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Design of DNG Metamaterial loaded Single fed Wideband Microstrip Patch Antenna at 28GHz for Millimeter wave Applications

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Abstract:- Nowadays, 5G is attracting the attention of communication services because of its fast data speeds and good channel capacity. The mm-wave band, in particular the 28-GHz frequency band, is thought to present a viable option for high-quality services in 5G networks due to its low absorption rates. The single feed wideband mm-wave micro-strip patch antenna resonated at 28GHz modeled with the dimensions of 4.8 X 7.55 X 0.254 mm^3 was presented in this article. In order to improve the radiation performance in terms of bandwidth, gain, and efficiency at 28GHz, a unique defective ground structure (DGS) is built with the double negative (DNG) rectangular split ring resonator (SRR) meta-material unit cell incorporated in a wide rectangular slot on a ground plane and slots on patch. The proposed antenna structure operated in frequency band from 26.79GHz to 29.2GHz with bandwidth of 2.4GHz. The maximum gain obtained over the band is 6.04dB and the radiation efficiency is 99.9%. The results demonstrated that the proposed antenna is well suitable for 5G mm-wave Applications. The proposed antenna was designed using HFSS-19 Software.

Keywords: *Microstrip Patch Antenna, 5G, mm-wave, DGS, SRR*

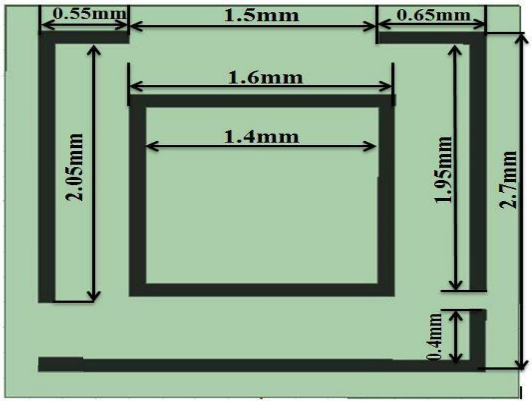
1. Introductin

The next generation of 4G mobile telecommunications standards is referred to as 5G[1]. Across the world wide the mobile data traffic is exponentially increasing year by year and the continuation of this data traffic will be expected in future also [2][3][4]. The traditional microwave bands facing a problem of shortage in its spectrum, Due to the shortage of that spectrum millimeter wave (mm-Wave) bands have been populated as suitable spectrum band for 5G mobile communication [5] [6]. The fifth generation wireless technology has the goal of enhancing the capacity and efficiency of communication network. Increasing the capacity of5G communication networks mean to deliver the communication services with respect to meet the requirements and demands of network users with faster and higher data rates. As a communication device [7] [8], the antenna plays a dynamic role in the field of communication. So, such deployment of a 5G communication technology need the antenna which can serve the data with high data rates and good channel capacity.

In this article the proposed antenna structure is operated in millimeter wave band ranging from 26.8GHz to 29.2GHz with a central frequency 28GHz. In literature survey it is observed that incorporating metamaterials in antenna structure gives significant in radiation enhancement interms of bandwidth, gain and radiation efficiency.So in this article double negative metamaterial is proposed to enhance the characteristics of the antenna.

2. Design of Metamaterial at 28GHz

Metamaterial is a artificial structure not existing in nature. These materials are used to control the behaviour of electromagnetic waves to get the required characteristics. According to the negative values of magnetic permeability and dielectric permittivity the meta-materials are classified. SNG (single negative) meta-materials exhibits the properties of either negative values of dielectric permittivity or negative values of magnetic permeability and are usually called as ENG (ε-negative) meta-materials or MNG (μ- negative) meta-materials.



The both magnetic permeability (μ) and dielectricpermittivity (ε) are negative [11] in a double negative (DNG) material. The proposed DNG meta-material modeled with two rectangular ring resonators, the outer ring split is shown in Figure 1 and resonated at required pass band ranging from 26.8GHz to 29.2GHz is shown in Figure 2.

Figure 1: Proposed DNG SRR Meta-material unit cell

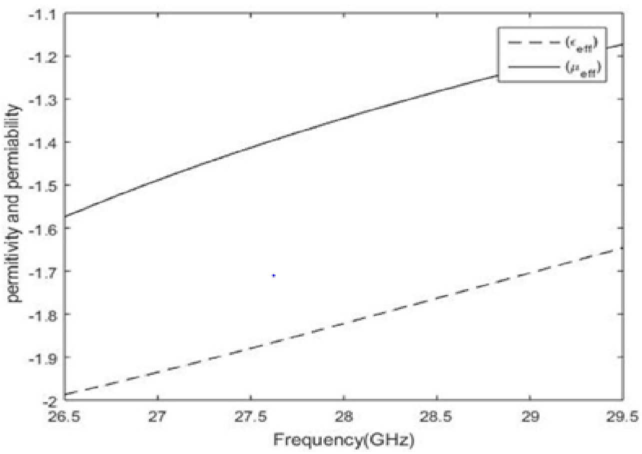


Figure 2: Permittivity (ε) and permeability (μ) characteristics of Proposed DNG SRR Meta-material

3. Design of Proposed antenna

The proposed antenna structure is designed using dielectric substrate Rogers RT/duroid 5880, its dielectric constant is 2.2 and it is simulated on HFSS-19 software with the dimensions of 4.8X7.55X0.254 mm^3 with respect to length, width and height as shown in Figure 3. A 3.5X2.8 mm^2 dimensioned patch is etched on top face of substrate; two inverted L-shaped slots and one vertical thin slit are incorporatedin patch as shown Figure 3(a) to radiate exactly at the frequency 28GHz. The bottom surface of substrate is filled with metallic ground. A novel defected ground structure is framed with incorporating the DNG meta-material unit cell in a 2.8X3.1 mm^2 dimensioned rectangular slot on a ground plane as shown in Figure 3(b), it caused to enhance the radiation performance.

After studying several parameters (parametric analysis), the proposed antenna structure is fixed with the dimensions of length of substrate L=7.55mm, Width of substrate W=4.8mm, Height of substrate h=0.254mm, length ofpatch Lp=2.8mm, Width of patch Wp= 3.5mm, width of feed line Wf=0.2mm and length of feed line Lf=1.0 mm.

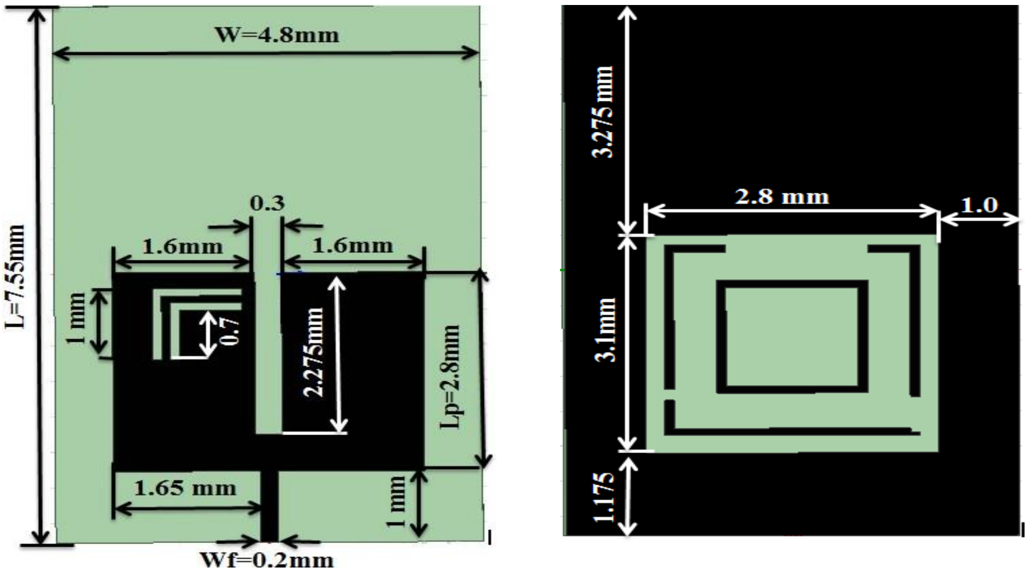


Figure 3: Proposed antenna structure (a) Top view (b) Bottom view

4. Results and Discussions

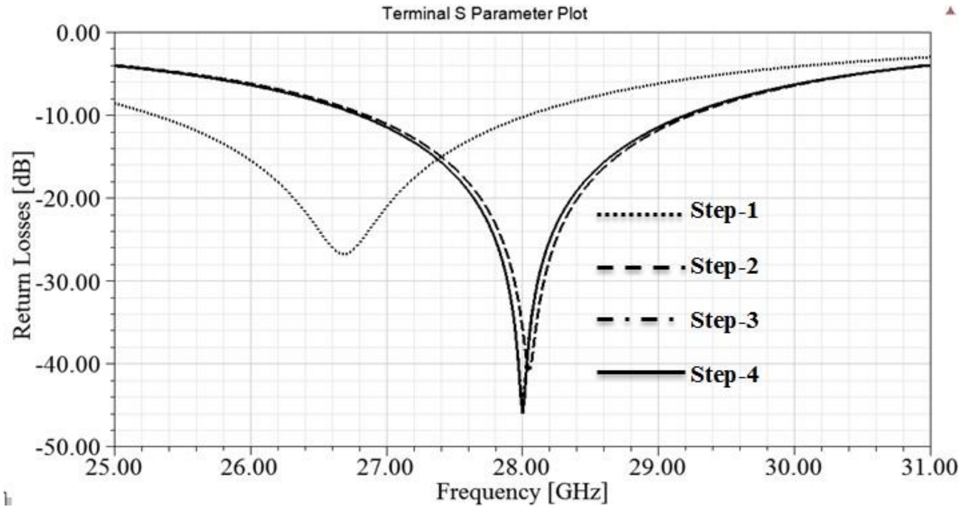
The design of micro strip antenna is done with different considerations as per the requirement of 5G wireless applications. The proposed antenna structure is modeled andsimulated using HFSS-19 software. The proposed antenna structure is analysed using four steps and is shown in figure 4.

Step-1: The patch with retangualr slotted ground resonated at 26.69GHz.

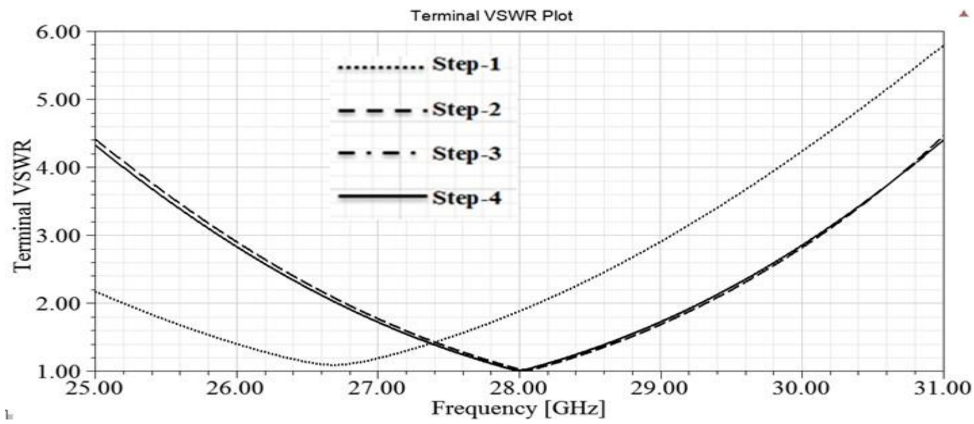
Step-2: The patch with DGS structure consists of rectangular slot and DNG metamaterial resonated at 2 28.0533GHz

Step-3: The patch with two inverted L shaped slots and DGS structure consists of rectangular slot and DNG metamaterial resonated at 28GHz

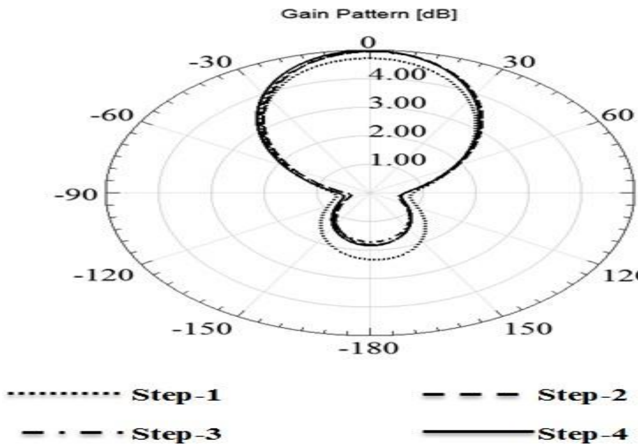
Step-4: Inaddition to Step-3 one vertical slot is added on patch to enhance the return loss and gain over the wideband.



(a) Return losses of proposed antenna structure as per various steps



(b) VSWR of proposed antenna structure as per various steps



(c) Gain pattern of proposed antenna structure as per various steps

Figure 4: Results of proposed antenna structure as per various steps

The radiation characteristics interms of Return losses, bandwidth, VSWR and the gain are studied by doing parametric analysis. Parametric analysis done by varying L(length of substrate), W (width of substrate) and Wf (width of feed line). The radiation characteristics of proposed antenna structure are observed by varying length of substrate (L) from 6.55mm to 8.55 mm and observed the degradation of antenna performance at surrounding values of L=7.55mm. It can observe from Figure 5 and Table 1.

Table 1: Results of proposed antenna structure by varying length of substrate(L)

Length of substrate (L)	Resonated frequency (GHz)	Return losses (dB)	Bandwidth range (GHz)	Gain(dB)
6.55 mm	28.8933	-18.6948	27.98-29.68	5.78
7.55 mm	28.00	-45.9698	26.79-29.20	5.90
8.55 mm	26.04	-14.0925	25.35-26.74	5.56

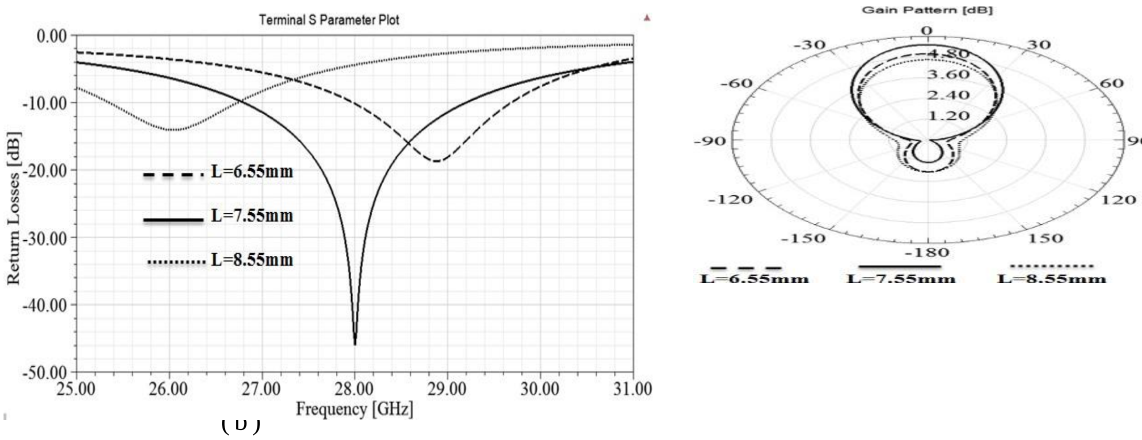


Figure 5: Results of proposed antenna structure by varying length of substrate (L)

As a next step of parametric study, the radiation characteristics of proposed antenna structure have been observed by varying Width of substrate (W) from 3.8 mm to 10.8 mm and it is observed the serious degradation of antenna performance in terms of return losses and gain at decreasing values to W=4.8 mm and at increasing values of W= 4.8 mm observed enhancement in gain, decrement in return losses and bandwidth. The Resonating frequency also shifted 28GHz to other frequencies is shown in figure 6.

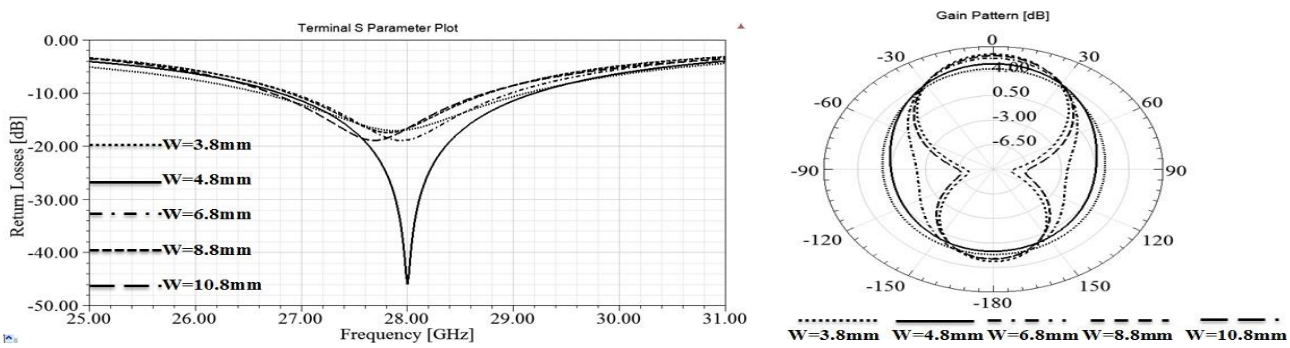


Figure 6: Results of proposed antenna structure by varying width of substrate

The radiation characteristics are also observed by varying width of feed line (Wf) from 0.1mm to 0.3 mm and it is observed that the degradation in return losses and shift in resonating frequency at surrounding values of Wf=0.2mm. It can observe from Figure 7 and Table 2 and the comparative results of proposed work with existing work in Table 3.

. Table 2: Analysis of proposed antenna structure by varying width offeed line (Wf)

Width of feed line (W_f)	Resonant frequency (GHz)	Return Loss (dB)	Bandwidth (GHz)	Gain (dB)
0.1mm	27.667	-14.81	26.84-28.43	5.8
0.2mm	28	-45.96	26.79-29.20	5.9
0.3mm	28.34	-16.28	27.07-29.58	5.9

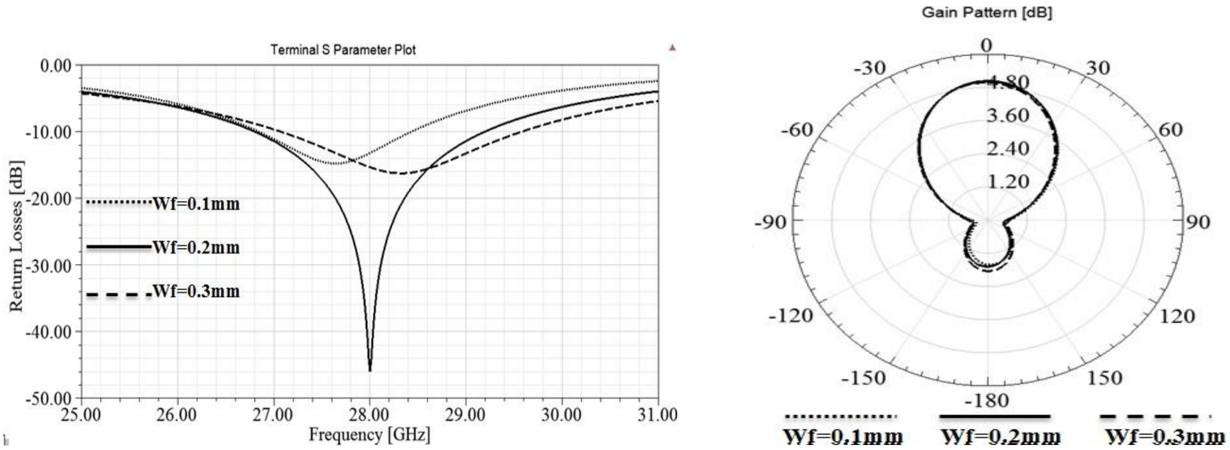


Figure 7: Results of proposed antenna structure by varying width offeed line (Wf)

Table 3: Comparative results of proposed antenna structure with the previouswork presented in literature

Ref.	Antenna size (mm)	Central freq. (GHz)	Return losses(dB)	Band width(GHz)	Gain(dB)	Efficiency (%)
[10]	30X30	27	-26.5	3.52	7.1	94.5
[15]	30X15	28	-22	6.4	5.42	85
[18]	30X30	28	-36	2	5.5	90
[16]	15X10	28	-32	3.8	5.83	89
[19]	30X30	28	-31	2.5	8	95
[13]	5X5	28	-56.95	1.38	7.6	98
[14]	11X15	28	-32.5	3	3	N.A
[17]	115X65	28.4	-26	1.22	9.65	75
[20]	63.5X70	28	-52	2.3	13.5	75
This article	7.55X4.8	28	-45.96	2.41	6.04	99.9

5. Conclusion

This article presented double negative meta-material incorporated mm-wave micro-strip antenna resonated at 28GHz. It is modeled on HFSS-19 software with the dimensions of 4.8 X 7.55 X 0.254 mm^3. A novel defected ground structure incorporated DNG metamaterial enhance the radiation performance interms of bandwidth, gain and efficiency. The proposed antenna operated in frequency band from 26.79GHz to 29.2GHz with bandwidth of 2.41GHz. The maximum gain obtained over the band is 6.04dB and the radiation efficiency is 99.9%. The results demonstrated that the presented antenna structure has efficient radiation performance and is well suitable for 5G mm-wave Applications.

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