Promising Stealth Technology Protocols in Defence

Prasanna Puttaswamy[1], Pramod Srivatsa Krishna Murthy[2]

[1, 2] *Prospective Research Scholars, Mysore, India.*

ABSTRACT: *In modern world, stealth technology has emerged with an utmost importance in the field of defence. Stealth technology's prime factor is to reduce/avoid the aircraft detection in enemy radar system. A normal combat aircraft can easily be detected on every radar system which poses an advantage to the enemies. In order to gain combat advantage, now a day's aircrafts are integrated with some of most prominent/sophisticated stealth technology to reduce visibility of the aircraft on enemy radar. In recent years, advancement in engineering and signal processing field made it possible for stealth technology realization in aircraft to deceive the enemy radar system effectively. However we are able to reduce visibility to certain limit due to some constraints either from environment or lack or even more sophisticated advanced radar system. Some important researches were carried out and succeeded enough to name it as stealth technology; one such is echo cancellation in aircraft. This paper presents and describes the stealth technologies, which are more prominent. These protocols can be realised practically with extensive research in these fields. Some of the technologies explained are so promising, it gives us almost zero visibility in other words it is almost impossible to detect aircraft even by some advanced radar system.*

KEYWORDS: *Controlled Intrinsic Impedance, RADAR, Stealth Technology.*

I. INTRODUCTION

RADAR (RAdio Detection And Ranging) is a technology which finds most versatile usage in military applications due to its ability in detection of objects using Electromagnetic waves that are invisible for the human eyes. The principle behind its operation is quiet simple, an antenna (transmitter) capable of converting electrical energy into radio waves is used to shoot the Electromagnetic waves in a particular direction, if, an object is struck by this wave, certain amount of this wave is reflected back to the source point where another antenna (receiver) is used to capture the echoed wave. Thus depending on the intensity of this echo the approximate distance & height of the object is calculated. To be on a winning side in a war, the basic aspect is being sneaky enough to enter an enemy ground without giving a clue to them. For a team, to do the said, they should have a technology which could make them invisible to the eyes of the enemy RADAR. Stealth mode of operation not only benefits towards gaining an upper hand in the war but also helps the ground troops to foresee the challenges they may face once entered into the enemies' territory. One of the main challenges to be considered in adapting the stealth features to the vehicle is its performance, the implementing of defensive stealth layers to the aircraft should be done with minimum or with no compromise on the aircraft's performance in the battlefield. This paper gives a detailed picture on the technologies that are available on the 'Stealth mode of operation' for a vehicle especially briefing on different ways to make an aircraft invisible to the eyes of the enemy RADAR system. There are several parametric techniques in which one has to gain knowledge to make an aircraft stealthy enough to sneak without any trace. Some of widely recognised parameters one should get a sight on include:

➢ Shape of the aircraft
➢ Stealth materials to be used
➢ Radar cross section element
➢ Infrared radiation reduction
➢ Visual detection reduction
➢ Active stealth monitoring

Although there is several stealth techniques based on different parameters, this paper gives a sight on stealth technologies that are in contrast to the Radar technologies. 'Radar Cross section technique' is one of the categories which are most widely debated & researched segment as it comes under target shaping, material selection & coating, passive cancellation and active cancellation. A paper on Radar cross section reduction [1] was referred in which the visibility of the aircraft was reduced to a margin of 20% compared with the aircraft without this system. The system uses pre calculated approach with the values of Omni directional RCS, clutter & noise databases were calculated in advance. This system utilised active cancellation technique where in a cancellation signal is transmitted alongside the incoming signal in real time,

which indeed provides the phase and amplitude required to cancel the coherent echo signal. System showed an approach to generate an anti phased electromagnetic signal to a target's scattered signal with the required expressions to achieve the real time characteristics of electromagnetic waves. The surface of the aircraft also plays a major role in its ability to being invisible, the use of materials which absorb the electromagnetic waves rather than reflecting back should be considered for the body building of the aircraft.
Some of the most promising protocols those can be referred/termed as stealth technology are listed below,

- Automatic Jammer's: In this, signal generator are employed/incorporated in aircraft which generates and transmits the exact replica of source wave.
- Low Reflecting materials: The more commonly/widely used technology is, using low reflective materials to manufacture aircraft.
- Controlled Intrinsic Impedance: This technology will majorly involve controlling the surrounding environment around aircraft, to achieve low reflection co-efficient.
- Advanced Aircraft Design: In this protocol either surface or the design of an aircraft is changed to suits low reflection of microwaves.
  These protocols are explained in following section

II.   STEALTH PROTOCOLS

2.1 Automatic Jamming System:-

For clear understanding of the concept let us consider the object that has to be identified as an aircraft. In order to deceive the radar we must reduce the radar cross section. There are several ways to minimize/reduce the RCS, one such technique is an Active cancellation. This is nothing but Automatic Jamming System. An Active cancellation technique works by transmitting coherent micro wave which is replica of an incident wave at the exact time of incident wave at real time. To avoid detection in radar to greater extent System must transmit the cancellation signal at the exact time of incidence with proper orientation, phase, and amplitude/energy.   When a signal strikes an aircraft, the receiver employed in the aircraft receives the signal then analyses the signal to obtain the orientation, frequency, phase and polarization to that source. Then the echo signal is generated & transmitted into the free space, which is practically difficult to achieve in real-time. Hence, we must employ database of noise signals in the system to avoid delay in the signal processing.
Considering the electric field component of an incident signal as $_1E^+$
Some amount of signal is reflected back & some are transmitted,

$$\text{i.e. } _1E^+ + _1E^- = _2E^+ \text{ ---(1)}$$

Where $_1E^+$ is incident signal
$_1E^-$ is reflected signal from aircraft
$_2E^+$ transmitted signal

Then the echo cancellation signal can be expressed as

$$S = 20\log\left[\frac{Ec}{Es}\right] \text{ --- (2)}$$

Where E_c is cancellation residual field and E_s target scattering field [], the complete invisible is achieved when S=0.

This protocol poses challenges especially in signal reconstructing and echo signal cancellation. However one can find the solution for this by improvising the noise cancellation technique. Since echo cancellation signal will always not the exact replica of the source wave.

2.2 Materials:

We all know that the radar works on the principle where micro waves are used to detect aircraft by analysing the reflected signal from the aircraft. All metal or objects will have their own reflecting properties, Hence sometimes the aircraft, particularly the stealth aircraft's are designed with such low reflecting material or coated with the material which will absorb the signal rather than reflecting the incident signal back to the source. These kinds of aircrafts possess a very poor result in radar's detecting performance.

2.3 Controlled Environment round an Object:

Another most promising stealth technology is by controlling the surrounding environment around any airplane (object), achieves/avoids the detection in any Radar System. This technology is most promising, because, once we achieve to control it then the implemented aircraft will be impossible to be detected by any radar/antenna as to alter environment to their benefits. In other words the radar/antenna has no control over this changed environment what's so ever, this gives us enormous advantage. However this might be very difficult for any to achieve.

Radar locates any airplane (object) by reflected micro/radio waves from that airplane (object), even micro/radio waves has certain limits while propagating in free space. Micro/radio/any waves propagates in electro-magnetic form, both are vector quantities. Consider the Electric field of wave is E and Magnetic field as H, All the waves propagating in free space is opposed which is termed as wave impedance or intrinsic impedance *theta*

Intrinsic impedance is defined as *ratio of the electric field to magnetic field of wave.*

$$\text{i.e. } \eta = \frac{E}{H} \text{ --(3)}$$

Now the Power of any sine wave in free space is given by, according to pointing theorem

$$P \ E * H \quad \text{w/m}^2 \text{-- (4)}$$

However average power density is given by

$$P_{avg}\frac{1}{2}E * H \text{ --- (5)}$$

Now let's see the relationship between the reflected wave and incident wave when incident wave contact/hits the airplane (object)

$$_1E = {_2}E$$
$$_1E^+ + {_1}E^- = {_2}E^+ \text{ --- (6)}$$

Where $_1E^+$ is an incident signal/wave, $_1E^-$ is reflected signal/wave from aircraft and $_2E^+$ is transmitted wave/signal

Similarly magnetic component will be

$$_1H^+ + {_1}H^- = {_2}H^+$$

The reflection co-efficient is given by

$$\varepsilon = \frac{\eta2 - \eta1}{\eta2 + \eta1} \text{ --- (7)}$$

Where $\eta1$ is intrinsic impedance of region 1 (free space) and $\eta2$ is intrinsic impedance of region 2 (controlled region around airplane).

Now the average power density of reflected wave in terms of incident wave and reflection co-efficient can be expressed

$$_1P^+{}_{av} = |\varepsilon2| \ {_1}P^+{}_{av} \text{ --- (8)}$$

From the above equation, reduce in reflection co-efficient results in reduced reflected power density. In order to reduce the reflection co-efficient we must control either intrinsic impedance of region 1 or region 2 (object region). This is what we must achieve.

Now consider η1 = 10, η2 = 20 and $_1E^+ = 100$

$$\text{Then} \qquad \Gamma = \frac{\eta2 - \eta1}{\eta2 + \eta1}$$

$$\Gamma = 0.33$$

Hence $_1P^-{}_{av} = 33$ w/m^2

Let us change intrinsic impedance of region 2 (around airplane) η2 = 10.2

Then $\qquad \Gamma = 0.01$ (approximately)

$\qquad$ Hence $_1P^-{}_{av} = 0.01$ w/m^2

By observing the above calculation one can say the controlled environment around airplane (object) / *intrinsic impedance around airplane* results in *low reflection co-efficient* which in turn reduces the *reflected power* as mentioned earlier, allows any *airplane (object) to travel without any detection* by any radar's.

2.4 Multidisciplinary surface fabrication:

Incidence of microwave at aircraft body happens at a particular angle, finding this angle & considering this as to be a constant parameter & if it happens to control the angle as to the echoed wave never reaches the point of source can be achieved with an incredible knowledge on the incident wave. Thus, achieving this can make the echoed wave to never reach the source or at least making it less intense so that it can never be traced at the source. If the said is made possible then it makes this protocol a perfect stealth technology for an aircraft.

Now let's practically see whether this proposal can be implemented in real time or not. We know that angle of incidence is equal to the angle of reflection:

$$\theta_i = \theta_r \text{ ---(8)}$$

It is obvious that we may not able to change the angle of incidence but it is possible to change the angle of reflection by changing the surface of the aircraft or at least changing the intensity of the reflected wave. This would effectively reduce the chances of aircraft being detected by the enemy radar. Now let us consider the incident wave to be at different time with different angle as shown in Fig 1. With different angle the reflected wave would not be as same as required by the receiver to spot the aircraft due to less intense wave.
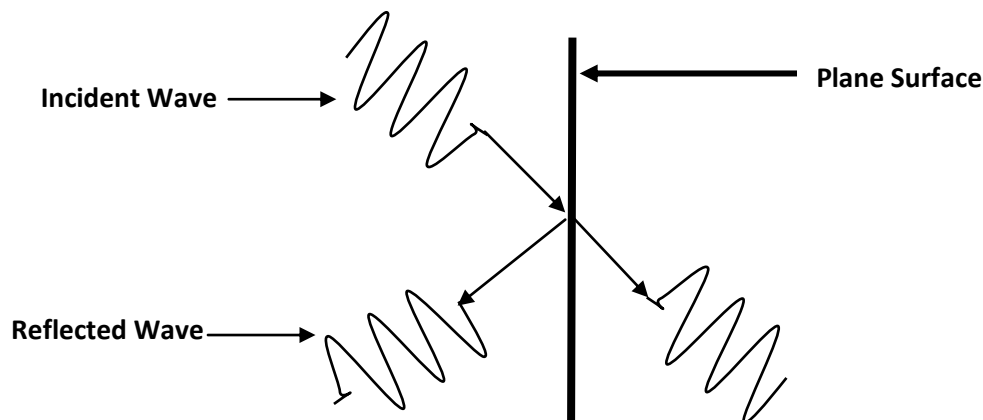
fig 1: oblige incidence

III.   CONCLUSION:

Some of the most prominent & reliable protocols available are explained in this paper with the aid of essential mathematical expression as a proof to support the protocols. it can be said that third & fourth protocols explained in the paper are best till date due to their efficiency to make an aircraft almost fully invisible. Due to our feasibility & resource exposure we are on a preparation to attempt the fourth protocol for its experimental approach.

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AUTHORS:

Mr. Prasanna Puttaswamy obtained his BE (Electricals & Electronics) from VTU in 2010 and M.Sc Honours (Embedded Microelectronics and Wireless System) from Coventry University UK, in 2012. He presently involved in experiment on sound wave and publication. His area of interest: Antenna, Embedded System, Radar and Microwave Engineering. E-mail id: prasanna.p06@gmail.com

Mr. Pramod Srivatsa Krishna Murthy, born in 1988, India, graduated with B.E in *Electricals & Electronics Engineering* in 2010 & obtained MSc honours in *Embedded Microelectronics & Wireless Systems* from Coventry University of UK in 2012. Currently working in a local embedded firm with alongside involvement in technical experiments & publications and ambitious to be a Research Scholar. Areas of interest are: Embedded Systems, Microwave Engineering, Antennas & Radar systems with few publications in the mentioned areas. E- mail id: prmdsrivatsa@gmail.com