pattern	Hemisphere	Hemisphere

COMPARISON OF RESULTS

The comparison of input performance of FR-4 reference RMPA with proposed multiple DGS RMPA are given in Table 9.

Table 9: Comparison of Results of reference and proposed RMPA

Sl No	Description	Reference RMPA	Proposed RMPA with multiple DGS
1	Resonance Frequency	4.06MHz	4.158GHZ
2	S_{11}	-14dB	-17 4dB
3	Bandwidth for S_{11} = -10dB	105MHz	415MHz
4	Gain	2.9 dB	3.9 dB
5	Input impedance	50 ohms	50 ohms
6	Radiation Pattern	Hemisphere with back lobe	Hemisphere with back lobe
7	Total Patch Resistance	217 ohm	223 ohms
8	VSWR	1.5	1.1

The comparison of FR-4 reference and FR-4 proposed RMPA with multiple DGS are given in Table 9. From comparison, it is observed that resonance frequency is higher in proposed RMPA and bandwidth is also more. The The gain and directivity and Radiation pattern are comparable. The total resistance of patch and input resistance are also comparable.. The VSWR of reference RMPA is around 1.5 and is acceptable. The VSWR of FR-4 proposed RMPA is found to be 1.1 is perfect matching of antenna with transmission line. From comparison the bandwidth of proposed FR-4 with multiple DGS is found be more and has better performance enhancement.

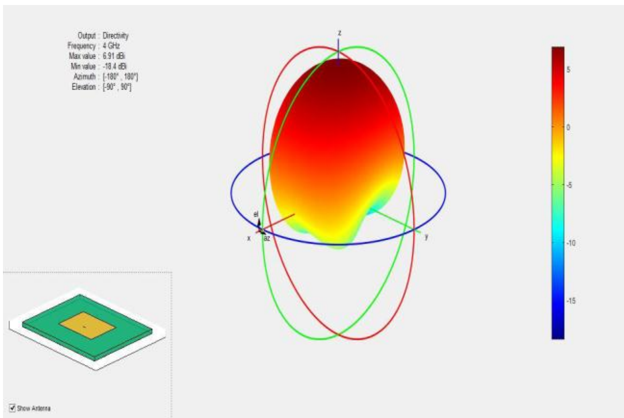

Figure 42: Radiation pattern for 1.6 mm FR-4 substrate RMPA using MATLAB.

Simulation of radiation pattern using MATLAB is shown in the above figure. MATLAB antenna tool box is used for this simulation. The resonance frequency is found to be 3.85GHz, maximum gain 6dBi and return loss equal to -16dB. These results are comparable with results of HFSS.

The 4GHZ Antenna is simulated in MATLAB is compared with the results simulated with HFSS. They are found to comparable and acceptable.

The comparison results sing are given in Table 10.

Table 10: Comparison of simulation results in HFSS and MATLAB

Sl No	Description	In HFSS	In MATLAB
1	Resonance Frequency	4.0 GHz	3.85GHz
2	Gain maximum	4.12 dB	6 dBi
3	S_{11}	-14 dB	-16 dB
4	Radiation pattern	Hemisphere	Hemisphere

CONCLUSION & FUTURE WORK.

Rectangular microstrip patch antenna(RMPA) is designed with FR4 without DGS and with multiple DGS. Bandwidth of reference antenna and proposed antenna with multiple DGS are compared. Bandwidth of reference RMPA is found to be 105MHz, whereas bandwidth of proposed antenna with multiple DGS is 415MHz. The increase of bandwidth is 310MHz. The percentage of bandwidth enhancement is 400%. Hence there is a bandwidth enhancement of 4 times the reference antenna bandwidth. There is also improvement in VSWR performance. Hence with multiple DGS performance of proposed microstrip patch antenna bandwidth is enhanced, without affecting performance of other parameters.

The Future work RMPA bandwidth enhancement can be extended for different shapes of microstrip patch with different feed methods and different shapes of slots. Gain enhancement can be combined to enhance gain along with bandwidth.

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