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Analysis of Radar Cross Sectional Area of Corner Reflectors

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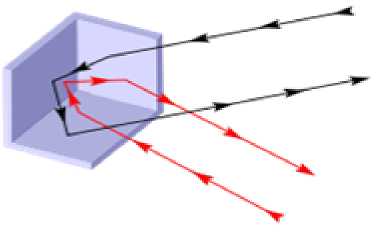
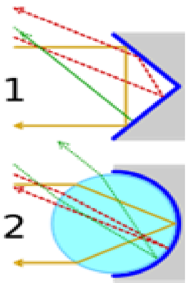
ABSTRACT : *Radar corner reflectors are designed to reflect the microwave radio waves emitted by radar sets back toward the radar antenna. This causes them to show a strong "return" on radar screens. A simple corner reflector consists of three conducting sheet metal or screen surfaces at 90° angles to each other, attached to one another at the edges, forming a "corner". These reflect radio waves coming from in front of them back parallel to the incoming beam. To create a corner reflector that will reflect radar waves coming from any direction, 8 corner reflectors are placed back-to-back in an octahedron (diamond) shape. The reflecting surfaces must be larger than several wavelengths of the radio waves to function.*

KEYWORDS : *Radar ,corner reflectors , wavelength.*

I. INTRODUCTION

A corner reflector is a retro reflector consisting of three mutually perpendicular, intersecting flat surfaces, which reflects waves back directly towards the source, but shifted. The three intersecting surfaces often have square shapes. Radar corner reflectors made of metal are used to reflect radio waves from radar sets. Optical corner reflectors, called corner cubes, made of three-sided glass prisms, are used in surveying and laser range finding .The corner reflector should not be confused with the corner reflector antenna, consisting of *two* flat metal surfaces at a right angle, with a dipole antenna in front of them. The incoming ray is reflected three times, once by each surface, which results in a reversal of direction. To see this, the three corresponding normal vectors of the corner's perpendicular sides can be considered to form a basis (a rectangular coordinate system) (x, y, z) in which to represent the direction of an arbitrary incoming ray, $[a, b, c]$. When the ray reflects from the first side, say x, the ray's x component, a, is reversed to $-a$ while the y and z components are unchanged, resulting in a direction of $[-a, b, c]$. Similarly, when reflected from side y and finally from side z, the b and c components are reversed. So the ray direction goes from $[a, b, c]$ to $[-a, b, c]$ to $[-a, -b, c]$ to $[-a, -b, -c]$ and it leaves the corner reflector with all three components of direction exactly reversed. The distance traveled, relative to a plane normal to the direction of the rays, is also equal for any ray entering the reflector, regardless of the location where it first reflects. Figure **(1)** shows the reflections in the corner reflectors.





(a)Working principle of a corner reflector (b) Comparison bet. (1)& (2) retro reflectors .

Figure (1) Reflections in the corner reflectors

The side dimension of a cube corner reflector is ideally greater than 10 wavelengths of the signal we are trying to reflect. In maritime navigation they are placed on bridge abutments, buoys, ships and, especially, lifeboats, to ensure that these show up strongly on ship radar screens. Corner reflectors are placed on the vessel's masts at a height of at least 4.6 meters above sea level. Marine radar uses X-band microwaves with wavelengths of 2.5 - 3.75 cm, so small reflectors less than 30 cm across are used. In aircraft navigation, corner reflectors are installed on rural runways, to make them show up on aircraft radar.

Corner reflectors can also occur accidentally. Tower blocks with balconies are often accidental corner reflectors for sound and return a distinctive echo to an observer making a sharp noise, such as a hand clap, nearby. Similarly, in radar interpretation, an object that has multiple reflections from smooth surfaces produces a radar return of greater magnitude than might be expected from the physical size of the object.

RADAR CORNER REFLECTORS : Corner reflector is a structure that is used as a radar target, often in calibrating test equipment such as in an anechoic chamber. 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, but care must be used to be sure that the surfaces join at exactly at 90 degrees, 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 (2) below, along with generally used coordinate systems. The conventions of using phi for elevation and theta for azimuth angle are used here, as in most antenna work. Note that the spherical coordinate systems are such that angles of zero for both azimuth and elevation give the maximum, (often called specular) return.

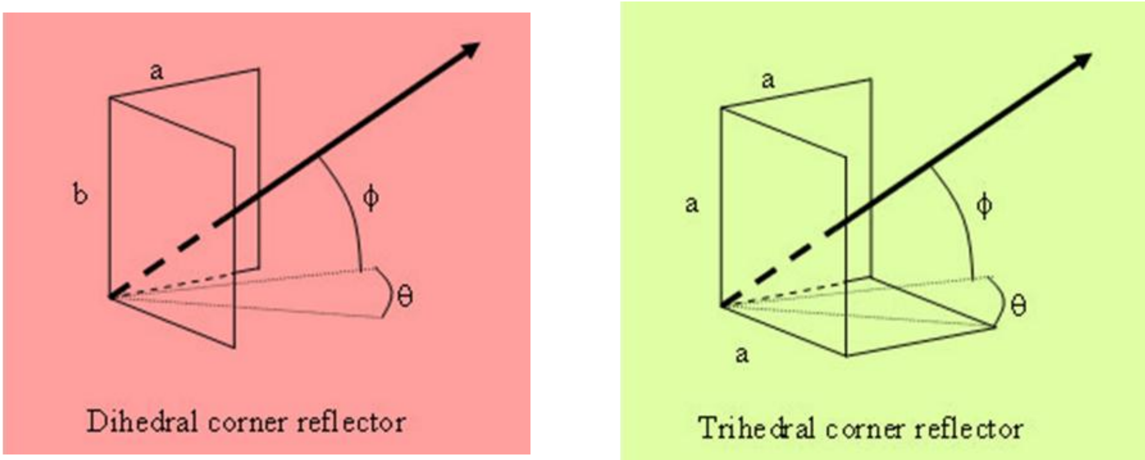


Figure (2) Dihedral and trihedral corner reflectors

Encountering a corner reflector in "real life", we notice that red taillights on vehicles "light up" when they are illuminated by your headlamps, even when they are on parked cars that are switched off. This is because they are constructed to have hundreds or even thousands of tiny optical corner reflectors built in. Optical corner reflectors work exactly as RF corner reflectors, even if the materials and dimensions are slightly different.

For the equations (1) and (2) ,, the lower-case Greek letter sigma (σ) is used to denote radar cross section. Here's the equations for maximum cross-section of both types of corner reflector, along their principal axes:

Dihedral:

$$\sigma = \frac{8\pi a^2 b^2}{\lambda^2} \quad \text{………………………} \quad (1)$$

Trihedral:

$$\sigma = \frac{12\pi a^4}{\lambda^2} \quad \text{………………………} \quad (2)$$

Note that for the trihedral case, the formula is accurate for reflectors with square sides. If they are cut into triangles or arcs, the constant "12" will be reduced

Equation (3) is for a flat-plate reflector's specular return:

$$\sigma = \frac{4\pi a^2 b^2}{\lambda^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Notice the RCS goes up as the fourth power of the side dimension "a" for trihedral. If we double the lengths of the edges, the RCS goes up by a factor of 16. The trihedral corner reflector has the strongest return for its size of any object.

When we are discussing RCS here, we mean the maximum RCS at the most favorable angle, which in the case of a corner reflector is 45 degrees from each plane surface. The trihedral corner reflector has a good return over a wide look angle, perhaps a 10 degree displacement we won't even notice a reduction in returned signal. Many times in practice the trihedral is used as a dihedral, because of the convenience of just setting it on a horizontal surface in the range. The cross-section is only reduced about -1.8 dB (in this case 10xlog(2/3) is the exact solution).

The RCS is also a function of the frequency squared. It is customary to write the equation using the wavelength in the denominator. The same units for "a" and lambda (λ) must be used in the equations.

Figure (3) shows a plot of the RCS for a trihedral corner reflector, with side dimension 10, 15 and 20 centimeters. At X-band the RCS of the 20 cm reflector is already almost 100 square meters.

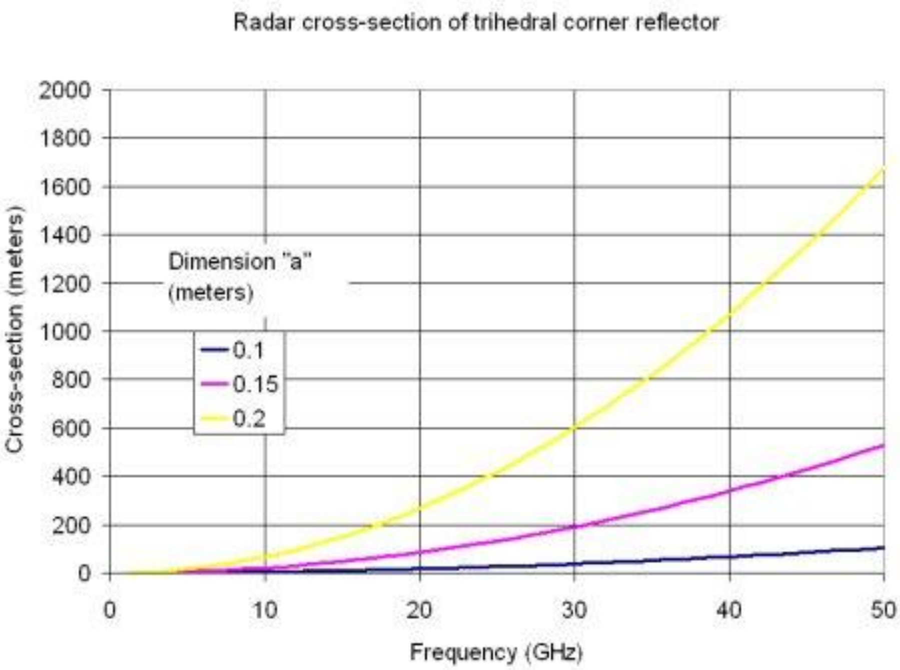


Figure (3) RCS for a trihedral corner reflector

II. METHODOLOGY

The proposed block diagram is based on using a microcontroller interfaced to external devices. An RF signal is generated by a transmitter and directed towards the corner reflector. The reflected echo is received by the receiver and get converted into digital format by the ADC in the microcontroller . The value of the reflected echo signal is displayed on the LCD. The block diagram shown in figure (4).

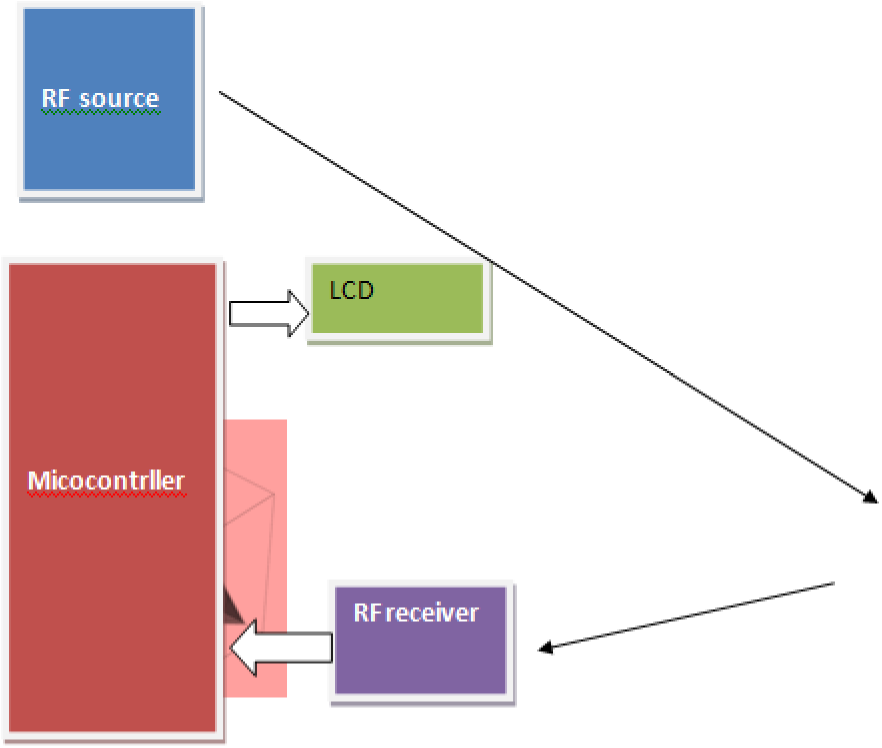


Figure (4) Block diagram of the design

The hardware components for circuit are :

Breadboard: breadboard (protoboard) is a solderless board, it is reusable, and thus can be used for temporary prototypes and experimenting with circuit design more easily.

Microcontroller :

Atmega 32 microcontroller is used in the design.

RF source:

An RF source is used to supply RF signals.

RF receiver :

An RF receiver is used to capture the reflected echo signal.

LCD :

An LCD is used as a display for monitoring the results.

Corner reflector:

A Corner reflector is used for the test procedure.

III. ALGORITHM

The microcontroller algorithm is based on performing the following steps :

[1] Activating the RF transmitter to supply RF signal .
[2] Transforming the reflected signal into digital format.
[3] Analyzing the value of the signal.
[4] Display the value on the LCD.

Bascom programming language is used in programming the microcontroller The algorithm is :

Start
Initialization :
[1] Put RF transmitter OFF.
[2] Display on the LCD " START EXPERIMENT".
[3] Call subroutine capture RCS of corner reflector.
End

Capture RCS of corner reflector :
[1] Put RF transmiter ON.
[2] Transform analog signal into digital format.
[3] Display RCS value on the LCD.

Return.

IV. RESULTS

An X-band transmitter is used in the experiment . three types of corner reflectors are subjected to the test . Twenty centimeters dimensions is considered for the length of the sides of the corner reflectors. Table (1) below shows the RCS (σ) for the three types of corner reflectors.

Table (1) The RCS (σ) for the three types of corner reflectors.

Sequence	**Corner reflector (type)**	**RCS (σ) in square meter**
1	**Flat**	**100**
2	**Bihedral**	**200**
3	**Trihedral**	**300**

V. CONCLUSION

Corner reflectors are very useful in the civil and military applications .It can be used as a guide for ships and aircrafts . It is also used in the camouflage operations . It is a passive means of deception in the military applications . It is simple to construct and it does not cost much . The reflection of the metallic structure of the corner reflectors creates a big value of RCS (σ) in the radar receiver.

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