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Defective ground structure and complimentary split ring resonator loaded compact wideband antenna for radiolocation applications

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ABSTRACT

A wideband compact antenna with wo Bandwidth enhancement techniques intended for radiolocation applications is presented. Defective ground structure (DGS) is used to enhance the bandwidth and complimentary split ring resonator (CSRR) has been used to generate the bandwidth at the lower frequency of the antenna which brings compact nature. A coax feed patch antenna radiating at X-band frequency of 10 GHz is loaded with DGS and CSRR. Proposed antenna with a bandwidth of 3.4 GHz has shown a considerable enhancement in the antenna bandwidth when compared with the antenna with CSRR alone which is having a bandwidth of 1.15 GHz and a basic patch antenna whose bandwidth is 0.91 GHz. Proposed antenna is having omni directional radiation pattern with a gain of 5.01 dB and without any null in the coverage area. A great increase in the current fields can be observed that the field currents by loading the patch and ground with CSRR and DGS respectively. The patch currents have increased from 2.76 v/m to 3.25 v/m and the ground currents have increased from 0 v/m to 2.45 v/m. Proposed antenna has been realized and its performance is measured using vector network analyzer, a near match in between the simulated result and measured result is observed.

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1. INTRODUCTION

One of the basic requirements of any RF device design these days is to have a compact structure for which we need a compact antenna with high bandwidth and a considerable gain to meet the data transfer needs of multiple applications. By having compact wideband antennas, the overall system size will be very small and it can accommodate multiple applications. Radiolocation is one such application, which require a compact handheld device to locate the objects beneath the ground. These systems should consume low power to have long working hours and to be user friendly the device should be of small size. To meet this requirement many researchers have proposed techniques to enhance the antenna parameters and to bring compactness to the antenna, like taking the substrates with high dielectric constant to achieve compactness but the cost of the system is increasing. We can also try increasing the electrical length of the patch by etching slots in the patch but it is affecting the radiation pattern of the antenna as the field current distribution of the antenna elements are affected. Nulls will form in the radiation pattern when we etch slots and there will be no uniformity in the pattern. Similarly, different techniques like loading patch with CSRR structures, introducing VIA's were proposed but every technique is having some disadvantage making it not useful for the proposed application.

Yi Hong Xie in [1] proposed loading a CSRR in the ground plane for dual band operation. But Both the bands are very narrow and resonating with linear polarization. Mohammad Saeed Majedi in [2] proposed introducing two verticals metallic VIAs and are loaded into the rectangular patch for dual band operation but the impedance bandwidth at both the bands is low. But Binfeng Zong in [3] proposed four annular ring slot loaded Mushroom Unit Cells are loaded into the patch for dual band operation. But the 10-dB return loss bandwidth at patch mode band and left-hand band is low. Many researchers proposed loading of a single CSRR structure in patch or in the ground to achieve dual frequency of operation and compact size. Hui Zhang [4] proposed an antenna in which two types of CSRRs are presented of which one is perpendicular and the other is parallel. Perpendicular CSRR is useful for generating wide bandwidth where as the parallel type CSRR is useful for generating dual bands. In this way dual frequency of operation is generated. In general, CSRR structures are loaded in the radiating element. But J. X. Niu [5] proposed a new technique of loading a CSRR in the ground plane for dual band operation. But Both the bands are very narrow and resonating with linear polarization. Several single-layer, single-feed CSRR loaded antenna structures are suggested for dual band operation where researchers used CSRR either for loading into the patch or into the ground plane. However, the reported 10-dB return loss bandwidth at both the bands is narrow.

Thus, these antennas do not serve the modern-day requirements [6-25]. For all the above-mentioned techniques we are able to achieve compactness but the bandwidth of the antenna is very low at both the operating frequencies. If we can design a CSRR structure and a DGS structure such the generated new frequency by CSRR is nearer to the lower side of fundamental frequency of the antenna and the generated new frequency by DGS is nearer to the upper side of fundamental frequency of the antenna then we can increase the bandwidth of the antenna and this technique is presented in this communication. A DGS and CSRR loaded compact wideband antenna is proposed in this communication to overcome all these drawbacks and serve for radiolocation application.

2. PROPOSED ANTENNA

A wideband antenna is presented in this communication which is having compact characteristic and can be used for the radiolocation applications. A basic coax feed patch antenna radiating at X-band frequency of 10 GHz is loaded with DGS and CSRR. The overall size of the antenna is 15×15×1.6 mm. Proposed antenna is designed and reliazed on a FR4 laminate. In the basic antenna the fundamental structure of the radiating element is a rectangular sheet and the ground plane is a uniform structure. Then in the next stage the radiating element is loaded with the CSRR structure to increase the bandwidth at the lower side of the resonating frequency and making the antenna a compact one. And in the further stage a DGS is loaded in the ground plane to increase the bandwidth of the antenna at the higher side of resonating frequency making the antenna a wideband antenna. The top view and rare view of fundamental antenna are shown in Figure 1 (a) and Figure 1 (b). Patch loaded with CSRR structure is presented in Figure 1 (c) and the CSRR structure is presented in the Figure 1 (d). Figure 1 (e) shows the antenna ground plane loaded with DGS structure. The optimized final dimensions of the proposed antenna are presented in the Table 1. The design equations for calculating the rectangular patch are given below:

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \tag{1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{2}$$

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \tag{3}$$

$$\Delta L = 0.412h\frac{\left(\varepsilon_{eff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{eff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{4}$$

$$L = L_{eff} - 2\Delta L \tag{5}$$

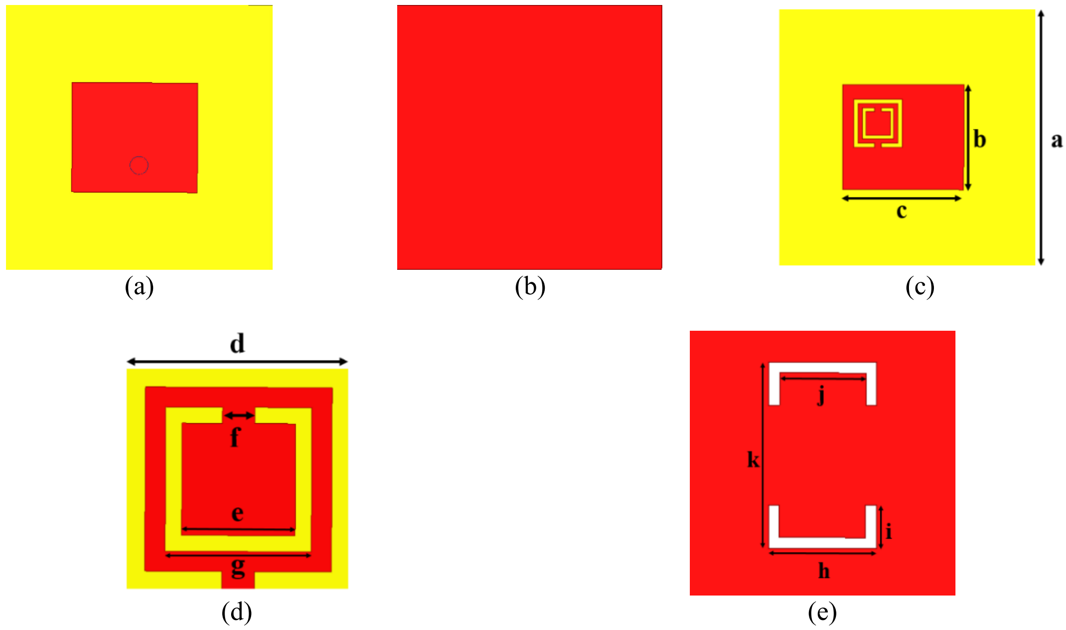


Figure 1. Basic and proposed antenna structures, (a) top view of basic antenna, (b) rare view of basic antenna, (c) antenna patch loaded with CSRR, (d) CSRR, and (e) antenna ground loaded with DGS

Table 1. Optimized antenna parameters

Parameter	Value(mm)
a	15
b	6.1
c	7
d	2.8
e	1.4
f	0.4
g	1.8
h	5
i	2
j	4
k	8.6

3. RESULTS AND ANALYSIS

Figure 2 shows the return loss of the antenna and Figure 3 shows the voltage standing wave ration of the antennas. From Figure 2 we can observe that the proposed antenna with CSRR and DGS loaded is having a bandwidth of 3.4 GHz and has shown a considerable enhancement in the antenna bandwidth when compared with the antenna with CSRR alone which is having a bandwidth of 1.15 GHz and a basic patch antenna whose bandwidth is 0.91 GHz. The antenna loaded with both CSRR and DGS is having a bandwidth ranging from 9.01 GHz to 12.41 GHz and the antenna loaded with CSRR is having a bandwidth ranging from 9.12 GHz to 10.27 GHz. The basic rectangular patch antenna is having a bandwidth ranging from 9.66 GHz to 10.57 GHz. At all the above frequencies the return loss value is less than -10 dB which is the impedance bandwidth of the antenna.

VSWR plot of the proposed antenna along with basic antenna and CSRR loaded antenna is presented in the Figure 3. The antenna loaded with both CSRR and DGS is having a VSWR ranging from 9.01 GHz to 12.41 GHz and the antenna loaded with CSRR is having a VSWR ranging from 9.12 GHz to 10.27 GHz. The basic rectangular patch antenna is having a VSWR ranging from 9.66 GHz to 10.57 GHz. At all the above frequencies the VSWR value is less than 2 dB which is the impedance bandwidth of the antenna. The gain of the proposed antenna in terms of the elevation gain and azimuthal gain patterns are shown in the Figure 4. The gain pattern in both the planes is similar which indicated that the antenna is radiating uniformly in all the directions. Figures 4 (a) and 4 (b) shows the elevation gain and azimuthal gain patterns of the basic antenna, CSRR loaded antenna and antenna with DGS and CSRR respectively, A decrement in gain value by 0.7 dB can be observed for the antenna with DGS and CSRR when compared to remaining two models.

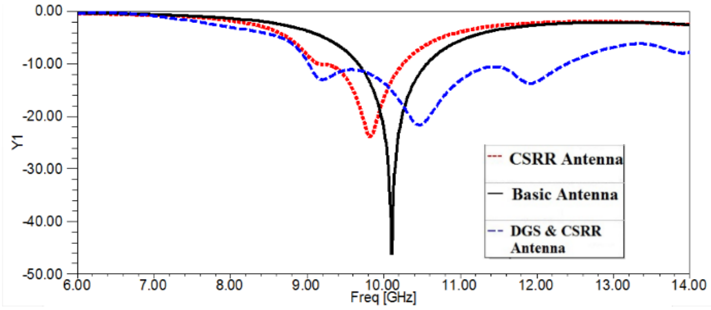


Figure 2. Return loss

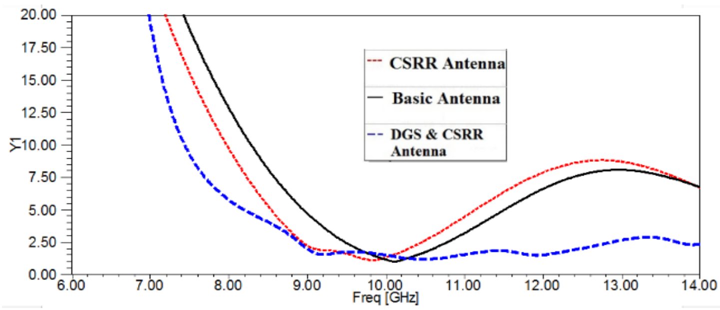
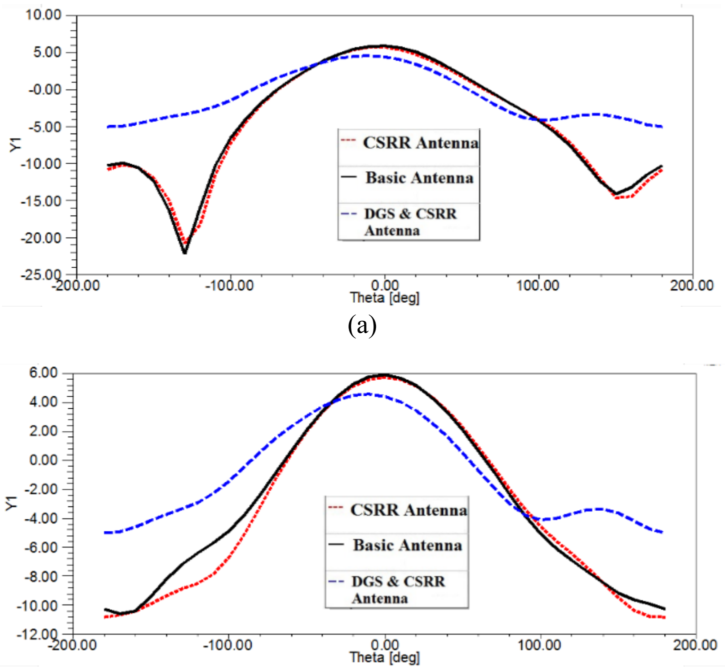


Figure 3. VSWR



(a)

(b)

Figure 4. Gain at 10 GHz; (a) elevation plane and (b) azimuthal plane

The radiation pattern of the antenna at the X-band operating frequency of 10GHz is presented in the Figures 5 and 6. Figure 5 shows the radiation patterns of the basic antenna, CSRR loaded antenna and DGS and CSRR loaded antenna in the elevation plane while Figure 6 shows the same in the azimuthal plane. Here in both the cases we can observe that the radiation pattern of the antenna is not affected by introducing the CSRR and DGS into the basic antenna even though we etched the CSRR in the radiating element and DGS in the ground plane.

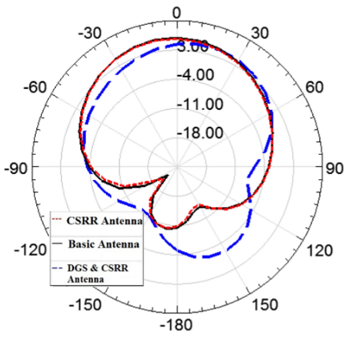


Figure 5. Elevation plane patterns

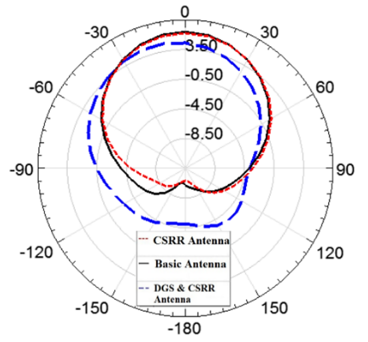


Figure 6. Azimuthal plane patterns

The current distributions of the proposed antennas at the X-band operating frequency of 10 GHz is presented in the Figure 7. Figure 7 (a) shows the current distributions of the basic antenna while Figure 7 (b) shows the current distributions of the CSRR loaded antenna. Here we can see that the field current has increased from 2.76 V/m in basic antenna to 3.25 V/m in CSRR loaded antenna. And this is due to the additional currents generated because of the introduction of the CSRR structure which is presented in figures below. Similar effect can be observed from Figure 7 (c) which shows the current distributions in ground plane of the basic antenna and Figure 7 (d) which shows the current distributions of the DGS loaded antenna. Here we can see that the field current has increased from 0 V/m in basic antenna to 2.45 V/m in DGS loaded antenna. The realized antenna model and its measurement using vector network analyzer is shown in the Figure 8. Figure 8 (a) presents the realized antenna model and Figure 8 (b) presents the measurement of antenna.

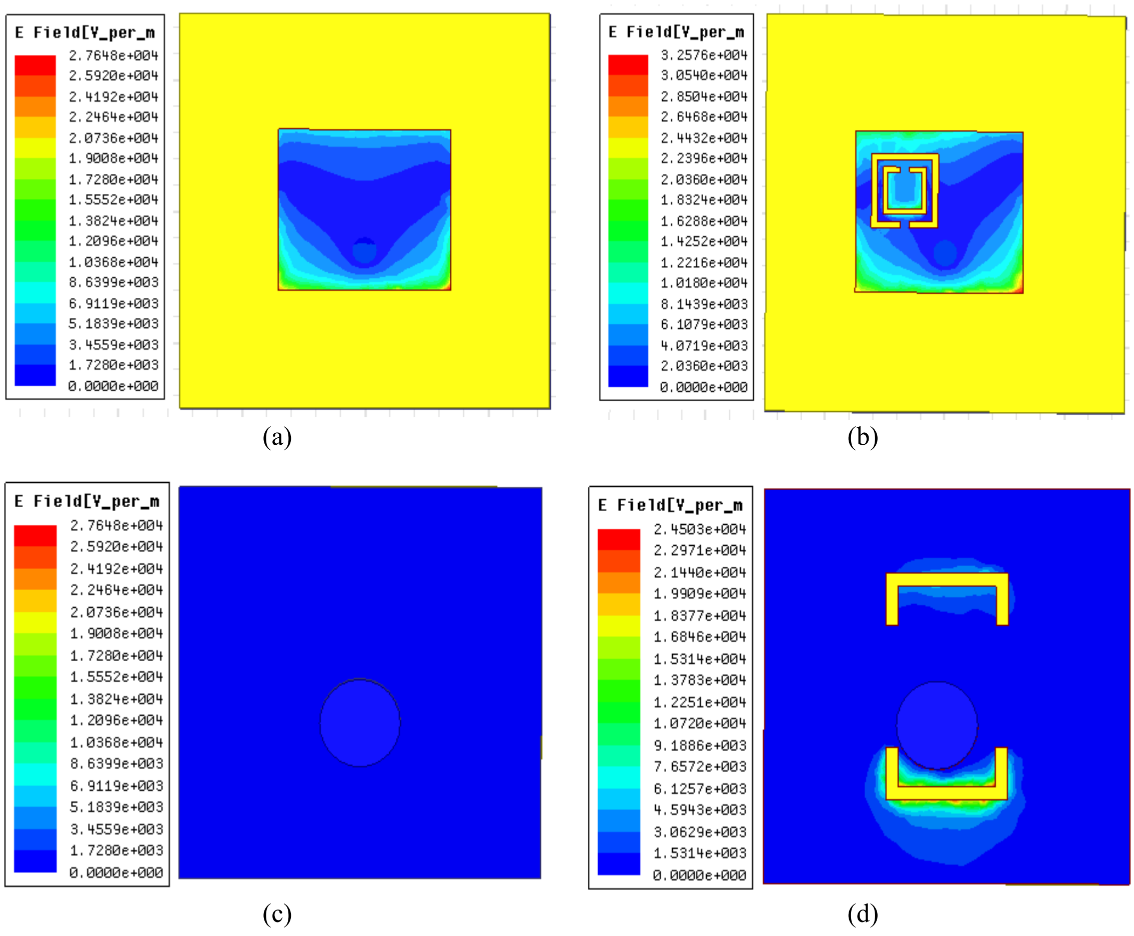
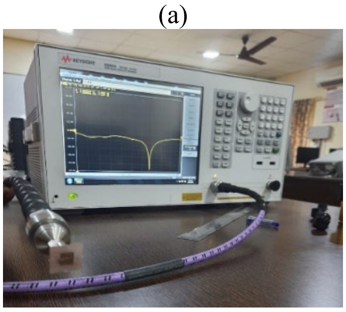


Figure 7. Current distribution; (a) basic antenna, (b) antenna loaded with CSRR, (c) basic antenna ground plane and (d) ground plane loaded with DGS

(a)



(b)

Figure 8. Realized antenna and measurement setup;
(a) realized antenna, and (b) antenna measurement using VNA

4. CONCLUSION

A wideband antenna is presented in this communication which is having compact characteristic and can be used for the radiolocation applications. Two Bandwidth enhancement techniques were integrated in the proposed model. Defective ground structure (DGS) is used to enhance the bandwidth and the technique of complimentary split ring resonator (CSRR) has been used to generate the bandwidth at the lower frequency region of the antenna to bring compact nature. A basic coax feed patch antenna radiating at X-band frequency of 10 GHz is loaded with DGS and CSRR. The overall size of the antenna is 15×15×1.6 mm. Proposed antenna is designed and reliazed on a FR4 laminate. Proposed antenna with a bandwidth of 3.4 GHz has shown a considerable enhancement in the antenna bandwidth when compared with the antenna with CSRR alone which is having a bandwidth of 1.15 GHz and a basic patch antenna whose bandwidth is 0.91 GHz. Proposed antenna is having an omni directional radiation pattern with a gain of 5.01 dB and without any null in the coverage area. A great increase in the current fields can be observed that the field currents by loading the patch and ground with CSRR and DGS respectively. The patch currents have increased from 2.76 v/m to 3.25 v/m and the ground currents have increased from 0 v/m to 2.45 v/m. Proposed antenna has been realized and its performance is measured using vector network analyzer, a near match in between the simulated result and measured result is observed which is evident that it can serve the X-band radiolocation application in a best way.

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