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Enrichment of Return Loss Characteristic of a Rectangular Microstrip Patch Antenna with Defected Structures for 5G Wireless Applications

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Abstract: The Rectangular Microstrip Patch Antenna (RMPA) with enriched impedance matching is proposed for 5G application. The conventional RMPA designed to resonate at 15.21 GHz, gives return loss (S_{11}) of -21.76 dB with a bandwidth of 1.58 GHz. The return loss and bandwidth of the proposed RMPA are improved by engraving square slots at the non-radiating edges of the patch and a square slot at center of the ground plane. The proposed RMPA resonates at 14.82 GHz with return loss -63.76 dB and having bandwidth of 1.61 GHz. The RMPA is designed using RT/Duriod-5880 with dielectric constant 2.2 and having thickness 1.524 mm. The proposed RMPA gives better impedance matching, increased bandwidth and shows compactness of 390 MHz compare to conventional configuration. The RMPA is simulated using HFSS v15.0.

Keywords* — *5G wireless applications, Rectangular MPA, Return loss, S_{11}, Defected Structures.

I. Introduction

5G is the trending generation of cellular mobile era. It is the beneficiary of 4G, 3G and 2G frameworks. 5G framework targets unrivaled data rate, curtailed latency, sparing the power, cost lessening, augmented system capacity, and mammoth gadget availability. The primary inspiration for 5G development is to inflate the broadband skill of portable networks, and to bear the cost of exact forthcoming for clients. Careful examination of the various fields like media, manufacturing, finance, health, development, agribusiness and transport are essential to guarantee that 5G norms at last meet the desires of the targeted customer group [1].

So as to meet elevated speed of communication in 5G, legitimate usage of the mobile network system will be desirable. Antenna architecture with stumpy profile, uncomplicated fabrication and enriched bandwidth are required for above idea. Microstrip patch antennas (MPA) are the most admirable choice for this purpose. However, low power usage capacity and constricted bandwidth are the main demerits. These bad marks can be overwhelmed by engraving defects over the patch and on the ground plane which is called defected structure concept. Defected Microstrip Structure (DMS) is an engraved imperfection on a patch of an antenna which can be in various shapes. Defected Ground structure (DGS) is an engraved deformity in ground plane which can be in various shapes. Another opened square microstrip inset feed antenna for WLAN framework provides an improvement in return loss[2].Exceptionally high bandwidth in MMW application has been accomplished by utilizing Split-ring spaces in halfway ground plane as DGS [3]. It has been demonstrated that return loss can be improved by presenting a pyramid shaped deformed ground plane for MPA operating at 5.5 GHz [4].Square Microstrip Patch with defected ground structure stipulates resonance at both lower and higher band of activity owing of moderate wave impact it further brings down the size of the structure [5]. Introduction of dumbbell shape DGS into MPA predominantly utilized for ISM band provides enhanced return loss [6].It has been accounted for an article wherein NTT Docomo of Japan has consolidated another 5G innovation called MIMO at 15 GHz accomplishing a bursting rate of 20 Gbps[7]. Investigation and plan of space cut H-formed microstrip antenna gives another way for improving the bandwidth [8]. Rogers RT Duroid-5880 having a low relative permittivity of 2.2 as a substrate has been accounted [9] for Tri-band antenna application which can give greater adaptability to 5G correspondence.

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After these examinations for 5G applications, two significant issues considered which are high speed and minimum reflection of power. A newfangled design of rectangular patch antenna encapsulated with square slots on patch as DMS element and square slot in the ground plane as DGS element has been intended for maximum return loss and enhanced bandwidth.

II. ANTENNA CONFIGURATIONS

The favored models for the examination of microstrip antennas are the transmission line model, cavity model, and full wave model. The transmission line model is minimal complex of all and it gives extraordinary physical comprehension. The geometry of the conventional and proposed antenna configurations are appeared in Figure-1.

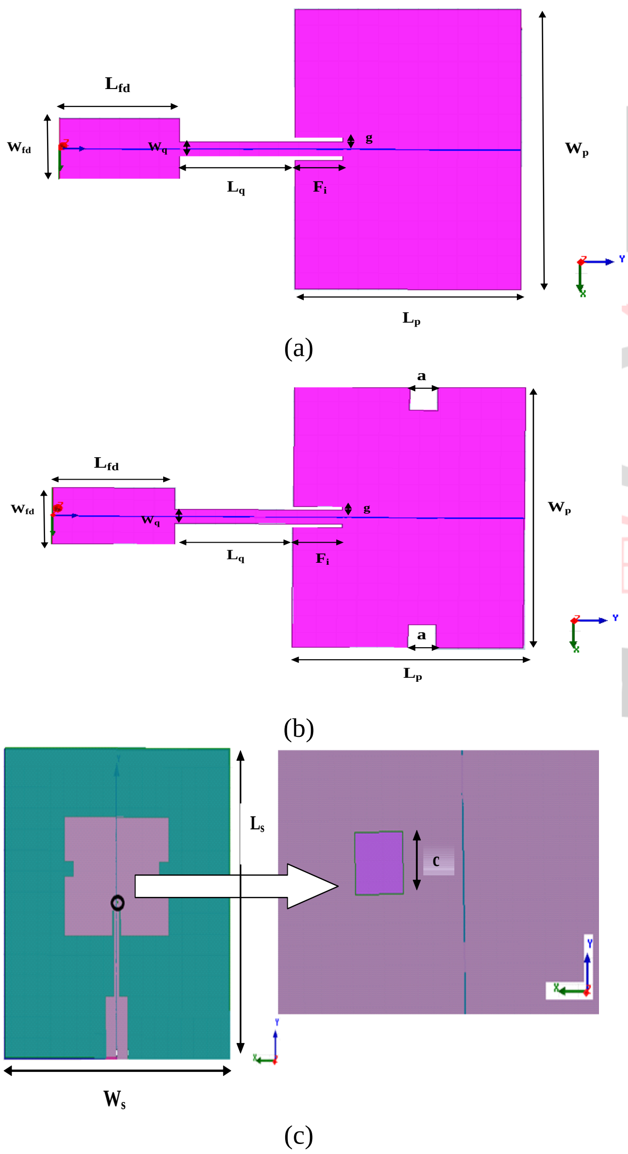

Figure-1: RMPA configurations, (a) Conventional RMPA, (b) RMPA with two square DMS slots (c) Square shaped defect in the ground plane, arrow shows bigger perspective of the deformity

The Figure-1(a) shows conventional configuration. The conventional MPA is designed using Rogers RT Duroid/ 5880 substrate with thickness h = 1.524 mm and ε_r = 2.2. The MPA is designed using Transmission Line Model (TLM), since it is a planar structure. The MPA dimensions are obtained from well known equations [10]. The optimized slot dimensions are presented in Table-1.

Parameters	mm
Patch width (W_p)	7.905
Patch length (L_p)	5.677
Width of feed line (W_{fd})	1.705
Length of feed line (L_{fd})	3
Length of Quarter Wave line (L_q)	2.91
Width of Quarter Wave line (W_q)	0.42
Inset gap (g)	0.1
Length of inset (F_i)	1.2
Width of the substrate (W_s)	17.049
Length of the substrate (L_s)	14.821
Square Slot width (a)	0.7
Square defect width (c)	0.06

Table-1: Dimensions of antenna elements

III. OPTIMIZATION OF SLOTS

We incorporate the idea of DMS for our target by engraving square slots at the centers of non radiating edges of the patch. The dimensions of the deformity can affect the resonating frequency and return loss characteristics due to

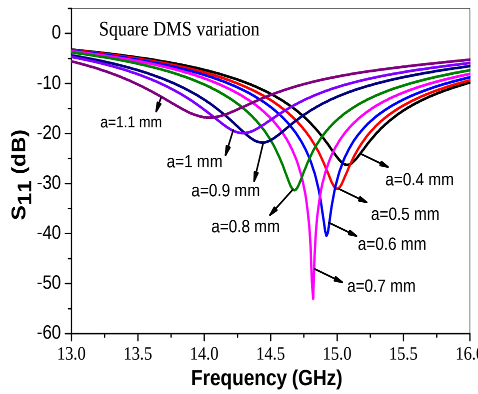

Figure-2: S_{11} plot of Rectangular MPA with square

variation of effective RLC values of an MPA. To extract the behavior of an MPA, optimization is carried out. The DMS defected MPA is appeared in Figure-1(b). The dimension of square DMS is varied in steps of 0.1 mm, as the dimension ‘a’ increases from 0.4 mm to 0.7 mm the impedance matching increases. a= 0.7 mm reports a maximum S_{11} of -53 dB and the resonating frequency is shifting towards the lower side. If the dimension ‘a’ increased further, the MPA behaves reverse effect as that of 0.4 mm to 0.7 mm. From 0.8 mm to 1.1 mm the MPA resonating frequency again shifting towards lower side but matching of MPA become

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decreases and is depicted in Figure-2. When the slot

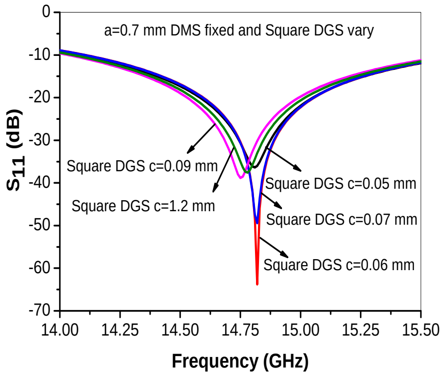


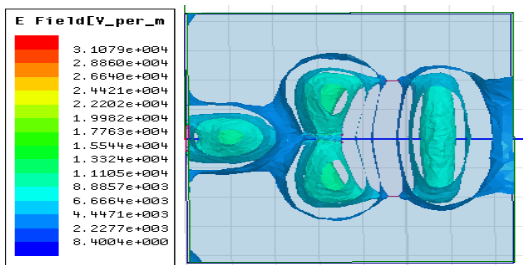
Figure-3: S_{11} plot of Rectangular MPA with square DMS slots and square shaped defect on the ground plane

dimension 'a' is at 0.7 mm the RMPA resonates at 14.82 GHz with a maximum S_{11} of -53.01 dB.

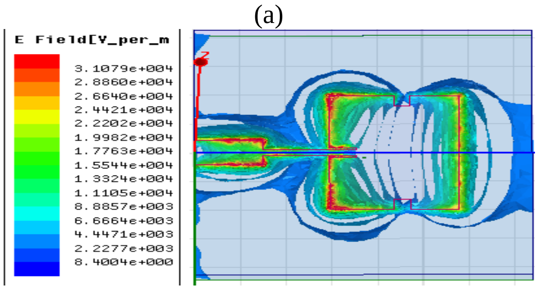
For further improvement of return loss we incorporate the idea of DGS by engraving square deformity in the ground plane. The proposed MPA with DGS structure is shown in Figure-1(c). The dimension of square DGS is also optimized and observed the return loss characteristics shown in Figure-3. The dimension of the DMS slots a=0.7 mm is retained and investigating through optimization of square DGS slot. Square DGS slot dimension is varied from 0.05mm to 1.2 mm. When the DGS slot dimension is at 0.06 mm, the RMPA gives further increase in matching of about -10 dB without changing the resonance.

IV. WORKING PRINCIPLES

The proposed RMPA enhances the return loss characteristics from -21.76 dB to a -63.76 dB due to the



(a)



(b)

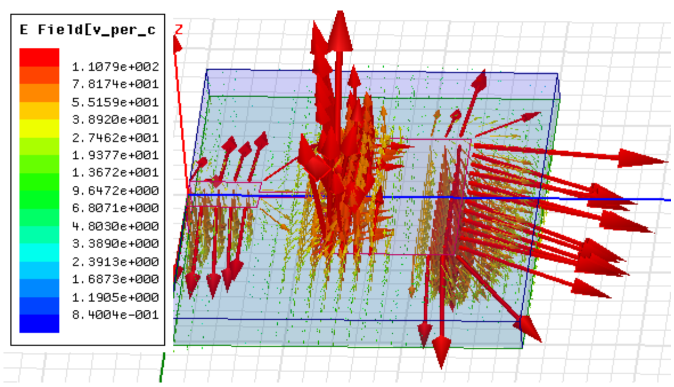
Figure-4: E-field distribution in Substrate at 230^0, (a) Conventional configuration, (b) proposed configuration

square slots at the non-radiating edges of patch and a very small square (c = 0.06 mm) slot in the ground plane as DGS element. The position of DGS element etched at (c/2, L_S/2) mm. The reason for 40 dB return loss enhancement is understood by following observations.

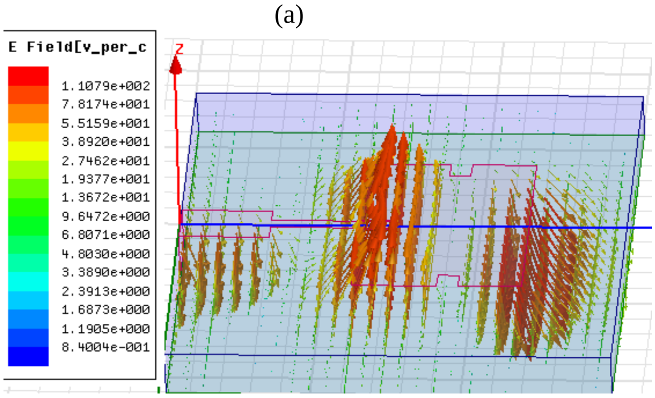
The E-field distribution in a substrate is observed and is shown in Figure-4. The E-field variation of conventional and proposed configuration is observed at 230^0, for the proposed configuration the E-field at the edges of the feed, transmission line and radiating edges of patch is densely concentrated when compared to conventional configuration. These concentrated E-field minimizes the reactive component of proposed RMPA and their by return loss enhancement is achieved, hence maximum power radiated by a proposed RMPA.

The Electric-field vector variation is observed to know the amount field vectors confining in to the substrate and is shown in Figure-5.

The Figure-5 (a) shows electric field vector confinement in to the substrate of a conventional configuration and it clearly shows not all field vectors are confined in to the substrate. Some orthogonal field vectors are fringed out from the substrate. Where as in proposed configuration due to DGS and DMS elements, these orthogonal components are suppressed and all field vectors confined in to the



(a)



(b)

Figure-5: Electric field Vector confinement in substrate at 200^0, (a) Conventional RMPA, (b)

substrate shown in Figure-5 (b).

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The surface current distribution on a radiating patch is observed for a conventional configuration, RMPA with DMS only and RMPA with DMS and DGS shown in Figure-6. For the conventional RMPA surface current

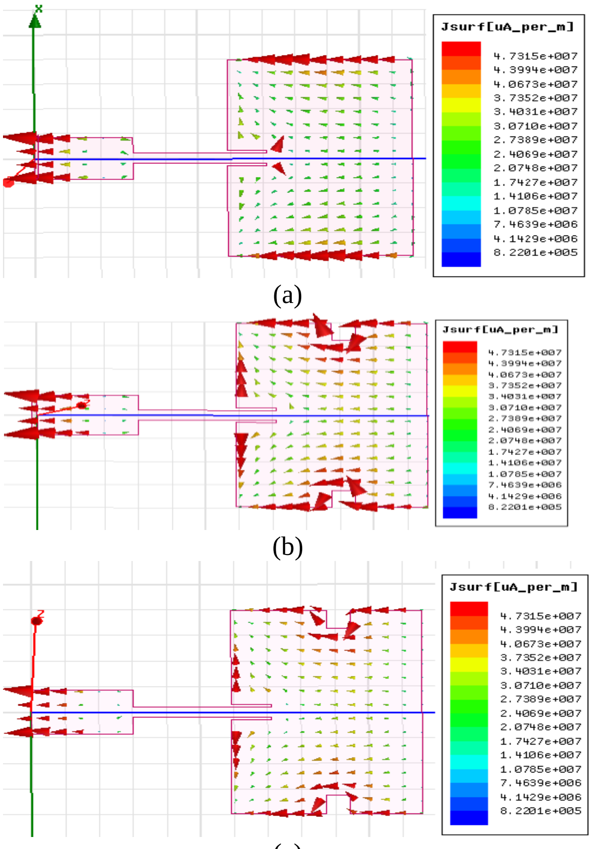

Figure-6: Surface current distribution on patch at 150^0, (a) Conventional RMPA, (b) RMPA with two square DMS slots (c) Proposed RMPA

intensity is larger at the non-radiating edges shown in Figure-6 (a). Due to two DMS slots the surface current intensity increases at the non-radiating edges and feed side radiating edge shown in Figure-6 (b), which enhances the return loss characteristics from -21.76 dB to -53.01 dB. Further a small square etched in the ground plane (c=0.06 mm) enlarges further return loss characteristics from 53.01 dB to 63.76 dB. Hence the proposed RMPA is almost a lossless electro-magnetic radiator due to maximum impedance matching.

V. RESULTS AND DISCUSSIONS

The conventional RMPA is resonating at 15.2 GHz with return loss (S_{11}) of - 21.76 dB and a bandwidth about 1.58 GHz is shown in Figure-7. The principle objective is to enrich the return loss and bandwidth. The goal can be accomplished by engraving square slots in the patch. The return loss has enriched with the improvement from -21.76 dB to -53.01 dB by lower shifting the resonating frequency to 14.82 GHz and a small expansion of 20 MHz in the bandwidth.

For the further enrichment of results, we executed a parametric investigation with the square deformity to a ground plane as DGS and its dimension is optimized to c = 0.06 mm, acquired the return loss of - 63.76 dB with 10 MHz bandwidth improvement at the same resonating frequency as shown in Figure-7. Other than 0.06 mm the RMPA gives poorer return loss characteristics shown as in

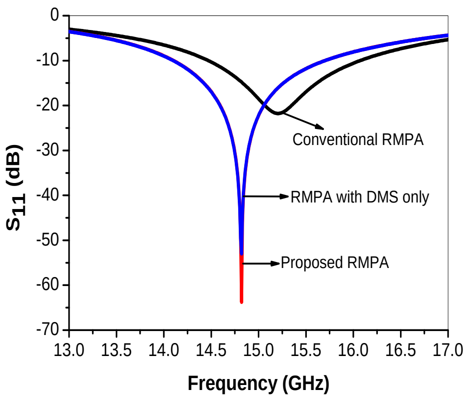

Figure-7: Comparison of S_{11} plots of conventional RMPA, RMPA with DMS and the proposed RMPA.

Figure-3.

The Figure-8 shows the radiation characteristics of a

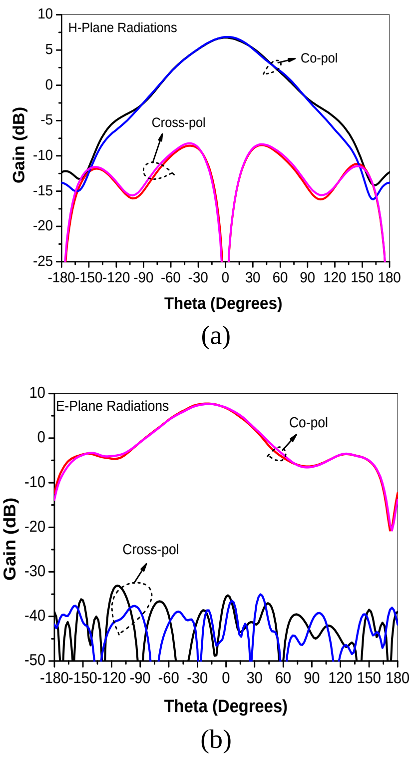

Figure-8: Comparison of Rectangular gain plots for the conventional RMPA with the proposed RMPA (a) H-plane (b) E-plane.

conventional and proposed configuration. The Figure-8 (a) demonstrates the H-plane radiation characteristics of conventional configuration and proposed configuration. The RMPA gives broadside radiations without much change in

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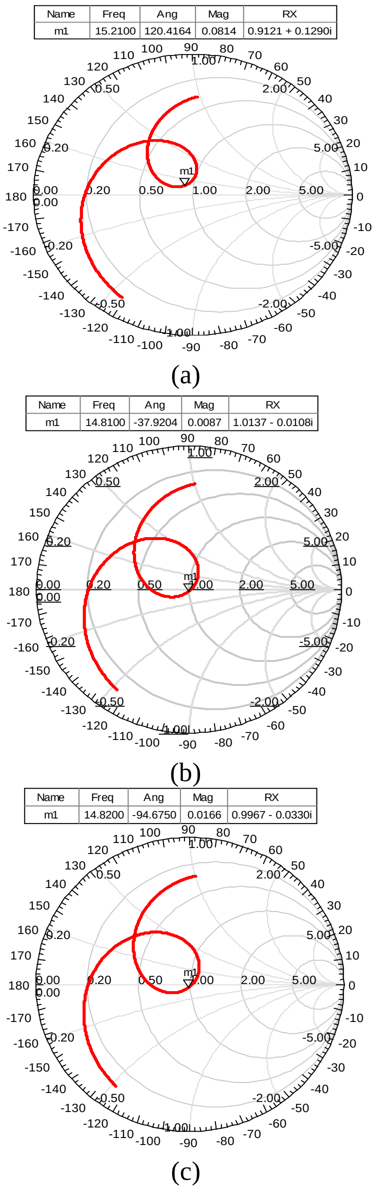

Figure-9: Smith Chart, (a) Conventional RMPA, (b) RMPA with two square DMS slots (c) Proposed

the co-polarization peak gain of about 7.5 dB and cross-polarization levels are at -10 dB. The Figure-8 (b) shows E-

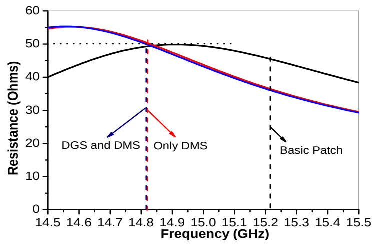

Figure-10: Input resistance of conventional, with DMS and proposed configurations

plane radiation characteristics with a co-polarization peak gain of about 7.5 dB with cross-polarization levels are well below -35 dB. The proposed RMPA return loss characteristics is -42 dB improvements obtained compared to conventional RMPA as shown in Figure-7.

The Figure-9 (a) shows the smith chart (S-parameter) of a conventional configuration and it behaves like inductive at its resonating frequency. The RMPA with DMS and proposed structures makes the reactive elements almost equal in magnitude their by cancel each other and are shown in Figure-9 (b) and (c). As a proof the Figure-10 shows input resistance of conventional, RMPA with DMS and proposed configuration.

The Table-2 shows the comparison of RMPA parameters of all three types of RMPA configurations.

For better transmission voltage standing wave ratio

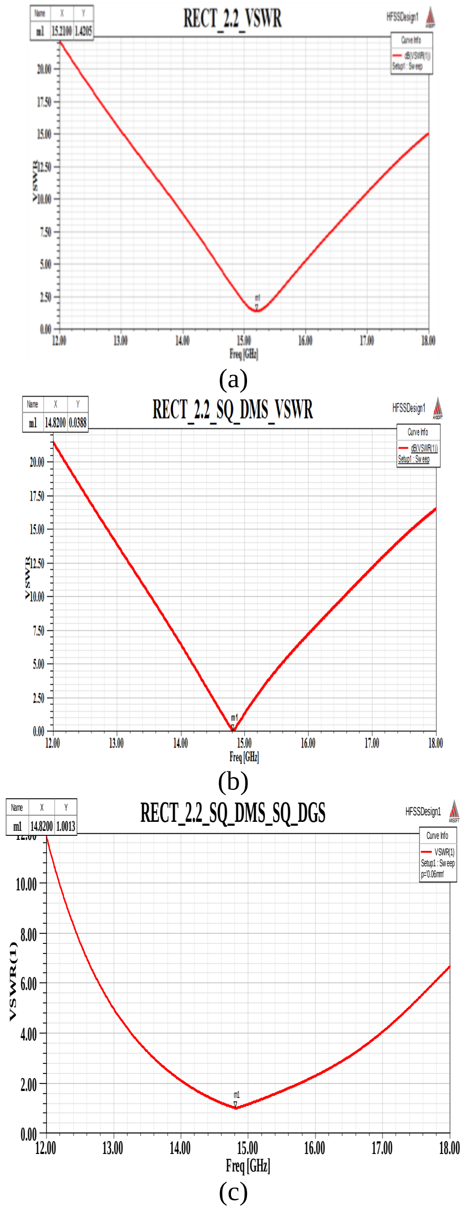

Figure-11: VSWR plots, (a) Conventional RMPA, (b) RMPA with two square DMS slots (c) Proposed RMPA

(VSWR) should always be less than 2.The VSWR obtained for proposed configuration is 1.001, which indicates the minimum reflection of power. Figure-11 depicts the VSWR plots for all three types of configurations. The Figure-12 shows radiation pattern in 3D polar distribution of energy for all three types of configurations.

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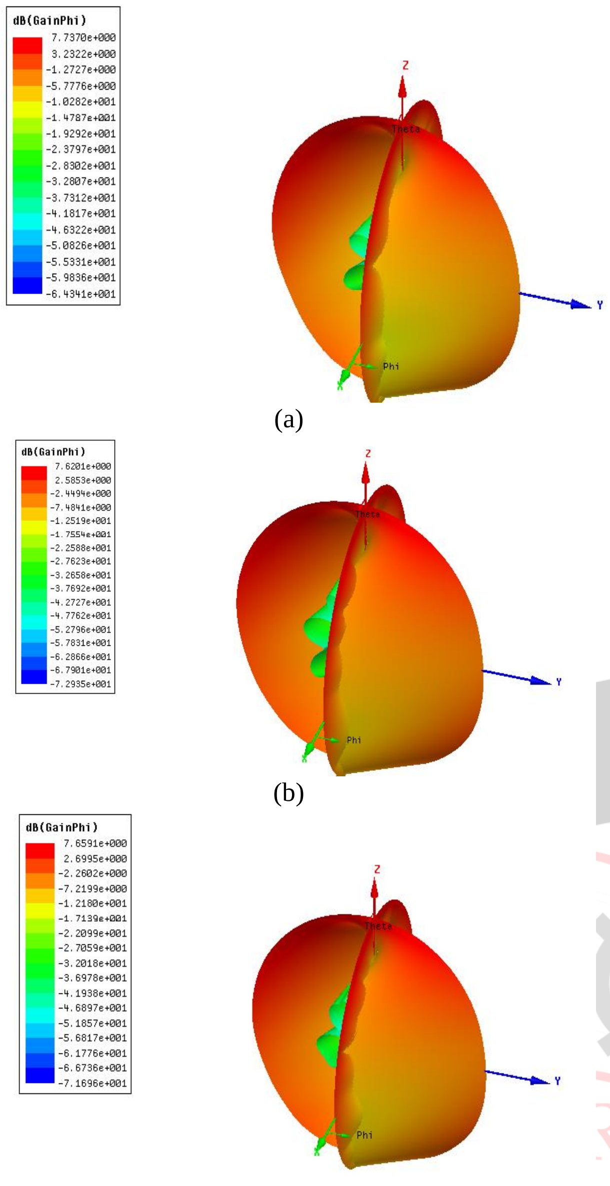

(a) (b) (c)

Figure-12: 3D polar radiation pattern, (a) Conventional RMPA, (b) RMPA with two square DMS slots (c) Proposed RMPA

Antenna Type / Properties	Basic RMPA	RMPA with two Square DMS Slots	RMPA with two Square DMS Slots & square DGS slot
Slot Dimensions	------------	a= 0.7 mm	a= 0.7 mm c= 0.06 mm
Resonant Frequency	15.21 GHZ	14.82 GHZ	14.82 GHZ
Return Loss(S_{11})	-21.76 dB	-53.01 dB	--63.76 dB
VSWR	1.420	0.038	1.001
Bandwidth	1.58 GHZ	1.60 GHZ	1.61 GHZ
% Bandwidth	10.38 %	10.79 %	10.86 %
Gain	7.737 dB	7.620 dB	7.659 dB

Table-2: Comparison of results obtained for three RMPA configurations.

VI. CONCLUSION

The Rectangular Microstrip Patch Antenna is designed using RT/Duroid dielectric substrate 5880 with $\varepsilon_r = 2.2$ having thickness h = 1.524 mm for 5G wireless communication. The radiating patch of conventional configuration is defected with square slots at the non-radiating edges and small square shape defect in the ground plane which enhances the return loss characteristics from -21.76 dB to -63.76 dB. Due to the two square DMS slots and a square DGS slot, the proposed RMPA gives almost 3 times greater in return loss characteristics and 30 MHz bandwidth improvement when compared to conventional configuration. The proposed RMPA shows compactness of 390 MHz by resonating at 14.82 GHz when compared to conventional configuration. The proposed structure is useful for future 5G applications and it is power consistent due to its better impedance matching.

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