ABSTRACT

Topic: - MILITARY RADARS

RADAR (Radio Detection and Ranging) is basically a means of gathering information about distant objects by transmitting electromagnetic waves at them and analyzing the echoes. Radar has been employed on the ground, in air, on the sea and in space. Radar finds a number of applications such as in airport traffic control, military purposes, coastal navigation, meteorology and mapping etc. The development of the radar technology took place during the World War II in which it was used for detecting the approaching aircraft and then later for many other purposes which finally led to the development of advanced military radars being used these days. Military radars have a highly specialized design to be highly mobile and easily transportable, by air as well as ground.

In this paper we will discuss about the advanced features and benefits of military radar, system configuration of a typical military radar, operating the radar, system functions, various terminal equipments used along with their functions and some of the important parts of the radar such as transmitter, receiver, antenna, AFC (Automatic Frequency Control) etc.

MILITARY RADARS

INTRODUCTION

Military radar should be an early warning, altering along with weapon control functions. It is specially designed to be highly mobile and should be such that it can be deployed within minutes.

Military radar minimizes mutual interference of tasks of both air defenders and friendly air space users. This will result in an increased effectiveness of the combined combat

operations. The command and control capabilities of the radar in combination with an effective ground based air defence provide maximum operational effectiveness with a safe, efficient and flexible use of the air space. The increased operational effectiveness is obtained by combining the advantages of centralized air defence management with decentralized air defence control.

ADVANCED FEATURES AND BENEFITS

Typical military radar has the following advanced features and benefits: -

- All-weather day and night capability.
- Multiple target handling and engagement capability.
- Short and fast reaction time between target detection and ready to fire moment.
- Easy to operate and hence low manning requirements and stress reduction under severe conditions.
- Highly mobile system, to be used in all kind of terrain
- Flexible weapon integration, and unlimited number of single air defence weapons can be provided with target data.
- High resolution, which gives excellent target discrimination and accurate tracking.

The identification of the targets as friend or hostile is supported by IFF, which is an integral part of the system.

During the short time when the targets are exposed accurate data must be obtained. A high antenna rotational speed assures early target detection and a high data update rate required for track accuracy.

The radar can use linear (horizontal) polarization in clear weather. During rains, to improve the suppression of rain clutter, provision exists to change to circular polarization at the touch of the button from the display console.

THE SYSTEM CONFIGURATION

A typical military radar system can be split up into three parts:

1) Radargroup

The radargroup consists of antenna, mast unit, remote control, high tension unit, LO/AFC (Local Oscillator/Automatic Frequency Control) unit, radar transmitter, radar receiver, video processor, waveguide drier and IFF interrogator.

The transmitter and receiver forms the active part of the system. The integrated radar/IFF antenna is fitted on the collapsible mast, mounted on the container. The container is connected by cable to the operator/control shelter.

2) Shelter

Shelter contains display unit, processor unit, TV monitor, colour PPI (Plan Position indicator), IFF control unit, air conditioner, battery charger with battery, Radio set with antenna for data link, radio set with antenna for voice transmission i.e. communication, filter box for radios.

3) Motor generator

The motor generator supplies the power to the whole radar system.

SETS OF TERMINAL EQUIPMENT

These are the sets of lightweight man portable units, which can be easily be stacked together and consists of: -

1) TDR (Target Data Receiver)

The TDR is either connected to a VHF-FM radio receiver or to a LCA to receive transmitted target data. The TDR itself is intelligent, it performs parallax correction, threat evaluation and it displays the result in a threat sequence, enabling the weapon commander to make the correct decision.

2) Radio Receiver or LCA (Line Connection Adapter)

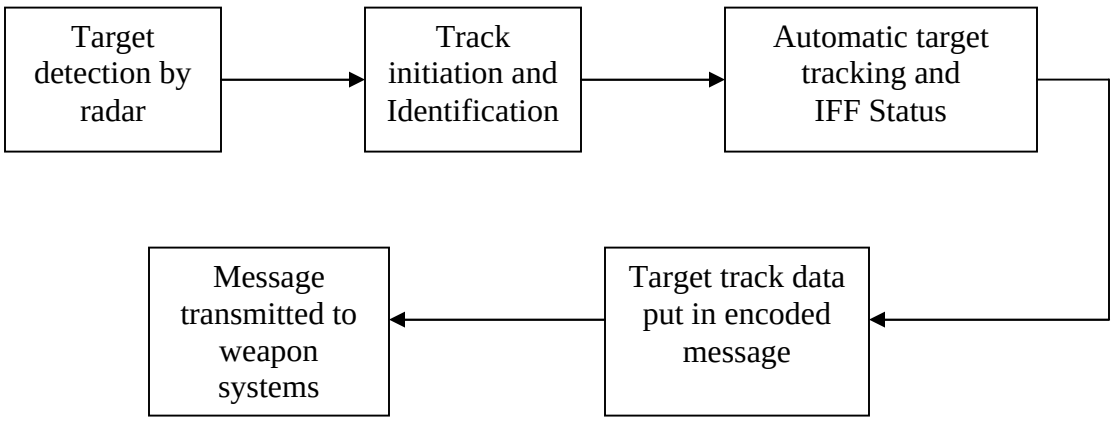
A radio receiver or LCA (with standard 2 wire telephone line) can be used to receive target data. In principle any VHF-FM radio receiver can be used as a part of the terminal equipment set. In case line connection is applied, no radio receiver is required. An LCA connects the 2-wire telephone line to the TDR cable.

OPERATING THE RADAR

The operator's main task is to watch the PPI (Plan Position Indicator) display, which presents only moving targets in the normal mode (MTI-MODE). Detected target can be assigned with the joystick controlled order marker to initiate target tracking. Target tracking is started and a track marker appears over the target echo. A label is displayed near the track marker. The system computer in the processor unit processes data on this tracked target. When an aircraft does not respond to the IFF interrogation it is considered to be unknown.

SYSTEM FUNCTIONS

The main task of the radar is to provide individual weapon systems, after an alert, with accurate target data. Therefore, the system has to perform certain functions as shown in the following block diagram: -



Data flow in a typical military radar system

- **Detection**

The detection function is supported by the search radar, the MTI processor and the PPI. On the PPI all moving targets, even those flying at low radial speeds, are displayed to the operator.

- **Automatic Target Tracking**

After target detection a track is initiated by indicating the target video with the joystick controlled order marker. The computer starts generating a track on the basis of the joystick data. A target track marker is displayed on the PPI over the target echo. Search

radar information is gathered and extracted by video extractor as plots. The computer evaluates the plot information, determines the position and speed of the target and updates the generated track.

- **Identification**

The identification function comprises: -

1) Interrogation of a target detected
2) Decoding IFF responses
3) Display of the decoded IFF responses on the PPI

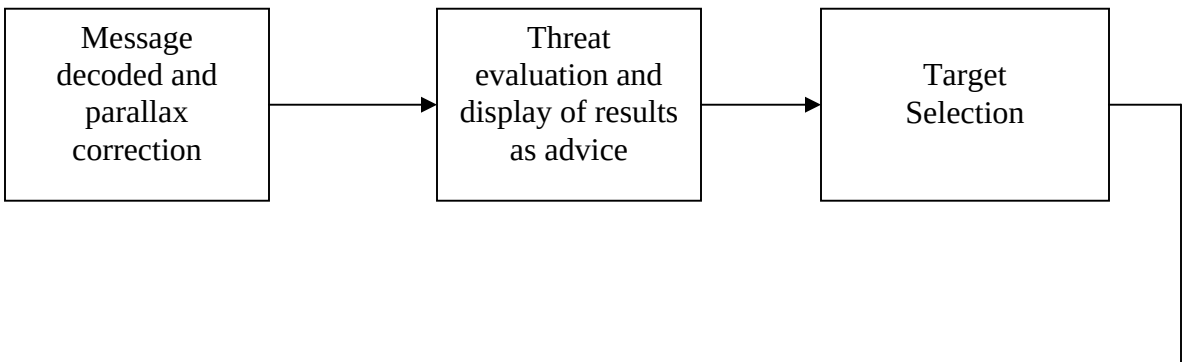
- **Reporting Function to External Terminal Equipment**

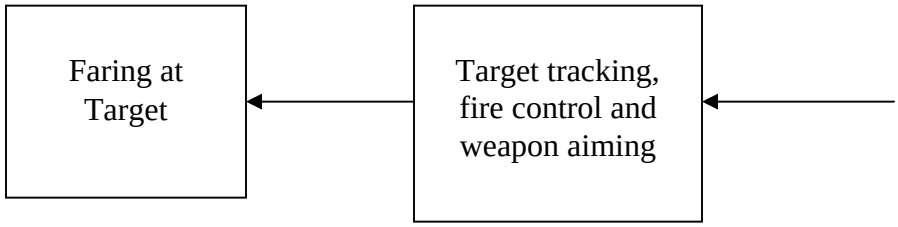
The data of the tracked targets is automatically converted to X and Y grid co-ordinates, with respect to preset co-ordinates of the radar location. The data is included in digital data message made up for all targets being tracked. The computer-originated message is encoded and automatically transmitted by VHF-FM radio or by line communication.

- **IFF Alarm**

The IFF alarm function alerts the operator that the IFF code setting has to be changed. The valid code is displayed to the operator. The IFF codes and their validity period are entered into the system in advance.

TERMINAL EQUIPMENT FUNCTIONS





Data flow at weapon systems

- **Target Decoding**

The target information is received and decoded. In case no, or disturbed target information is received, it is indicated on the TDR.

- **Parallax Correction**

The parallax correction function is performed by the TDR. Through this function the target data received in the X and Y co-ordinates is transferred into polar co-ordinates, with respect to the entered weapon position.

- **Threat Evaluation**

The data of the targets received is processed by a threat evaluation program, built in to the TDR. This program places all the targets in a sequence according to their threat priority and displays the result (azimuth angle of four most threatening targets) as an engagement advice.

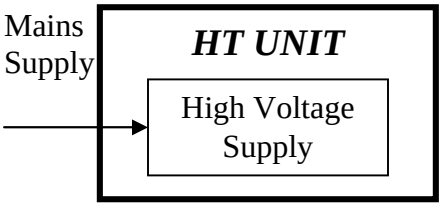
FUNCTIONAL DESCRIPTION OF RADAR SUBSYSTEM

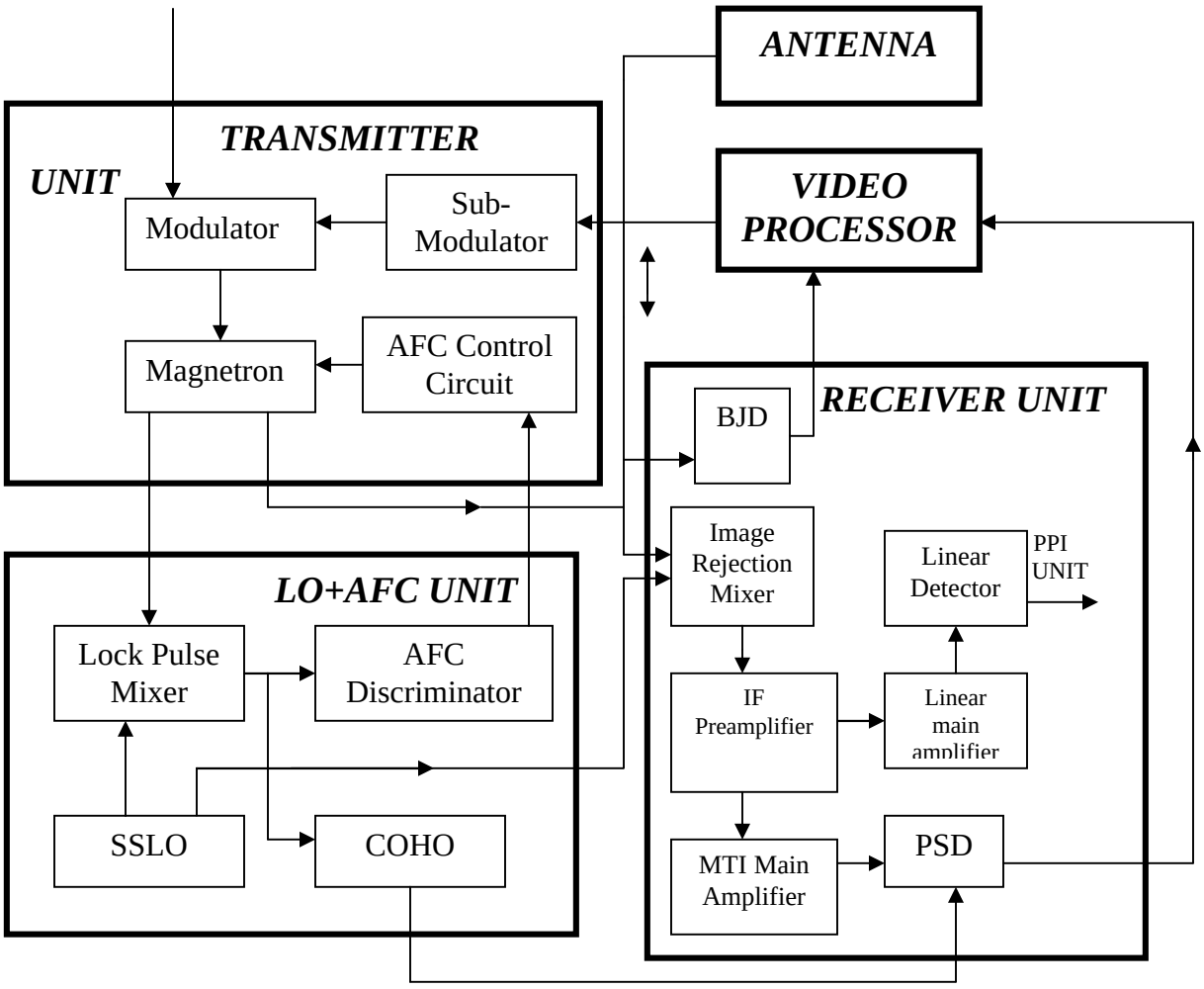
The detection of air targets is accomplished by the search radar, the video processor and the colour PPI unit. The colour PPI unit provides the presentation of all moving targets down to very low radial speeds on a PPI screen

The search radar is pulse Doppler radar (also called MTI radar) i.e. it is capable of distinguishing between the echo from a fixed target and that of a moving target. The echoes from fixed target are eliminated, so that the echoes from the moving targets are presented on the screen.

The great advantage of this is that it is possible to distinguish a moving target among a large number of fixed targets, even when the echoes from these fixed targets are much stronger. To achieve this the search radar makes use of the Doppler effect, if the target having a certain radial speed with respect to the search antenna is hit by a series of transmitter pulses from the search radar antenna, the change in range between this target and antenna is expressed by successive echo pulses in phase shifts with respect to the phase of the transmitter pulses.

For moving targets the phase difference from echo pulse to echo pulse is continually subject to change, whereas for fixed targets this is a constant. The distinction between the echo signals from a fixed target and moving target is obtained by detecting the above phase differences.





Block Diagram of Radar

The main units of radar subsystem are: -

1) HT Unit

The high tension unit converts the phase mains voltage into a DC supply voltage of about in the order of kV for the transmitter unit.

2) Transmitter Unit

The transmitter unit comprises:

a) Modulator

The modulator consists of the following components: -

- **Start Pulse Amplifier**

The start pulse amplifier unit comprises: -

An amplifier which amplifies the pulses from the video processor, a thyratron for discharging the pulse-shaping network. These pulses then trigger a monostable multivibrator.

- **Pulse Unit**

The pulse unit comprises of pulse shaping network and pulse transformer.

The pulse discharge of the pulse- shaping network will occur only if the magnetron impedance transformed by the pulse transformer is about equal to the characteristic impedance of the pulse-shaping network.

The thyratron diodes ensure that the remaining negative voltage, caused by the mismatch, on the pulse-forming network is directed to earth.

If the mismatch is too large, capacitor is charged by the discharge current to such an extent that relay (reflection coefficient too high) is activated. This relay switches off the high voltage.

b) Magnetron

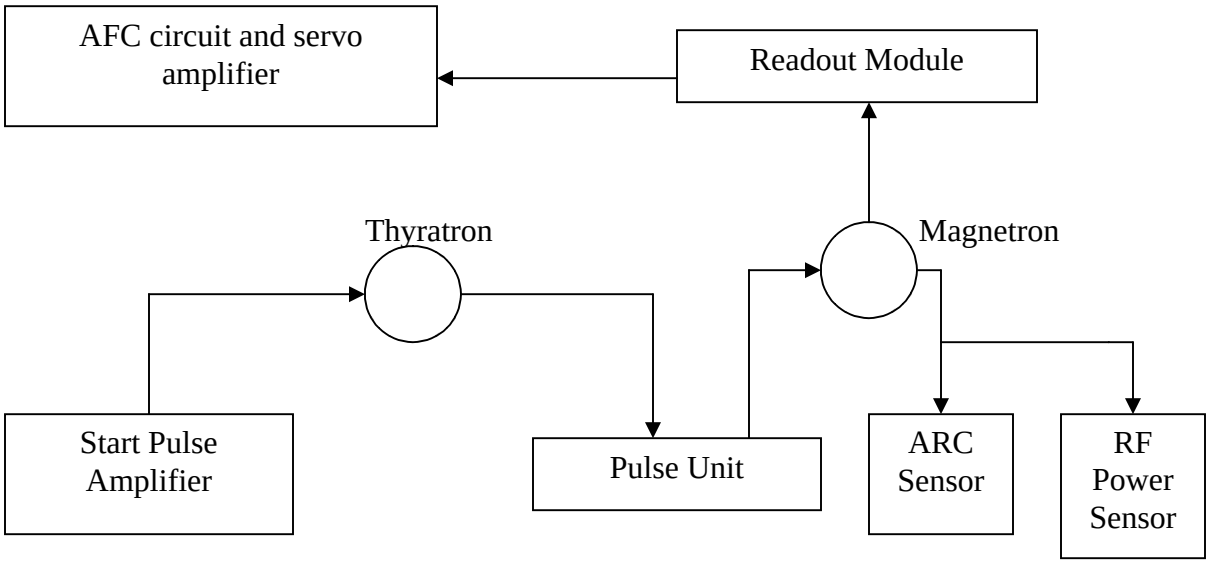
The magnetron is a self-oscillating RF power generator. It is supplied by the modulator by high voltage pulses, whereupon it produces band pulses. The generated RF pulses are applied to the receiver unit.

The PRF of the magnetron pulses is determined by the synchronization circuit in the video processor, which applies start pulses to the sub-modulator of the transmitter unit. This sub modulator issues start pulses of suitable amplitude to trigger the thyratron in the

modulator. On being triggered the modulator, which is supplied by the high tension unit, produces high voltage pulses.

As a magnetron is self oscillating some kind of frequency control is required. The magnetron is provided with a tuning mechanism to adjust the oscillating frequency between certain limits. This tuning mechanism is operated by an electric motor being part of AFC control circuit. Together with circuits in LO+AFC unit, a frequency control loop is created, thus maintaining a frequency difference i.e. the intermediate frequency of the receiver between the output frequency of the SSLO and the magnetron output frequency.

The magnetron unit comprises a coaxial tunable magnetron, servo motor driving an adjustable plunger.



Transmitter Unit

3) LO+AFC Unit

The LO+AFC unit determines the frequency of the transmitted radar pulses. It comprises of: -

1) Lock pulse mixer

2) AFC discriminator

3) Solid State Local Oscillator (SSLO)

4) Coherent Oscillator (COHO)

The SSLO generates a very stable low power RF signal lower than the desired transmitter frequency. This signal is split in two branches and distributed as local oscillator signal to two mixers.

These are: -

1) Image rejection mixer in the receiver unit
2) Lock pulse mixer

The lock pulse mixer mixes the SSLO signal with a fraction of the magnetron power. The mixer output consists of AFC lock pulse, provided that the magnetron is correctly tuned. The AFC lock pulses are applied to an AFC discriminator, which checks their frequency. If the frequency of the AFC lock pulses is unequal to IF, a positive or negative control voltage for the AFC control circuit in the transmitter unit is developed, to force the magnetron frequency to the desired value. Thus the AFC loop is closed.

The AFC lock pulses are also applied to COHO. The COHO outputs a signal with a frequency of AFC lock pulse, and is synchronized with the phase of each transmitter pulse. In this way a phase reference signal is obtained required by the phase sensitive detector in the receiver unit.

4) Receiver Unit

The receiver unit converts the received RF echo signals to IF level and detects the IF signals. By detecting the IF signals in two different ways, two receiver channels are obtained called MTI channel and linear channel.

The RF signals received by radar antenna are applied to the low noise amplifier. The image rejection mixer mixes the amplified signals with the SSLO signal, to obtain an IF signal. After amplification the IF signal is split into two branches viz. a MTI channel and a linear channel. A fraction of amplified received signal is branched off and applied to broadband jamming detector (BJD).

In the MTI channel, the IF signal is amplified again by the MTI main amplifier, and applied to the Phase Sensitive Detector (PSD). The second signal applied to the PSD is the phase reference signal from the COHO.

The output of the PSD is the function of the phase difference between the two inputs to the PSD. The polarity pulses indicate whether the phase difference is positive or negative. The phase differences between the COHO signal and IF echo signals from a fixed target is constant whereas those between the COHO signals and IF echo signals from a moving target is subject to change.

The PSD output signal is applied to the canceller in video processor.

In the linear channel, the IF signal is amplified again by the linear main amplifier and subsequently applied to the linear detector. The linear detector output signals are passed on to the colour PPI drive unit.

5) Antenna

The search antenna is a parabolic reflector, rotating with a high speed. In the focus of the reflector is a radiator, which emits the RF pulses, and which receives the RF echo pulses.

In the waveguide is the polarization shifter, which causes the polarization of the RF energy to be either horizontally or circularly.

6) Video processor

The video processor processes the MTI video from the MTI receiver channel, to make the video suitable for the presentation on the colour PPI screen.

7) Protection Units

There are some protection units such as arc sensor to protect the magnetron against arcing and RF power sensor maintaining the RF power.

CONCLUSION

Military radars are one of the most important requirements during the wartime, which can be used for early detection of ballistic missile and also for accurate target detection and firing. Radar system discussed here has a built in threat evaluation program which automatically puts the target in a threat sequence, and advises the weapon crew which target can be engaged first. Most essential, the target data is available to the weapon crew in time, so the can prepare themselves to engage the 'best' target for their specific weapon location.

A magnetron radar system is relatively simple and reliable. As a consequence, minimum maintenance is required and thus the system life cycle costs can be kept low.

REFERENCES

1) Skolnik 'Introduction to Radar Systems' McGraw Hill

2) 'Electronic Communication Systems' by Kennedy, Davis Fourth Edition

3) Bharat Electronics Limited website www.bel-india.com

4) Various other internet sites and journals