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Comparative Study of Notched Circular Slotted and Rectangular Slotted Microstrip patch antennas (MPA) for wideband applications

Parul Bansal*, Ekambir Sidhu**, Sonia Goyal***
*(Department of Electronics and Communication, Punjabi University, Patiala
Email: parul.bansal4900@gmail.com)
** (Department of Electronics and Communication, Punjabi University, Patiala
Email: ekambirsidhu1988@gmail.com)
*** (Department of Electronics and Communication, Punjabi University, Patiala
Email: goyalsonia_82@yahoo.co.in)

ABSTRACT
In this paper, two equivalent Microstrip patch antenna designs for wideband band applications have been proposed. The antennas are designed using radiating patch on one side of the dielectric substrate (FR4) and a reduced ground plane on the other side of substrate. Among two antennas, one antenna has a notched circular slot on the patch and other has a rectangular slotted patch. A comparative analysis of both antennas has been carried out in terms of various antenna parameters such as return loss (dB), bandwidth, gain and VSWR. The antennas are designed and simulated using CST Microwave Studio 2010. Both antennas cover frequency bands corresponding to IMT, WLAN and Wi-MAX applications. MPA with notched circular slot provides good return loss of -41.57dB at 4.5GHz and -46.78dB at 6.2GHz in comparison to rectangular slot MPA which provides a return loss of -26.45dB at 4.7GHz and -24.36 dB at 6.2 GHz. The antennas are approximately equivalent in terms of bandwidth (2.7GHz). The gain is sufficiently large at high resonant frequencies and VSWR is less than two for both the antenna designs.
Keywords - Microstrip patch antenna, Notched circular slot, Rectangular slot, Reduced ground plane, Return loss, VSWR

I. INTRODUCTION

Microstrip antenna, also acknowledged as patch antenna is usually fabricated on a dielectric substrate which acts as an intermediate between a ground plane at the bottom side of substrate and a radiating patch on the top of substrate [1]. The patch is primarily made of perfect electric conductor (PEC) material like copper. The patch can be of several shapes like rectangular, circular, triangular, elliptical, ring, Square and many more but commonly, rectangular shape is widely used [1]. While designing an antenna, the most important parameter is to select a substrate. The substrate consists of a dielectric material which perturbs the transmission line and electrical performance of antenna. The size of an antenna depends on the dielectric constant of substrate. Higher the dielectric constant, lower is the size of antenna [2]. Varieties of substrates with different dielectric constants are available but fire resistance 4 (FR4) material with dielectric constant of 4.4 has been used in these antenna designs. The antenna can be fed by various methods like coaxial feed, proximity coupled microstrip feed and aperture coupled microstrip feed [3]. Feeding is a mean to transfer the power from the feedline to the patch which itself acts as radiator. Microstrip line feed has been used in MPA designs because it is relatively simple to fabricate [3].

Microstrip antenna have been commonly used for wireless applications because of its miniaturization, low cost, light weight, better efficiency, ease of installation, ease of mobility, and is relatively inexpensive to manufacture from printed circuit board (PCB) of specific characteristics and dimensions. However, the MPA suffers from a drawback that it handles less power and has limited bandwidth [4].

The bandwidth of MPA can be improved by either using a slotted patch [5] [6] or a reduced ground plane [7] [8]. The slot on the patch can be of any shape like H-slot [9], E-slot [10], circle, rectangle etc. These techniques can also be used to improve the return loss along with bandwidth enhancement.

In this paper, it has been analyzed that by using circular slotted MPA and rectangular slotted MPA with reduced ground plane, the bandwidth gets doubled in comparison to a simple MPA without slotting and with full ground plane. Different shapes of slots have different impact on antenna parameters. MPA with circular slot provides better return loss than MPA with rectangular slot.

II. ANTENNA GEOMETRY

Fig 1 represents the geometry of a notched circular slotted MPA. As shown in the Fig 1, the shape of patch is rectangular with a circular and rectangular slot simultaneously cut on it. The patch is fed by a Microstrip feed line of certain specified width. Fig 2 depicts the configuration of rectangular slotted MPA having a rectangular slot cut on the radiating rectangular patch. The antennas are fabricated on FR4 substrate having relative permittivity of 4.4 and thickness of 1.6mm. The width of the feed line is adjusted to make sure that the impedance of antenna is 50 ohms. The bottom of the substrate consists of ground plane which is partially reduced to improve antenna bandwidth. The various dimensions of both antennas are listed in Table 1 and Table 2 respectively.

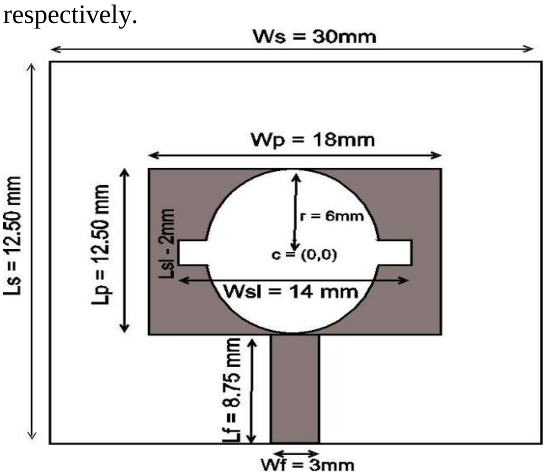

Fig 1(a): Top View of Notched Circular Slotted MPA

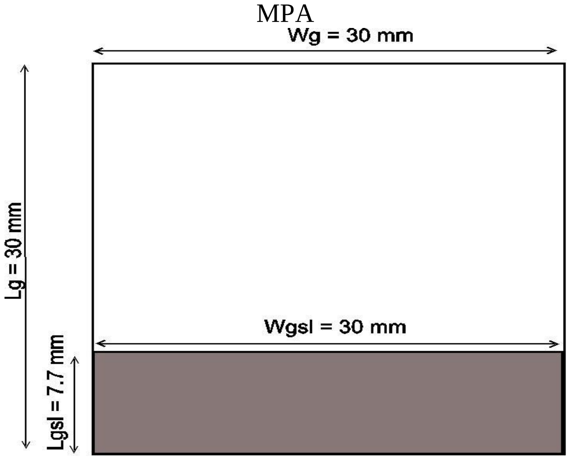

Fig 1(b): Bottom View of Notched Circular Slotted MPA

Table 1 Dimensions of notched circular slotted MPA

Antenna Parameter	Specification
Length of substrate (L_s)	30mm
Width of substrate (W_s)	30mm
Length of Patch (L_P)	12.50mm
Width of Patch (W_p)	18mm
Length of feed (L_f)	8.75mm
Width of feed (W_f)	3mm
Radius of circular slot (r)	6mm
Coordinates of Centre of circle (c)	(0,0)
Length of rectangular notch in circle (Lsl)	2 mm
Width of rectangular notch in circle (Wsl)	14mm

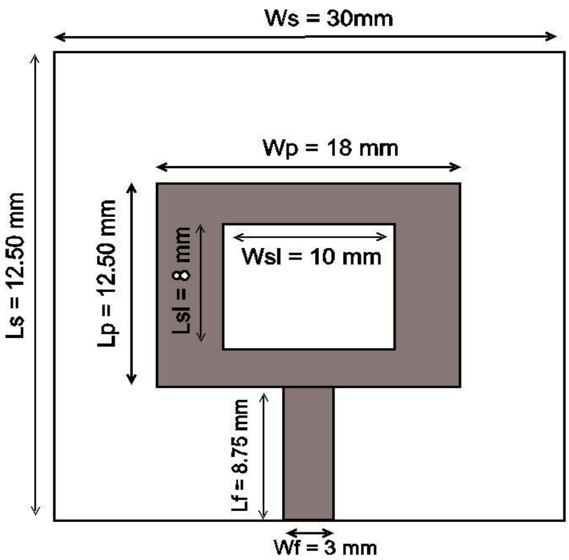

Fig 2(a): Top View of Rectangular Slotted MPA

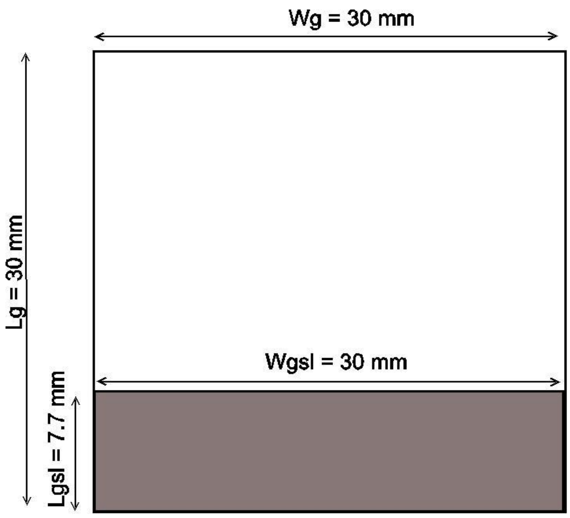

Fig 2(b): Bottom View of Rectangular Slotted MPA

Table 2: Dimensions of Rectangular Slotted MPA

Antenna Parameter	**Specification**
Length of substrate (L_s)	30mm
Width of substrate (W_s)	30mm
Length of Patch (L_P)	12.50mm
Width of Patch (W_p)	18mm
Length of feed (L_f)	8.75mm
Width of feed (W_f)	3mm
Length of slot (Lsl)	8mm
Width of slot (Wsl)	10mm

III. Results and Discussions

The designed antennas have been simulated using CST Microwave Studio 2010 and the performance of the antenna has been analyzed in terms of return loss, VSWR, radiation pattern and gain. Meanwhile, the experimental results have been also obtained using E5071C ENA series network analyzer and concluded that the practical results approximately matches with the simulated theoretical results.

Fig 3 represents the simulated results of return loss for both antenna designs. It has been observed that the return loss for notched circular slot MPA is -41.57dB at 4.5GHz and -46.78dB at 6.2GHz and for rectangular slot MPA, return loss is -26.45dB at 4.7GHz and -24.36 dB at 6.2 GHz. Therefore, notched circular slot MPA provides better return loss i.e. amount of reflected power is less. The simulated bandwidth of the proposed antennas is same i.e. 2.7GHz

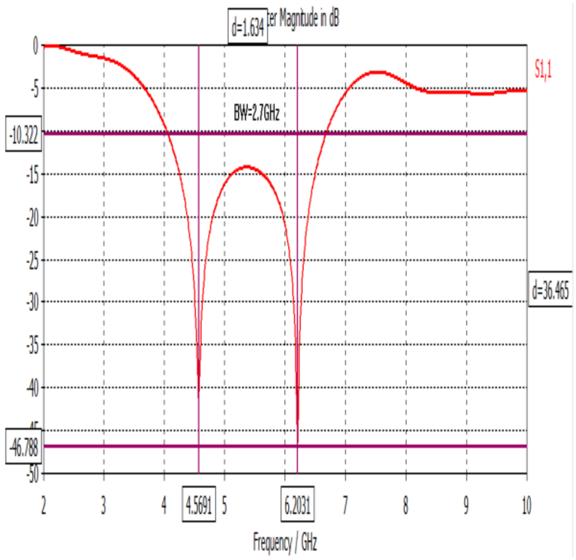

Fig 3(a): Return Loss Plot of Notched Circular Slot MPA

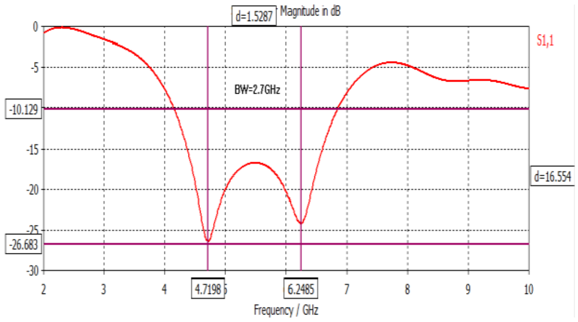

Fig 3(b): Return Loss Plot of Rectangular Slot MPA

Fig 4 shows the 3D radiation pattern for directivity of notched circular slotted MPA. The directivity at resonant frequencies has been obtained and analyzed. The directivity is 2.997dBi at 4.5GHz and 4.108 dBi at 6.2 GHz. It has been observed that directivity is better for higher resonant frequencies than lower frequencies.

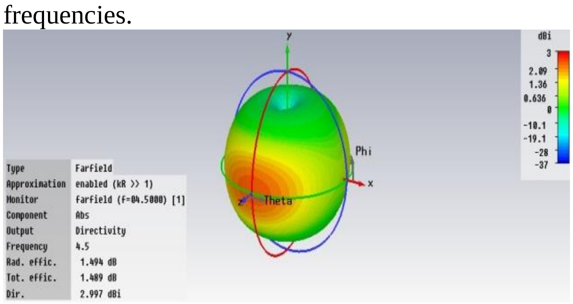

Fig 4(a): Directivity of Notched Circular Slot MPA at 4.5ghz

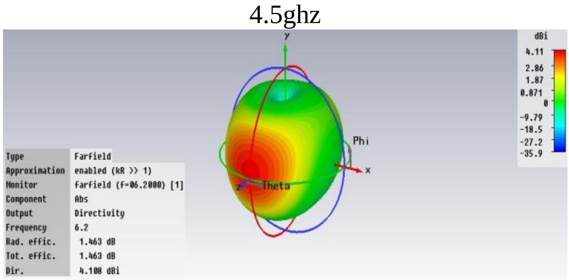

Fig 4(b): Directivity of Notched Circular Slot MPA at 6.2 GHz

Fig 5 depicts the 3D radiation pattern for directivity of rectangular slotted MPA. The directivity is 3.008 dBi at 4.7 GHz and 3.813 dBi at 6.2 GHz. The directivity is higher at high resonant frequency in comparison to lower frequencies.

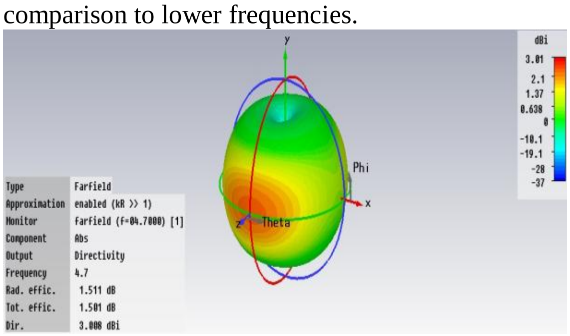

Fig 5(a): Directivity of Rectangular Slot MPA At 4.7 GHz

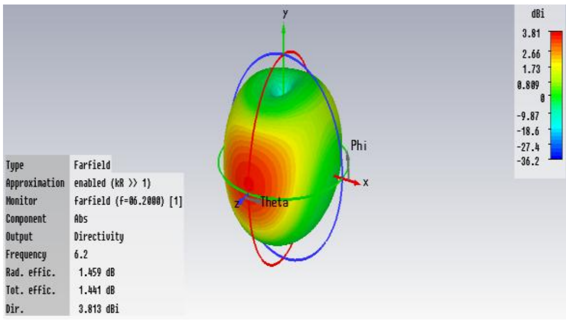

Fig 5(b): Directivity of Rectangular Slot MPA at 6.2 GHz

Fig 6 illustrates the simulated results of gain for notched circular slotted MPA. The 3D radiation pattern shows that the gain is 4.491 at 4.5 GHz and 5.57dBi at 6.2 GHz. It shows clearly that the value of gain is higher for high frequencies.

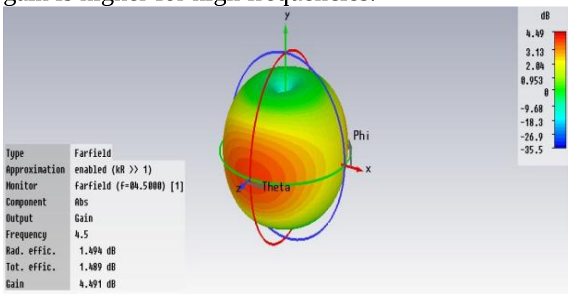

Fig 6(a): Gain of Notched Circular Slot MPA at 4.5 GHz

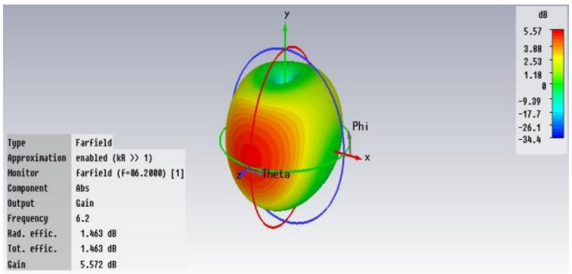

Fig 6(b): Gain of Notched Circular Slot MPA at 6.2 GHz

Fig 7 shows the 3D radiation pattern plot of gain for rectangular slotted MPA. The gain is 4.528 dB at 4.7 GHz and 5.271dB at 6.2 GHz. It can be concluded that the gain is better for higher frequencies as for circular slot MPA.

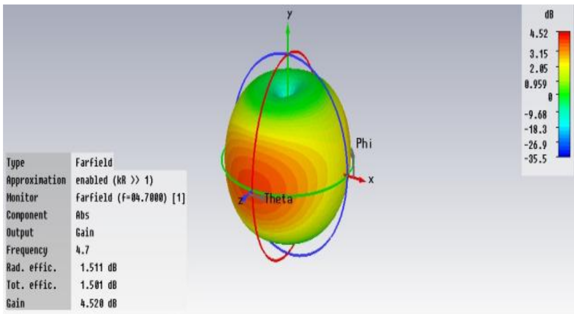

Fig 7(a) Gain Plot of Rectangular Slot MPA at 4.7 GHz

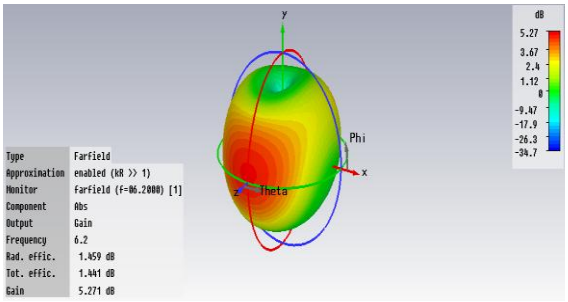

Fig 7(b): Gain Plot of Rectangular Slot MPA at 6.2 GHz

Fig 8 and Fig 9 depict the simulated VSWR plot for notched circular slotted MPA and rectangular slotted MPA respectively. Fig 8 shows that the VSWR at 4.5 GHz is 1.07 and 1.01 at 6.2 GHz and Fig.9 represents VSWR of 1.10 at 4.7 GHz and 1.13 at 6.2 GHz. The VSWR values corresponding to resonant frequencies is far below the satisfying criteria of VSWR (i.e. VSWR <2).

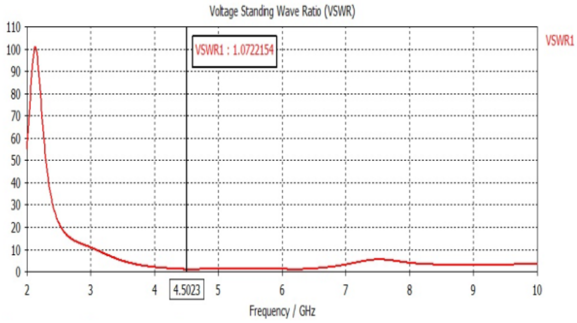

Fig 8(a): VSWR Plot of Notched Circular Slot MPA at 4.5 GHz

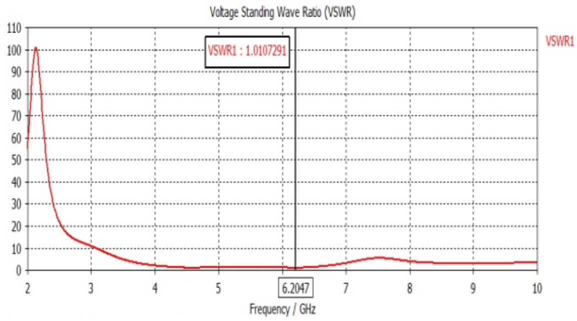

Fig 8(b): VSWR plot of Notched Circular Slot MPA at 6.2 GHz

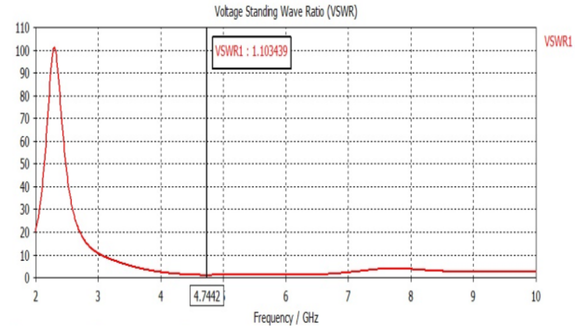

Fig 9(a): VSWR Plot of Rectangular Slot MPA at 4.7 GHz

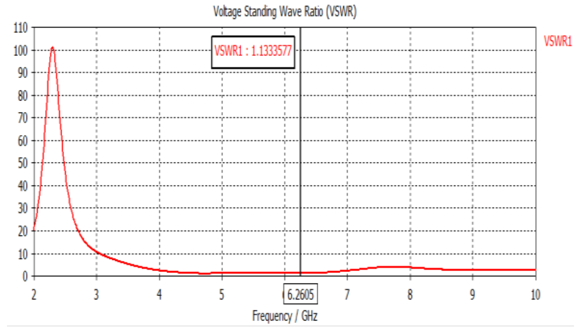

Fig 9(b): VSWR Plot of Rectangular Slot MPA at 6.2 GHz

IV. EXPERIMENTAL VERIFICATION

The proposed antennas has been physically designed as shown in Fig 10(a) and Fig 10(b) and tested using E5071C ENA series network analyzer. The experimental results of notched circular slotted MPA and rectangular slotted MPA is shown in Fig 11(a) and Fig 11(b) respectively.

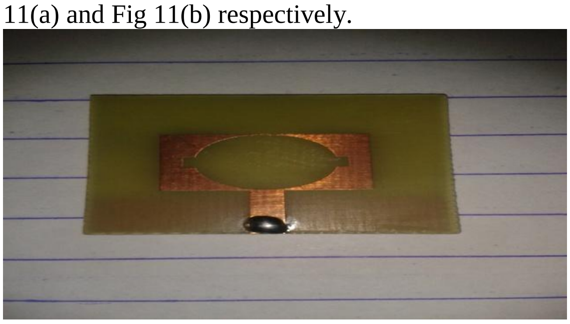
Fig 10(a): Notched Circular Slotted MPA

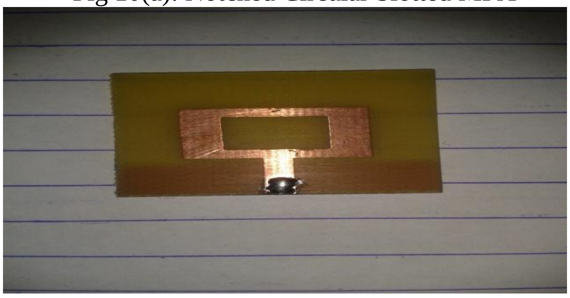
Fig 10(b): Rectangular Slotted MPA

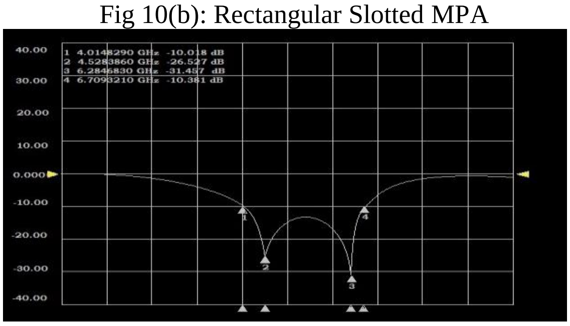

Fig 11(a): Experimental Results for Notched Circular Slotted MPA

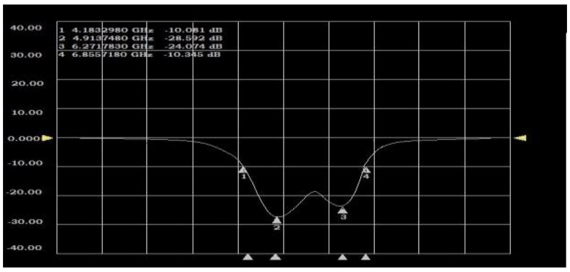

Fig 11(b): Experimental Results for Rectangular Slotted MPA

V. CONCLUSION

From the above discussion, it has been concluded that both the antennas (notched circular and rectangular slot MPA) have different impact on the antenna parameters. The antennas are equivalent in terms of the resonant frequencies and bandwidth. The selection of designed antenna for any application depends on the requirement. For example, rectangular slotted antenna is relatively simple to design whereas on the other side, if better return loss is required then circular slotted antenna can be designed. It can also be noticed that notched circular slotted MPA provides sharp well defined resonant frequencies in comparison to rectangular slotted MPA. The comparison of the proposed antennas in terms of various parameters has been shown in Table 3.

Table 3: Comparison of Simulated Antenna Designs

Antenna parameters	**Notched Circular slotted MPA**	**Rectangular slotted MPA**
Return loss	-41.57dB at 4.5GHz and -46.78dB at 6.2GHz	-26.45dB at 4.7GHz and -24.36 dB at 6.2 GHz
Bandwidth	2.701 GHz	2.720 GHz
Resonant frequencies	4.5 GHz , 6.2 GHz	4.7GHz,6.2 GHz
Sharpness of peaks	More sharp	Less sharp
Complexity in designing	More complex	Less complex

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