10th INTERNATIONAL SCIENTIFIC CONFERENCE ON DEFENSIVE TECHNOLOGIES
OTEH 2022
Belgrade, Serbia, 13 – 14 October 2022

DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF PASSIVE CORNER REFLECTOR FOR GROUND SURVEILLANCE RADAR TESTING

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Abstract: *Ground surveillance radars are intended for the detection of moving targets on the ground, from the ground. This implies a significant impact of relief, vegetation and infrastructure facilities on radar performance. Therefore, when evaluating the performance of these radars, it is important to have objects with a large radar reflex surface, which can move, in order to create more or less controlled test conditions. One solution may be an off-road vehicle. But, this solution is expensive if the tests are frequently conducted and short-lived, which is exactly the case in the development phase. A much more cost-effective solution is a man equipped with a passive radar reflector. The passive radar reflector should be clearly visible for radar from a wide range of angles in both azimuth and elevation planes. Also, it should be light and comfortable to be carried by one person. This paper presents the design, fabrication and performance evaluation of one such reflector intended for testing ground surveillance radar in the Ku band.*

Keywords: *radar, corner reflector, radar testing .*

1. INTRODUCTION

Every radar aim, object, from which the emitted electromagnetic wave is reflected, is basically a radar reflector. However, in general sense, specific geometry structure created to have desired radar reflexive surface and predefined reflexivity diagram, will be considered a reflector. [1, 2]

Radar reflectors can be used for different [3], mutually opposed, purposes. For example, they can be used for enlargening of radar visibility of small vessels at sea and for marking the sea coast for navigation safety. They can be used and for numerous radar testings (as in our case). Opposing purpose is considered to be use of reflectors in elecronic war (EW), when, using the reflector, false aims, targets, baits are formed for deceiving prurposes. We needed reflectors for testing of small infantry radars [4], border protection radars. Problems and solutions are similar to those applied for increasing of radar visibility of small vessels at sea and for marking the sea coast, so they are aplicable for those purposes also.

2. RADAR CROSS SECTION

Term target cross section is easiest to explain by radar equation. The radar range equation (or shorter: the radar equation) represents the phisical depedences of the transmit power, which is the wave propagation up receiving the echo signal. Below is one of the more basic forms for a single antenna system. The maximum radar detection range is

$$R_{\max} = \sqrt[4]{\frac{PG^2\lambda^2\sigma}{(4\pi)^3 S_{\min}}}, \qquad (1)$$

Where P = transmit power, S_{min} , minimum detectable signal, G antena gain, λ transmit wavelength, σ target cross section.

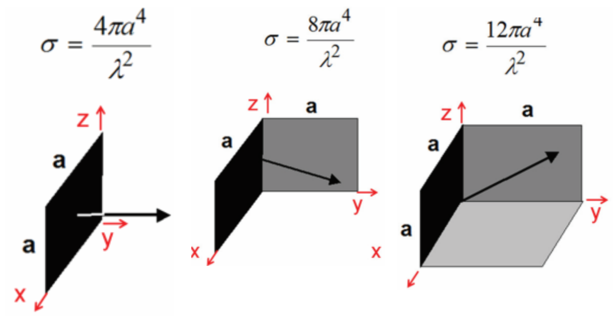
The radar cross section of a target is a fictitious, but useful, characteristic of the body. The RCS of all but the simplest of objects varies by orders of magnitude as the viewing angle changes, sometimes over as little as a fraction of a degree. This being the case, we almost always measure our target echo characteristics as functions of aspect angle.

The result is a set of RCS patterns with the amplitude of the echo, usually in the decibel scale, charted along the ordinate and the aspect angle along the abscissa.

3. RADAR CORNER REFLECTOR

Corner reflector is a structure that is used as a radar target, often in calibrating test equipment. Corner reflectors are used for many reasons: they have very high radar-cross-section (RSC) for a small size, the high RCS is maintained over a wide incidence angle, and an exact solution is known for their RCS. Corner reflectors are easy to make from sheet metal such as aluminum and they are robust enough to maintain good flatness.

There are two main types of corner reflectors, dihedral and trihedral. The dihedral has two surfaces that are on orthogonal planes, the trihedral has three. Sketches of the two are shown in figure 1 (b and c) below, along with generally used coordinate systems.



a) plate b) dihedral c) trihedral

Figure 1. Planar test targets.

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Target	Dimensions	Max RCS
Sphere	D: diameter	$\sigma = \pi D^2/4$
Plate	a, b: length, width	$\sigma = 4\pi a^2 b^2/\lambda^2$
Cylinder	r: radius, L: length	$\sigma = 2\pi r L^2/\lambda$
Dihedral Reflector	a, b: length, width	$\sigma = 8\pi a^2 b^2/\lambda^2$

Figure 2 shows geometric model of the triangular pyramidal trihedral corner reflector: θ is incident angle and φ is azimuthal angle.

4. NEW CORNER REFLECTOR CLASTERS

For obtaining the desirable reflexivity diagram it is necessary to construct complex structure which we will name reflector cluster. In horizontal plane it is desirable that reflexivity diagram is approximately omnidirectional. In horizontal plane we need reflector clusters that have reflexivity diagrams suitable for specific situations in the field. For example, when radar is on lower position than the surveilled field, it is necessary that the diagram is directed downwards, and when opposite situation, upwards. It is similar with the application on buoys at sea or marking of sea coast.

In this article we will not elaborate theoretical and constructional details but it will be the theme of the other articles to follow. We will show the realization of two types of reflector clusters and their measured reflexivity diagrams.

In new reflector cluster constituent elements are triangular trihedal corner refectors (Figure 2). Base are the equilateral reflectors with 90^0 angle. Rest of the reflectors are construed to optimize space and obtain the simplicity of construction.

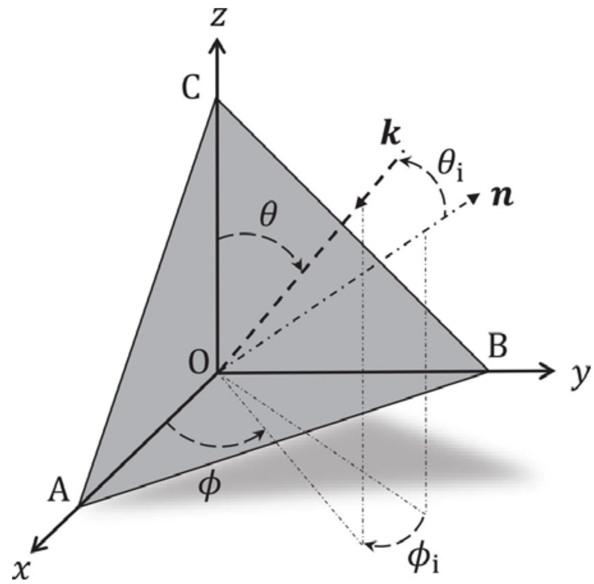

Figure 2. Geometry of the trihedral corner reflector.

We combined two different groups of reflectors and selected two types of clusters: Type 1 and Type 2 (Figure 3, and Figure 4).

Measures are performed in the Ku band. In Figure 5. reflexivity diagram in horizontal plane cluster type 1 is shown. Maximum reflexivity measured is 43.85 dB, the mean is 39.5 dB.

In Figure 6. reflexivity diagram in vertical plane is shown. Maximum reflexivity measured is 44.25 dB, the mean is 38.8 dB.

In Figure 7. reflexivity diagram in horizontal plane cluster type 2 is shown. In all the figures, as a reference, metal disc reflexivity diagram is shown.

Also, these clusters showed good performances and on the radar field testing, which is their final purpose.

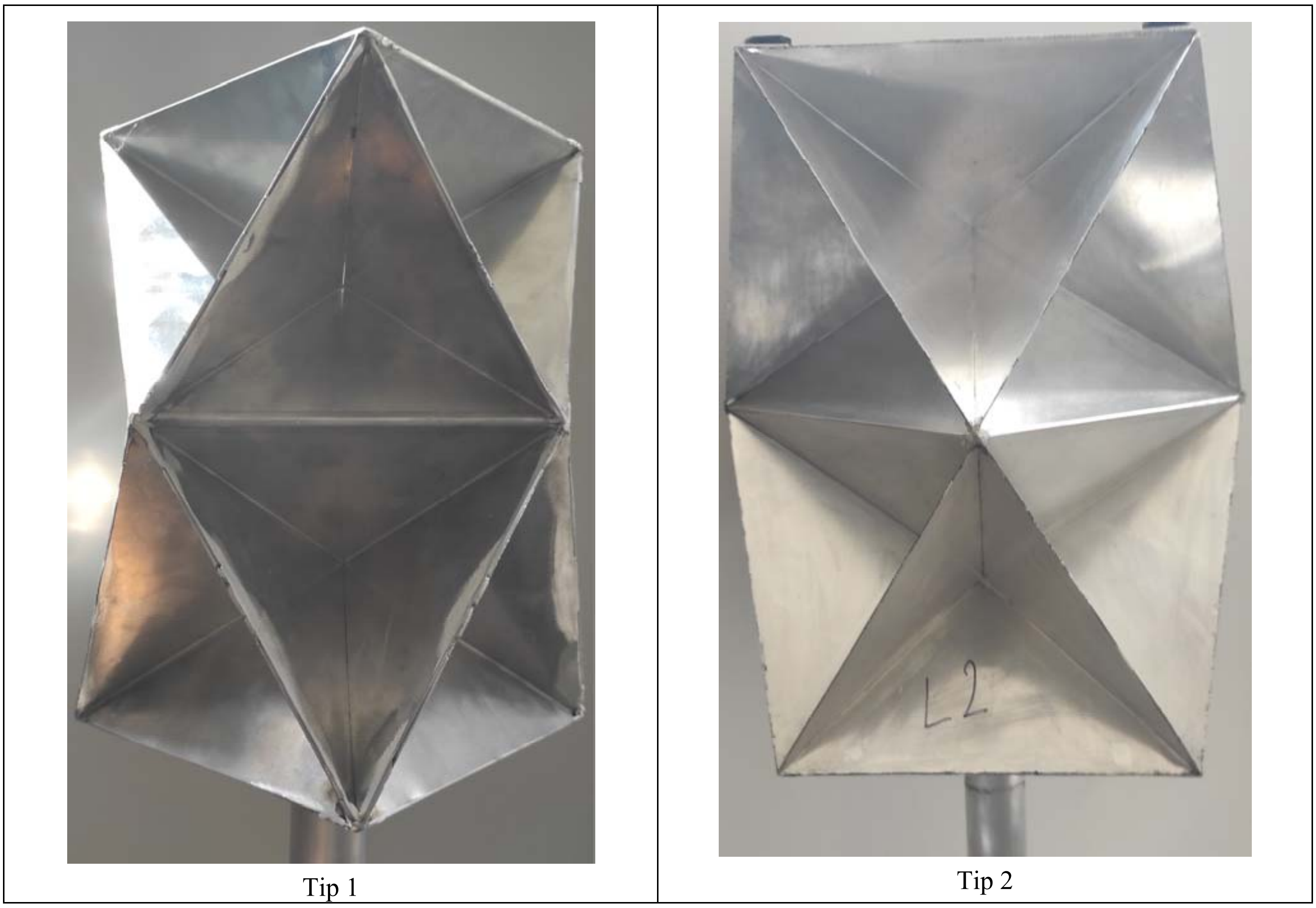

Figure 4. Cluster configuration Tip 1 and Tip 2.

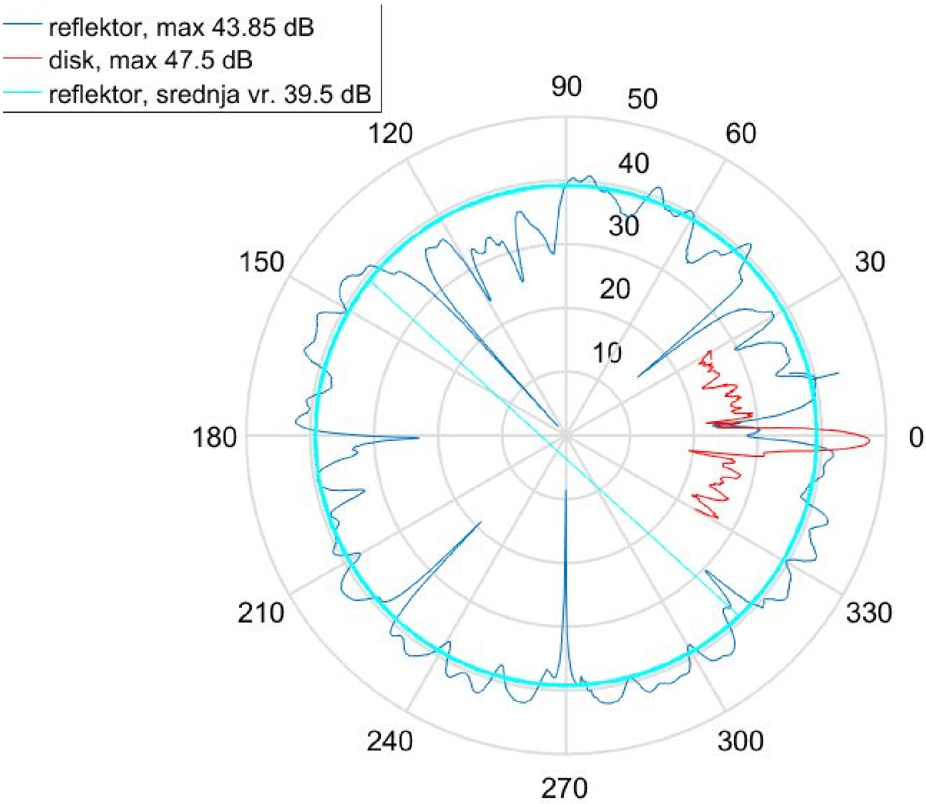

Figure 5. Cluster Type 1 – measured reflexivity diagram in horizontal plane.

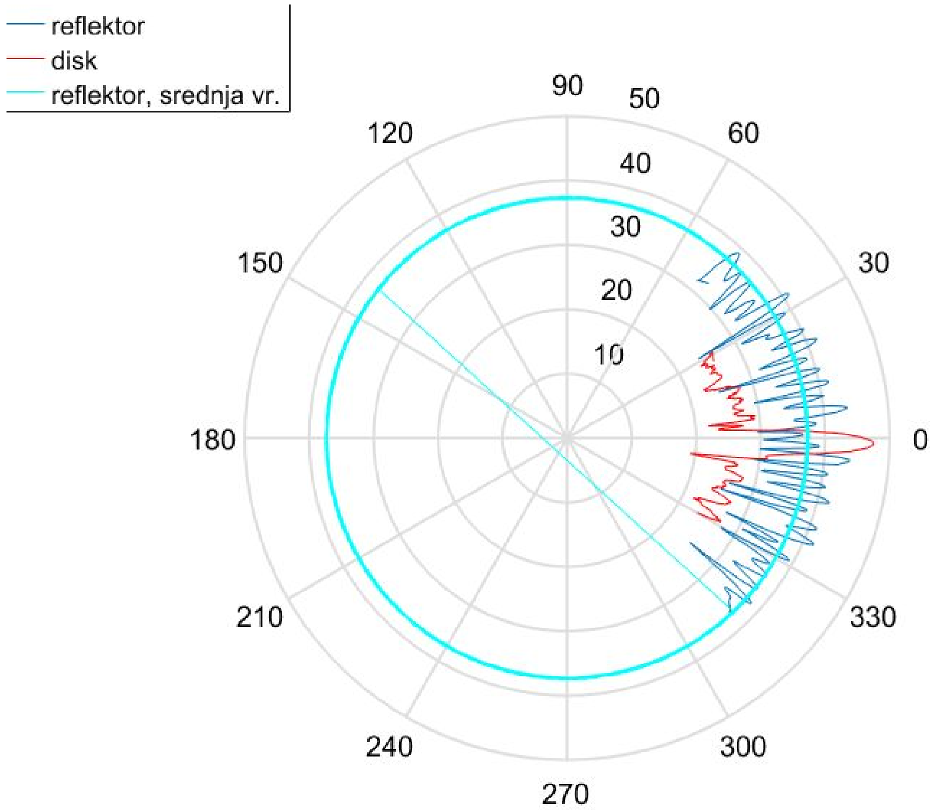

Figure 6. Cluster type 1 – measured reflexivity diagram in vertical plane

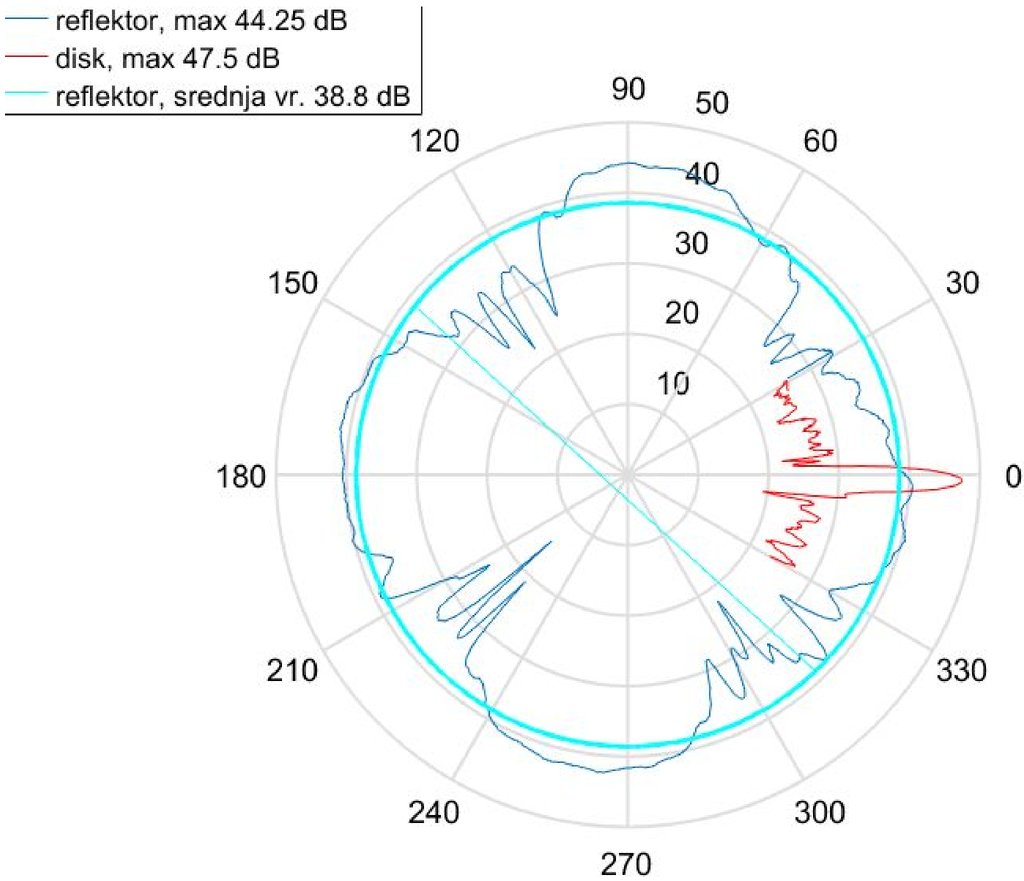

Figure 7. Cluster type 2 – measured reflexivity diagram in horizontal plane

5. CONCLUSION

First developed, and later on construed reflector clusters, have excellent reflexivity diagrams in both planes (horizontal and vertical).

These specific examples are made to be suitable for manual use. They are made of aluminum sheet 0.5mm thickness. The whole construction with the axis, longed to be suitable for holding, weighs less than 2kg. However, in field testing it turned out to be too heavy for longer carrying, so we made a version with aluminum sheet 0.2 mm thickness. Aluminum sheet that thin is shown to be impossible to affix by usual techniques, so we developed special manufacturing procedure.

In next step, we will develop the clusters adapted to be mounted on the off road vehicle. Those solutions will be suitable for applications on the ships, for marking the sea coast and for geodesic testing.

References

[1] KNOT, E. F., SHAEFFER, J. F., TULEY, M. T., “*Radar Cross Section,”* Artech House, Norwood, MA, 1985.

[2] SKOLNIK, M. I., “*Radar Handbook,”* McGraw Hill, NY, 1990.

[3] SUKHAREVSKY, OLEG, SERGEY NECHITAYLO, and VITALY VASILETS. "Using Corner Reflectors to Increase Backscattering of Radar Targets." In 2020 IEEE Ukrainian Microwave Week (UkrMW), pp. 207-212. IEEE, 2020.

[4] SIMIĆ S., GOLUBIČIĆ Z., ZEJAK A.J., “Design of High Resolution, Coded, Portable Battlefield Surveillance Radar PR-15”, Proc. of 4th International Conference OTEH 2011, Belgrade, Serbia, October, 2011.

[5] Goble,A.T. "Confusion reflectors." Electronic Countermeasures (1978): 18_1-18_23.