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Octagonal Antenna for Radar Cross Section Reduction Applications

D. A. JAMRO[++], G. A. MALLAH[*], F. A. MANGI, A. H. BHATTI

Department of Physics and Electronics, Shah Abdul Latif University, Khairpur

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Abstract: The Octagonal UWB antenna with an octagon aperture is designed and demonstrated experimentally for RCS reduction applications. In this design, the required RCS reduction is achieved by adopting the size reduction technique. The size miniaturization is obtained by converting circular patch into the octagonal. Afterward, non-effective area of the patch is subtracted in the form of octagon aperture. The scattering performance of the modified antenna is satisfactory in the entire operational frequency range. In addition, the modified antenna has advantages on reference antennas inthe RCS reduction. The outcomessuggest that the proposed design will provide a future prospect for low RCS antenna applications.

Keywords: Octagonal antenna, radar cross section (RCS), scattering,size miniaturization

I. INTRODUCTION

Radar, as a principal kind of equipment for the detection of objects, has got wide applications in modern military operations (Heidrich and Wiesbeck 1992). (Oraizi and Abdolali 2008) (Zheng, *et al.*, 2008) (Li, *et al.*, 2009) (Li, *et al.*, 2008) (Zheng, *et al.*, 2008) Therefore, the radar stealth performance of military systems and platforms acts as a vital measure of their survivability in enmities. The radar stealth of friendly objects found through properly designing can assist friendly objects effectively and avoid the incoming threats generated by hostile radars. The hostile radar detection of friendly objects can be delayed and the fighting capability of unfriendly radar systems can be diminished. Thus, the survivability of friendly objects can be improved (Ruan, 1998)

Therefore, antenna designing with low RCS has a significant role in stealth systems. Different methods have been used for reducing RCS of antennas in literature. The RCS of an antenna can be reduced by using lumped (Pozar, 1987) and distributed loads techniques (Volakis, *et al.*,1992) Moreover, radar absorbing material (RAM), antenna shaping, using active and passive cancellation technology and employing Frequency Selective Surfaces are the other described practical methods (Li, *et al.*, 2010). In Ultra Wide Band (UWB) operation, the RAM coating methods cannot produce an intended effect due to its narrow operation band (Planar Octagonal-Shaped UWB 2014). (Jiang *et al.*,2010) (Hu *et al.*,2007). The discussed techniques for RCS reduction are not suited because they increase the cost of the system and decreases the antenna efficiency. Therefore, the RCS reduction is highly challenging on being keeping its radiation performance constant (Huang and Hsia 2005).

In order to solve these issues, a modified octagonal antenna has been presented to reduce RCSbased on a reference antennas in (Planar Octagonal-Shaped UWB 2014). In this study first, we have modified circular patch into an octagonal which make the size miniaturization so as to contribute to RCS reduction. Later on, an octagon aperture is notched on it to balance impedance matching and drastically reduce the radar cross section (RCS) of targets for the purpose of stealth. By so doing, the detectability of radar antenna decreases in accordance with (Knott, *et al.*, 2004) hence, in this rational RCS of modified antenna reduces.

2. THEORETICALANALYSIS

The antenna is efficient scatter and its scattered properties are associated with resistance of feed termination. The RCS of the antenna is given by:

$$\sigma = \left| \sqrt{\sigma_s} + \sqrt{\sigma_a} e^{j\phi} \right|^2 \tag{1}$$

where φ is the difference in between modes of the antenna (Jiang, *et al.*, 2010). The mathematical form of a scattering of the antenna is given by:

$$\overline{E^s}(Z_l) = \left[\frac{(1-\Gamma_a)\overline{E^s}(\infty) + (1+\Gamma_a)\overline{E^s}(0)}{2} \right] + \left[\frac{\Gamma_l}{1-\Gamma_l\Gamma_a} \frac{1-\Gamma^2_a}{2} \left(\overline{E^s}(\infty) - \overline{E^s}(0) \right) \right] \tag{2}$$

[++]Corresponding emails deedar.jamro@salu.edu.pk, farman.mangi@salu.edu.pk, ghulam.ali@salu.edu.pk ,altaf.bhatti@salu.edu.pk
[*]Department of Computer Science, Shah Abdul Latif University, Khairpur, Sindh, Pakistan

The RCS (σ)of the antennacan be determined from equation (1).

The antenna RCS is used in radar equation hence has vital role, it is also used to reduce detection range of targets.

Mathematically, radar equation is given by:

$$R_{\max} = \sqrt[4]{\frac{P_t G A_e \sigma}{(4\pi)^2 S_{\min}}} \quad (3)$$

For all given parameters, the detection range is proportional to the fourth root of the target RCS:

$R_{\max} \propto \alpha \sqrt[4]{\sigma}$ in (Knott, *et al.*, 2004)

In this paper, an idea is thought by changing the circular patch into theoctagonal patch. The length of each side of the octagonal patch is a = 11.48 mm. Afterward, an octagon aperture is notched on it. The computed are as of patches are given by: The area of circular referred patch is given by:

$$A = \pi r^2$$
$$A = 3.14 \times (15)^2$$
$$A = 706.5\ mm^2 \quad (4)$$

The area of modified octagonal patch is given by:

$$A = 2a^2\left(1+\sqrt{2}\right)$$
$$a = 11.48mm$$
$$A = 2(11.48)^2\left(1+1.41\right)$$
$$A = 265.99mm^2 \quad (5)$$

Equation (5) shows that the area of anoctagonal patch of designed antenna is decreased that is used to reduce RCS.

3. GEOMETRYOF ANTENNA

The geometry of modified patch is shown in **(Fig. 2)**. The octagonal patch of sides *a = 11.48 mm* is put in the model. The feed lines of length *15* mm and *2* mm are printed on one side of the substrate. On its other side is the ground of length *Lg=17* mmand width *Wg = 52*mm. The substrate of length and width *L=W=52* mm is loaded with dielectric constant of ϵ_r = *4.6* and has height of h_s= *1.2* mm. Ground plane increases the transmitted power of antenna and minimize signal reflection from the load.

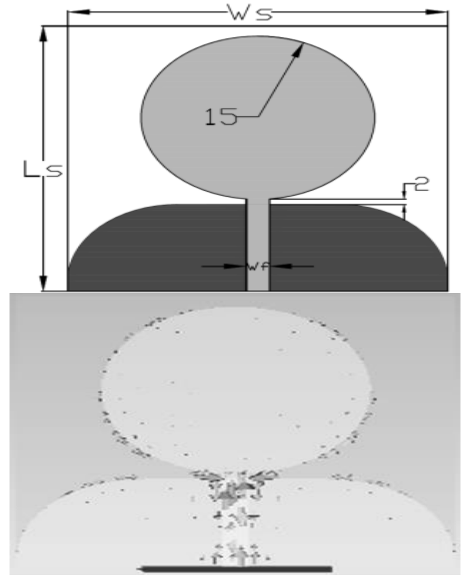

Fig.1(a) View of surface current distributions in reference antennas

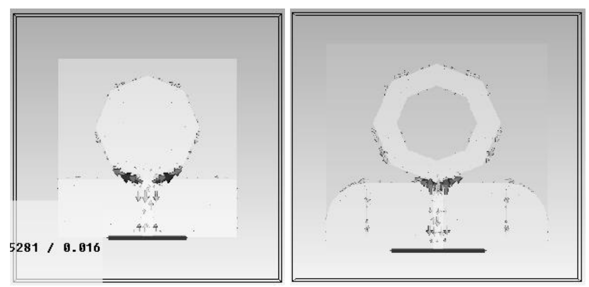

Fig.1(b) View of surface current distributions in modified antennas

It is obvious in **Fig.1 (a)** that surface current distribution is minimum at the centre of circular patch hence we have notched octagonal aperture at the centre.

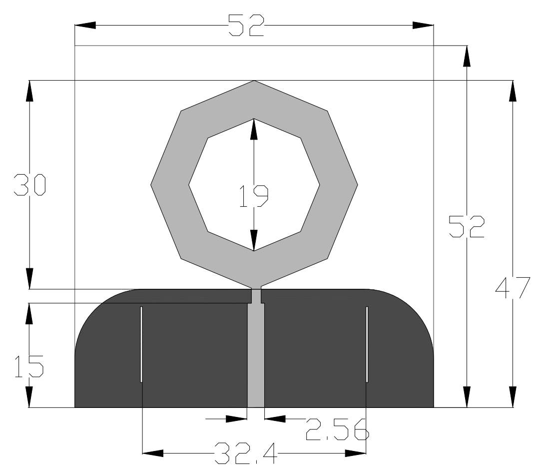

Fig.2. Simulated model of modified antenna

4. RESULTS DESCRIPTION

In this research, the simulations are done based on Computer Simulation Technology (CST). In **(Fig.1(a)** the cones shows that at the center of octagonal patch surface current is found to be minimal. Therefore, octagonal-shaped area on the patch is subtracted so as to reduce the size of the antenna and decrease detectability of radar antenna in accordance with equation (3) and (Knott, *et al.*, 2004) so as to contribute to RCS reduction. Therefore, in this rationale, an octagon aperture is notched for RCS reduction.

The ground slot is cut to change the surface current of the modified antenna as in **(Fig.1 (b)** at the slots of ground plane surface current will change the magnetic flux and induces current as well, hence the scattering field counteracts because of the different phase. By doing so the structural mode scattering field reduces as in (Hu *et al.*, 2007), which account for the total RCS reduction of designed antenna. The ground slots serve as resistance circuits so as to enhance impedance matching.

The most used parameter concerned with working of theantennais returned loss curves. If S_{11} has value 0 decibels, then the antenna will not radiate. In order to make antenna good radiating the value of S_{11}has been reduced. The S_{11} less than -10 dB of modified antenna are achieved in the entire frequency of 2-20 GHz as shown in **(Fig.2) .**The simulated S_{11} curves are almost coherent. In addition, **(Fig. 2)** shows the effect of the height of substrate on scattering parameter. It is clear that as the height of substrate decreases the antennas scattering power increases. Moreover, at a frequency of 13GHz height of substrate 1.2mm gives optimal value.

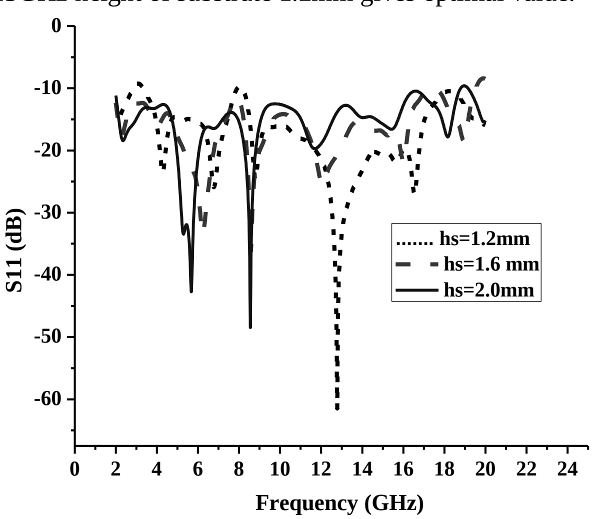

Fig.2 Effect of hs on the S_{11} of proposed antenna at 2-20GHz

Gain comparison of the referenced and proposed antenna is shown in **(Fig. 3).** The entire trend is that with increasing frequency, again of the modified antenna also rises in value, as shown in Fig.3.The gain curves of both the antennas are almost consistent. Moreover, at some higher frequencies of about 8.5 to 10.9GHz,a gain of the modified antenna has advantages over referred patch and the maximum gain difference between them is about 1.3dBi at a frequency of 10 GHz

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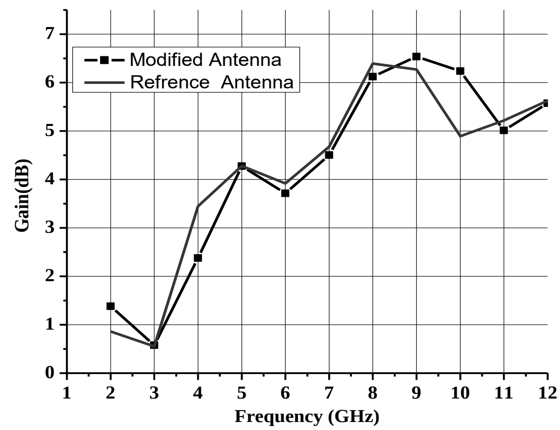
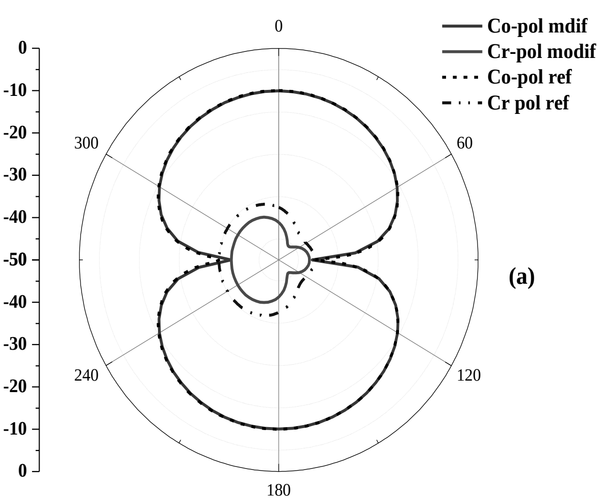


Fig.3 Gain comparisons of referenced and modified antenna

The simulated co-polar and cross- polar radiation pattern of referenced and modified antennas at $\theta = 90^0$ in XY-plane for frequencies of 2GHz, 4GHz, 6GHzand 9 GHz. It is shown that at lower frequencies radiation pattern is bidirectional while with increasing frequencies it scatters and becomes Omni-directional as shown in **(Fig.4).** The simulated comparisons o shows that the radiation patterns of the two antennas are almost the same.



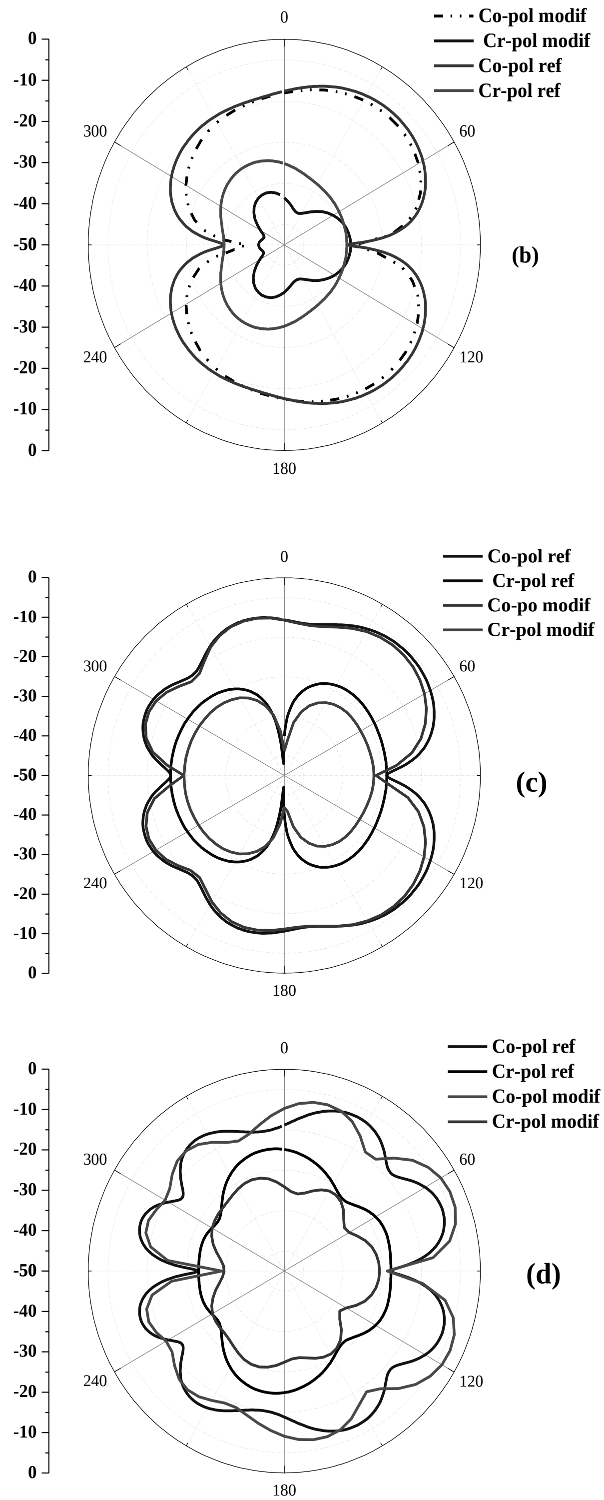


Fig.4. Simulated co-polar and cross-polar radiation pattern of referenced and modified antennas at θ= 90^0 in XY-planefor frequencies of (a) 2GHz, (b) 4GHz (c) 6GHZ (d) 9 GHz

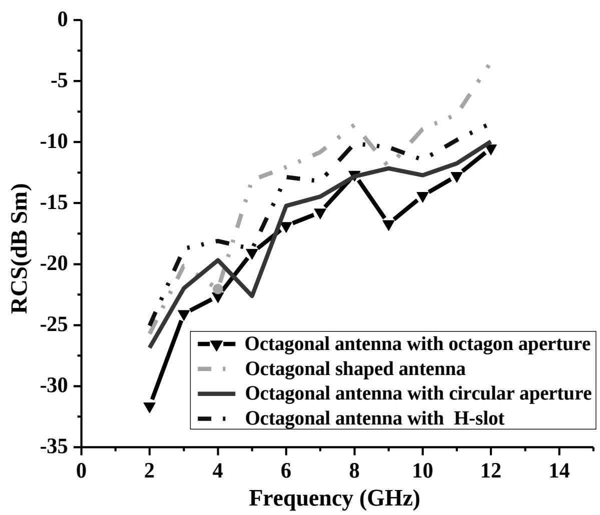


Fig.5 Comparisons of RCS with different radiating patches

The referred and designed models are provided with a load of50 ohms. The RCS curves of both the antennas are computed. The comparisons demonstrate that designed antenna has the advantage in RCS reduction. The RCS of designed model is reduced to desired range, which is due to the comparatively small size of the octagonal patch of the proposed antenna. Ground slots, size miniaturization, and shaping techniques have to do some trade-off between the RCS and the scattering parameter so as to get required reduction in RCS. In Fig.5, the comparison of RCS with different radiating patches shows that the maximum RCS reduction is achieved in anoctagonal antenna with octagon aperture. Moreover, the proposed antenna has improved RCS as shown in **(Fig. 6)**

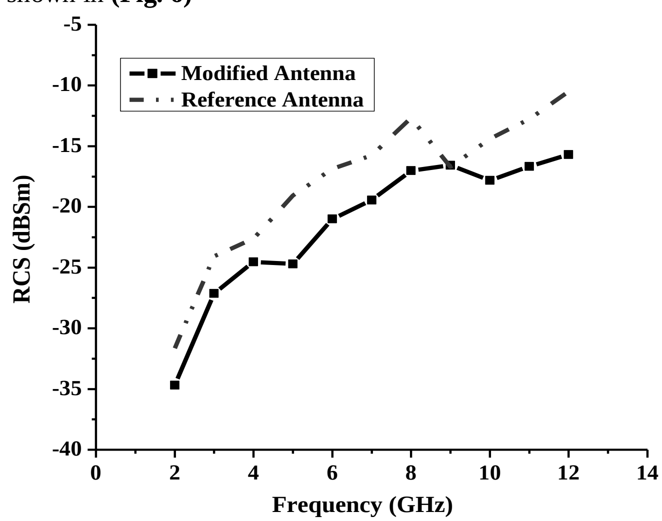


Fig.6. RCS Comparisons between modified and reference antennas

5. CONCLUSION

In this paper a modified octagonal antenna is examined for RCS reduction applications.The simulations validate that the modified antenna has better S_{11}at all the operational frequency. The gain curves of both the antennas are almost consistent. Hereby, the RCS of proposed design is bettered in broadband frequency. The proposed antenna can be used where for the requirement of low RCS property.

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