Sindh Univ. Res. Jour. (Sci. Ser.) Vol. 48 (4) 869-872(2016)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

UWB Antenna Design with Reduced Radar Cross Section

D. A. JAMRO, G. A. MALLAH*, A. A. SHAH**

Department of Physics and Electronics, SALU, Khairpur

Received 7th May 2015 and Revised 28rd October 2016

Abstract: In this research an Ultra Wide Band (UWB) antenna design is investigated for Radar Cross Section (RCS) reduction applications. The intention of antenna design is to realize RCS reduction. The H- shaped slot on patch is notched to make size reduction of antenna and to contribute for enhancing impedance matching. The scattering curves of both the referenced and designed antenna are probably the same. The simulation analysis of antenna parameters demonstrates that the RCS of antenna has been reduced to desired value, when size of radiating patch increases to 15mm.Therefore, the designed antenna gives the possibility of future success for low RCS antenna applications.

Keywords: UWB Antenna, Radar Cross Section, miniaturization, Scattering.

I. INTRODUCTION

The radar antenna has wide applications in advanced military operational systems. Radar, as a main sort of hardware for the identification and location of objects, has discovered wide applications in current military operations. In this manner the radar stealth performance of military systems and platforms goes about as a basic measure of their survivability in dangers. The radar stealth of benevolent items got through legitimately outlining can help well disposed protests viably keep away from the approaching dangers produced by unfriendly radars (Cengizhan and Cimen, 2011) (Knott, 2004). The antagonistic radar discovery of amicable objects can be postponed and the battle capacity of unfriendly radar frameworks can be debilitated. Therefore, the survivability of friendly objects can be improved (Jiang *et al.,* 2010) (Knott, *et al.,* 2004).

"The radar stealth or radar low observability has been usually achieved through reducing the radar cross-section. According to public reports, shaping and radar absorbing materials are two radar stealth techniques that have been relatively well developed and extensively applied. However, certain components as well as subsystems installed on modern military stealth platforms have been theoretically or experimentally classified as dominant scattering sources of the platforms, such as the antenna system which may contain the antenna and Radomes. The dominant scattering sources can usually generate strong radar cross-section, which tends to be a threat to the stealth performance of the whole platform. Due to the operating characteristics of those components and subsystems, the simply direct use of traditional radar cross-section reduction techniques may affect their operating performances (Hai-yang *et al.,* 2011).

In order to improve the radar stealth of the whole of a military platform, radar cross-section reduction design of components exhibiting strong radar cross-section is of practical significance. Many techniques for RCS reduction of antennas have been studied in literature (Hai-yang *et al.,* 2011) (Horng-Dean Chen, 2011). The shaping methods and radar absorbing materials are two radar stealth techniques that have been well developed and widely used. However, in Ultra Wide Band (UWB) operation, the radar absorbing materials (RAM) coating methods do not produce an intended effect because of narrow operation band (Horng-Dean Chen, 2011).The RAM coating methods will also degrade the performance of onboard antennas i.e. antennas on ship, plane, train and other vehicles, so cannot be used in these situations (Horng-Dean Chen, 2011). (Huang and Hsia. 2005).

The monopole antenna has many advantages and it does not affect the aerodynamic properties of the platforms (Hu, *et al.,* 2007) Hence to solve the major issue of RCS reduction the H-shaped UWB antenna design is investigated in this paper. The proposed antenna is based on printed circular disc monopole antenna in (Hong, *et al.,* 2009) .According to the surface current distributions on the patch of the designed antenna, the metallic region of

++Corresponding author Email: deedr.jamro@salu.edu.pk, ghulam.ali@salu.edu.pk, azhar.shah@usindh.edu.pk
* Shah Abdul Latif University, Khairpur
**Institute of ICT, University of Sindh Jamshoro

minimum current amplitude is reduced in the form of H-slot. Hence, the RCS of the proposed design will be reduced, while its radiation performance maintained the same.

This paper is organised as follows: In section II materials and methods are discussed in terms of a theoretical and mathematical method for determining the total RCS of antenna and the scattering field of antenna feed with load is presented. Section III describes the implementation of antenna structure and its working mechanism. Section IV presents the discussion of methods and modelling for simulated and depicted results relating to antenna scattering characteristics.

2. MATERIALS AND METHODS

When light falls on targets they disperse the energy in all directions. This spatial distribution of energy is called scattering. The antenna scattering depends on microstrip feed impedance. The antenna RCS (σ) is divided in two categories. The structural mode RCS (σ_s) and antenna mode RCS (σ_a). The relation between them is given by:

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

where φ is the difference in phase between these two modes (Liang, *et al.*,2005). Antenna scattering is investigated based on (Liang, *et al.,* 2005). The scattering field of antenna feed with load is given by the equation:

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

The equation (2) is the mathematical form of scattering field of antenna in open- and-short circuits. The RCS (σ) of antenna can be computed with the help of equation (1).

The basic form of the radar range equation is given by:

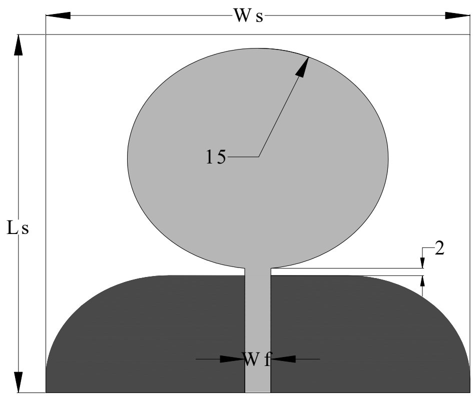
$$R_{\max} = \sqrt[4]{\frac{P_t G A_e \sigma}{(4\pi)^2 S_{\min}}} \qquad (3)$$

where $R_{\max}$ represents the maximum detectable range of the transmitting antenna (Finkenzeller. (2004)

3 IMPLEMENTATION MECHANISM

The geometry of reference antenna is shown in **(Fig.1 (a).** The surface current distribution of referred antenna is depicted in **(Fig.1 (b).** The size of patch of reference antenna is 15 mm and has no any slots either on its patch or ground. It has been analysed from simulations that minimum current is at the centre of circular patch hence non effective area is subtracted in the form of H-slot.

The geometry of designed model and detail of parameters is depicted in **(Fig.2 (a).**The surface current distribution of the modified antenna is shown in **(Fig.2(b).**The slots are also notched on the ground to balance radiation performance of designed antenna. The substrate of length and width L=W=52 mm is loaded with dielectric constant of ϵr = 4.6 and has height of hs = 2 mm. The ground is curved at both the edges for stoping the radiating beam to gradient.



Fig,1 (a).The geometry of reference antenna

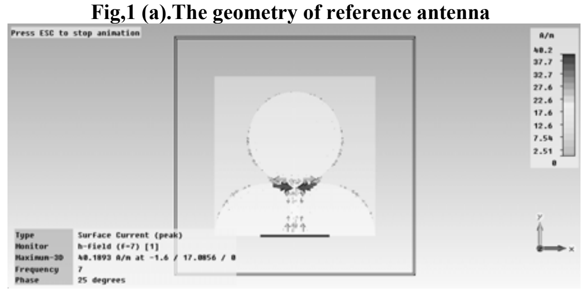


Fig.1 (b) The Surface current distribution of referenced antenna

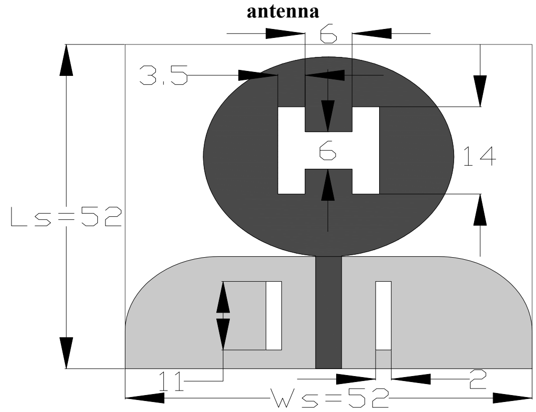


Fig.2 (a).The Geometry of modified antenna

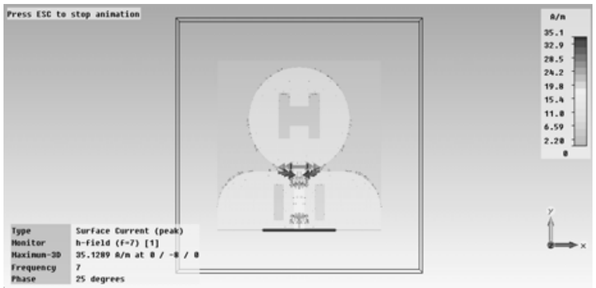


Fig.2 (b).The Surface current distribution of modified antenna

4. RESULTS AND DISCUSSION

In this paper antenna is designed and simulated by using CST software. These simulations resulted in discovering areas of deficient surface currents. Therefore, from simulations has been found that current is minimum at the centre of patch. Hence the H-slot is used for size miniaturizations.

The most common character of antenna during its working is scattering parameter and is represented by S11. It determines the reflected power of antenna; hence it is also termed as reflection coefficient. If value of S-parameter is 0dB, this means that all the power is reflected back and hence antenna does not radiate. In this model the value of S11 has been reduced so as to make antenna good radiator.

In **(Fig. 3),** almost all the curves approaches to -10dB, this demonstrates that the size miniaturization technique does not affect on the radiation performance of antenna. The reflection coefficient curves below -10 dB of the modified design are obtained in the whole frequency range to cover C-band, X-band and W- band applications as depicted in **(Fig. 3).** It is also clear that at r = 15mm S11 gives well coherence with reference curve.

The cuts on the ground plane changes the flux and so electromotive force has been induced which produces current. In this principle, the cuts on the ground act as impedance matching circuit to enhance impedance matching and so make antenna performance balanced.

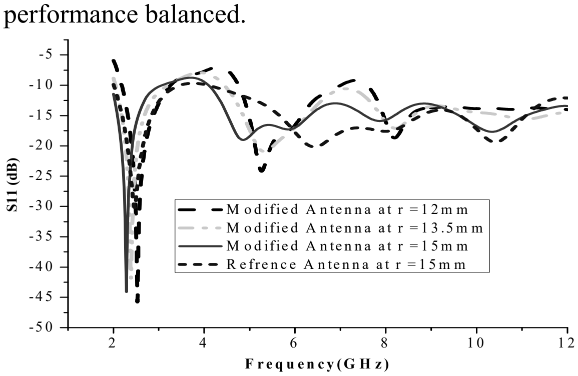


Fig.3. Comparisons of return loss curves of the reference antenna and modified antenna at different size of patches

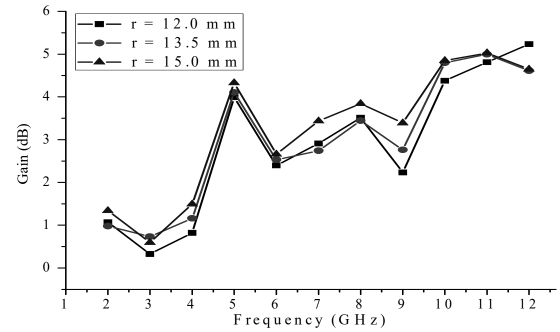
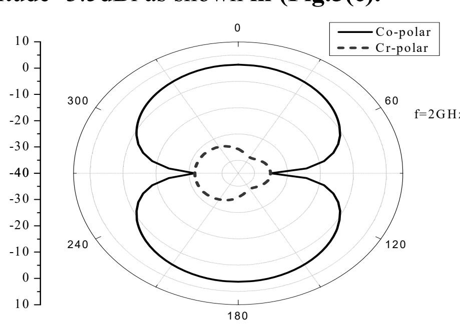


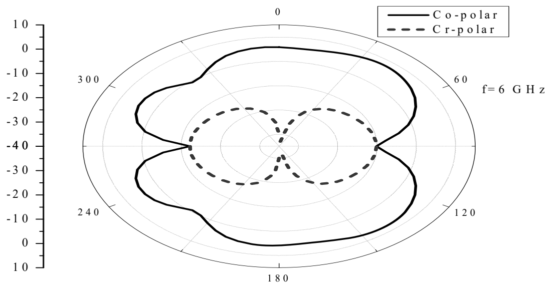
Fig. 4. Effect of r on gain curves of the modified antenna

The effect of size of radiating patch on the gain curves of the modified antenna is shown in Figure4 , it is found that with increase in size of patch gain increases and vice versa. Maximum gain is achieved at r =15 mm. It is clear from gain curves of designed model that the peak gain raises by increasing frequency to some specific level. After certain limit S11 reduces therefore the peak gain decreases.

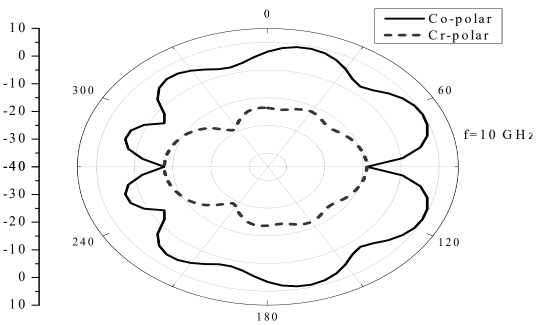
The radiation pattern of most antennas demonstrates a pattern of lobes at different angles, edges and directions where the transmitted signal strength or intensity reaches a maximum. The radiation pattern of the designed antenna in Figure5 shows the far field E-field at $f = 90^{\circ}$. Moreover, it demonstrates a pattern of lobes at frequency of 2.0 GHz mostly on two directions where the transmitted signal strength reaches to a maximum value. The radiated signal strength is max in major lobes. However the unwanted radiations at lower frequency are negligible in undesired directions but can never be completely eliminated therefore the size of side lobes is very small and so is almost invisible. The simulations show that the main lobe magnitude is 1.3dBi and its direction is on 180° as shown in **(Fig. 5(a)**.The magnitude of main lobe radiation at frequency of 6 GHz is 2.7dBi and is directed at angle of 140° and side lobe has magnitude -1.8dBi as shown in **(Fig. 5(b).** Where as the magnitude of main lobe at frequency of 10GHz is 4.8dBi and its direction is at angle of 65° and side lobe has magnitude -3.5dBi as shown **in (Fig.5(c).**



(a)



(b)



(c)

Fig. 5. The simulated co-polar and cross polar radiation pattern of the modified antennas at θ= 90^0 in xy-plane for frequencies of (a) 2 GHz (b) 6 GHz (c) 10 GHz

The radiation pattern analysis demonstrates that the unwanted radiation pattern i.e. cross polar radiations has a direct proportion with frequency of antenna

The equation (3) is the Radar range equation shows that the maximum detection range decreases due to subtraction of non effective area of the patch. Hence according to the surface current distributions in this design non effective region of antenna is deducted in the shape of H-slot which makes RCS reduction. Figure6 shows that as the size of circular patch increases RCS improves.

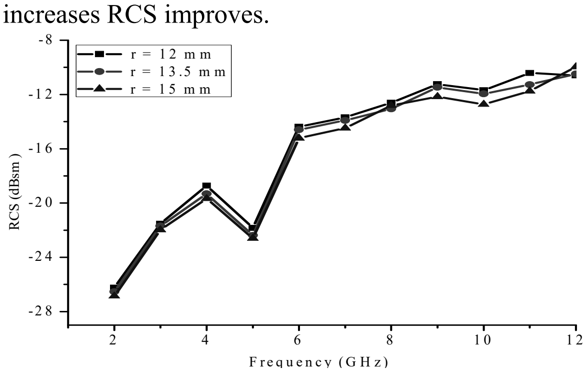


Fig.6. Effect of r on RCS of the modified antenna

The modified antenna is terminated with 50Ω load and RCS curves are calculated and compared to show the effect of size of patch in the RCS reduction. The RCS of proposed antenna is largely reduced, which is due to the relatively small radiating patch of H-shaped slot on the designed antenna. Hereby, ground slots and H-slot on patch have to do some trade off between the RCS and the scattering parameters, achieve an improved RCS.

5. CONCLUSION

The UWB antenna with miniaturization sizing techniques for RCS reduction applications is studied in this paper. The outcomes show the RCS of modified model has been reduced to a desired value in the whole working frequency band. The reflection coefficient curves of both the antennas are nearly the same. Moreover the radiation performance of the designed antenna is stable which suggests that modification did not affect on the overall performance of antenna. The analysis and outcomes demonstrates that the modified design can be used where low RCS property is involved.

REFERENCES:

Cengizhan M. D., S. Cimen, (2011) Member, IEEE, and Gonca, Cakır, Member, IEEE "Planar Octagonal-Shaped UWB Antenna with Reduced Radar Cross Section" IEE transactions on antennas and propagation, V. 62, 6,

Finkenzeller. K. (2004) RFID Handbook Fundamentals and Applications in Contactless Smart Cards Identification [M], 2nd ed. West Sussex, U.K.: Wiley,

Hai-yang X., H. Zhang, Gui-yuan Li, Qi-bo Xu, etc. (2011) "An ultra-wideband fractal slot antenna with low backscattering cross section," Microwave and Technology Letters, Vol. 53, No. 5, 1150 1154,.

Horng-Dean Chen, (2011) "Broadband CPW-fed Square slot antennas with a widened tuning stub", IEEE transactions-on-antennas-and-propagation.

Huang C.Y. and W.C. Hsia. (2005) 'Planar elliptical antenna for ultra-wideband communications', Electronics Letters, 41

Hu S, H Chen, and C L Law, (2007) "Backscattering cross section of ultra-wideband antennas," IEEE Antennas Wireless Propagation Letter, V. 6, 70–73.

Hong, T. S., X. Gong, W. Jiang, Y.-X. Xu and X. Wang (2009) "A novel ultra-wideband antenna with reduced radar cross section" Progress In Electromagnetics Research, PIER 96, 299–308,

Jiang W., G. Shu-xi, H. Tao, W. Xing, (2010) "Fan-shaped antenna with low RCS for ultra- Wideband application," Acta Electronica Sinica, V. 38, No. 9, 2162-2165, (in Chinese).

Knott, E. F., (2004). "Radar Cross Section", 2nd edition, SciTech, Raleigh, NC,

Liang, J., C. Chiau, (2005) "Study of printed circular disc monopole antenna for UWB s systems," IEEE Trans. Antennas Propag. V. 53, 11, 3500–3504.