A Review On Military Radars

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Abstract. In today's world, surveillance is one of the most crucial operation in military and combat applications. Every year, trillions of dollars are spent on military research and advancements. This research papers takes a review and analyses radar technology along with its military applications. It breaks down the current state of the technology, the challenges that are being faced along with innovations that are combating those challenges.

Keywords: Radar, Transmitter, Signal, Frequency, Echo, Receiver, Range

1. Introduction

1.1. Radar Communication

RAdio **D**etection **A**nd **R**anging (RADAR) is a method of determining the position, speed and various parameters of a target using electromagnetic waves, particularly radio waves. A radar consists of two primary components, a transmitter and a receiver. The transmitters emits a signal which is reflected off of the target. The receiver collects the signal reflected from the target and analyses it to determine the various parameters such as range, direction, velocity and other characteristics of the target. The primary principle of radars is the doppler effect.

Radars are generally classified into two main types based on the type of signal the radar operates on

- **Pulse Radar**
- **Continuous Wave Radar.**

Pulse Radar

Short pulses are transmitted by the antenna and each echo pulse corresponds to the original transmitted pulse.

Continuous Wave Radar

In a continuous wave radar, the transmitter sends out a continuous signal. However, the frequency is modulated and the range is determined by the change in frequency of the echo.

1.2. Principle and Working of Military Radars

Various radar systems can measure various characteristics of a target such as direction, height, distance, speed, path, etc. Hence, these systems can detect airplanes, ships or other such vehicles/obstacles. The frequency of electromagnetic signals generate is unaffected by darkness, extreme weather, clouds and other obstacles making radar systems an optimal and efficient choice.

The speed of the target is measured by the principle of Doppler frequency shift. Based on the speed of the moving target, doppler effect shifts the frequency of reflected radio waves. This principle is specifically effective in detecting moving objects than stationary object.

Modern radar systems have a wide variety of functionalities and setup configurations for various applications. However, its most important and fundamental use is to calculate the range of a particular target by measuring the time delay between the transmitted and received signal.

Basic design of radar system

The following diagram represents an overview of a radar system. The transmitters sends out an electro-magnetic signal. The signal is reflected off of the target and received by receiver. The electrical signal received by the antenna is called echo or return. In order to produce highly accurate results, the transmitted signal must be powerful and the echo must be received by a sensitive receiver.

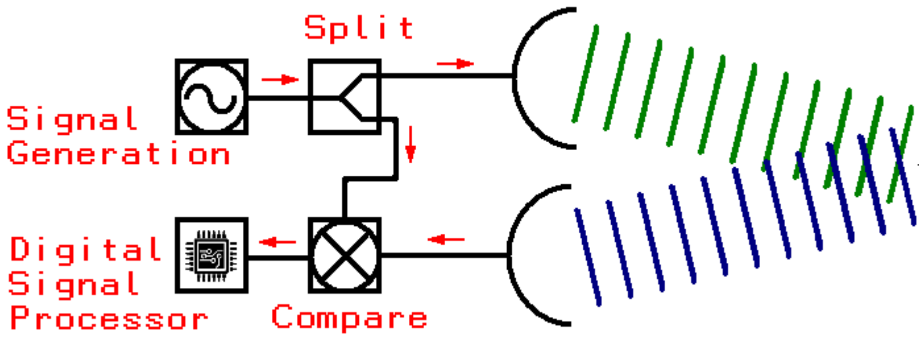

Fig 1. Block diagram of a basic radar system **[1]**

The targets produce a diffuse reflection in a wide number of directions which is known as scattering. Backscatter is referred to as the reflection in the opposite direction of the incident ray.

Radars transmit electromagnetic radio waves that travel at approximately the speed of light. Although extremely quick, a minute delay is formed between transmission of the signal and the reception of the echo. The range of the target can be computed by analysing the time delay which is directly proportional to the range.

For long-range radars, very short pulses are used to measure the time difference between the echo pulse and the original pulse to establish the range of the target. However, for shorter ranges, the radar constantly transmits but the frequency of the signal is modulated to distinguish between echo and the transmitted signal.

2. Current Developments in Radar Technology

The current technological trends are actively being research and engineered to make further advancements in the applications of military radar.

2.1 Active Array Radar

Active array radar is ship-borne multi-function 3D radar with four fixed sensors providing the following capabilities:

- Air tracking range of upto 150km for 200 various targets
- Surface target tracking range of upto 32 km for 150 various targets
- Missile guidance system supported by the radar capabilities

2.2 Multiple Band Radar

Each single radar band posses certain characteristics which allows it to perform optimally for certain tasks (eg. surveillance, tracking, pin-pointing, etc.). With a multiple band radar, various tasks can be carried optimally by specifically choosing the required radar bands. Hence providing significant flexibility in the operation of Battle-space Management and Air Defence Systems (BMADS).

2.3 Modular Equipment Configuration

By introducing modular, standardised and solid-state components, even complex radar systems will become more optimised and efficient. They will no longer consist of thousands of various items, but rather a smaller set of easily available and highly efficient components. Resulting in lower production and maintenance costs. Further, digital technology can be incorporated to digitise and future-proof complex and expensive systems.

3. Challenges Currently Faced By Military Radars

3.1 Availability tradeoffs for today's complex systems[2]:

ROTHR is a relocatable, bi-static land-based radar system. Its purpose is to track and detect targets at extremely large distances by refracting high frequency signals off the ionosphere. The system is generally used for naval operations covering a specified

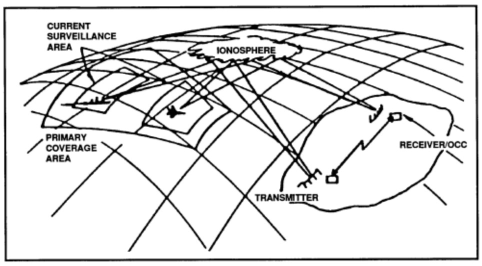

Figure 1: ROTHR Concept

large surveillance area. It is used for detection, tracking, early-warning, and number-of-vehicles information for aerial as well as naval vessels.

Maintainability, reliability, and redundancy are some of the most crucial parameters of any system, particularly for military radars which consists of thousands of complex parts which have exorbitant costs. To achieve availability goals, difficult decisions are faced requiring tradeoffs among redundancy, reliability, and costs of spare parts. For the Navy's Relocatable Over-the- Horizon Radar (ROTHR) Project, such tradeoffs involved millions of dollars.

Readiness Based Sparing (RBS) has become the standard technique to achieve a degree of supply support in order to meet a system's Operational Availability (Ao). For complex systems, the costs can exponentially grow in order to accommodate spare parts. Thus, RBS is required for more complex, and more accurate methods to achieve cost-effective sparing for highly complex systems which exhibit a high degree of redundancy.

$$A_o = \frac{\text{MTBCF}}{\text{MTBCF} + \text{MTTR} + \text{MSRT}}$$

Where: MTBCF = Mean Time Between Critical Failures
MTTR = Mean Time To Repair
MSRT = Mean Supply Response Time.

Fig 2. Equation to determine the Operational Availability

A spreadsheet was used to compute and compare the system gain in Ao per dollar of unit cost, for each spare part added. This summary spreadsheet compared the Ao, gain per dollar calculated for three different relationships:

1. parts with multiple and highly complex Ao relationships.
2. parts in equipments with simple redundancy
3. parts in series

In order to meet the appropriate system standards, the calculated Ao unit cost gain of each spare was ranked, and spares were added in that order, reranked and the process was repeated, until the system's Ao goal was achieved.

The method of optimally selecting spare parts resulted in achieving the system Ao goal of 95%, all while saving $4 millions per ROTHR installation; a significant jump from the Navy's standard demand based stocking which was able to achieve an Ao of only 65%. The above method was quite clearly extremely effective in not only increasing the Ao but decreasing the costs drastically along with it.

4. Future Prospects of Radars

Modern military radar face four main threats:

- Low Radar Cross Section (RCS), i.e., Stealth-crafts
- Electronic Counter Measures (ECM)
- Anti Radiation Missiles
- Low-altitude flying vehicles

Technological advancements are fundamental pillars of the society which promote innovation and growth. The progress in radar theory, rapid development of microelectronics technology and the constant need to enhance combat and tactical devices in military applications are constantly pushing the boundary of radar technology.

4.1 Frequency Domain Matched Radar:

A combination of multi-frequency and ultra-wide band radar will further the use of radars to an unprecedented level. The radar frequency can be modified according to the required specification s based on the target characteristics. Thus, maximising radar effectiveness to counter the four main threats.

4.2 Ultra-High Resolution Radar:

Ultra-high resolution radar will produce range domain imaging of targets with the help of multiple scatterers on a single target, therefore challenging the conventional radar design approach for point-like targets. However, extending the high-resolution radar will demand more complex processing.

4.3 Satellite-Bourne Radar:

Unlike the current surface-based and airborne radar systems, a satellite-borne radar is able to identify targets without facing obstruction from geographic features. Thus, accomplishing surveillance and tracking functions over a large area regardless of the geographical terrains. Surveillance from space may be as revolutionary as GPS was for navigation purposes.

4.4 Disperse Radar:

Multiple compact radar deployed over a wide region, whose detection opportunities are combined in disperse radar. They form an "information space," which helps gather multiple data points for a target when it enters a specific surveilled area.

5. Conclusion

It is quite evident that the need for highly advance, efficient and robust military and defensive surveillance systems has attracted the focus of researchers and engineers from all across the globe. Military radar systems are relieved heavily upon by some of the most advance military organisations and much like any other technology, they have reached an inflection point where significant growth can be seen in the upcoming years. In our opinion, introducing standardised, solid state equipment parts will give a significant boost and allow manufacturing and installation to become quick, efficient and cheaper compared to the current standards. The foundation has been laid to innovate new technologies, optimise current systems and propel the technology forward.

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