NAVAL AIR TRAINING COMMAND

NAS CORPUS CHRISTI, TEXAS **CNATRA P-820 (02-14)**

FLIGHT TRAINING INSTRUCTION

RADAR THEORY T–45C

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1. CNATRA P-820 (Rev. 02-14) PAT, "FLIGHT TRAINING INSTRUCTION, RADAR THEORY, T-45C" is issued for information, standardization of instruction, and guidance for all flight instructors and student aviators within the Naval Air Training Command.

2. This publication shall be used as an explanatory aid to support the Advanced Strike Flight UMFO Training System. It will be the authority for the execution of all flight procedures and maneuvers herein contained.

3. Recommendations for changes shall be submitted via CNATRA TCR form 1550/19 in accordance with CNATRAINST 1550.6E.

4. CNATRA P-820 (New 12-94) PAT is hereby superseded, and will be cancelled when the last student enrolled in the CNATRAINST 1542.158F completes the curriculum.

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FOR

RADAR THEORY

T-45C

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INTERIM CHANGE SUMMARY

The following Changes have been previously incorporated in this manual:

CHANGE NUMBER	REMARKS/PURPOSE

The following interim Changes have been incorporated in this Change/Revision:

INTERIM CHANGE NUMBER	REMARKS/PURPOSE	ENTERED BY	DATE

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RADAR THEORY

100. INTRODUCTION

Radar is an essential weapons platform in today's military. It is a primary active sensor used in operational warfighting units, and is incorporated in most tactical aircraft. Proper understanding and interpretation of radar is a vital component towards successfully prosecuting and engaging hostile/enemy contacts. Radars vary considerably in size, composition, and performance depending upon their intended function and location. Radar platforms include land based, shipboard, and airborne assets.

101. ELECTROMAGNETIC ENERGY

In order to understand the basic operation of radar systems, a working knowledge of electromagnetic (EM) energy is required. The mathematics and complex concepts of electromagnetic energy and circuitry are beyond the scope of this Flight Training Instruction (FTI). However, a basic understanding of the radar fundamentals, characteristics and limitations is essential to effectively operate the radar and analyze the displayed information.

1. Electromagnetic Spectrum

Electromagnetic (EM) radiation is made up of oscillating electric and magnetic fields. The Electromagnetic Spectrum (EMS) is the range of all possible electromagnetic radiation (Figure 1-1) and includes:

a. Gamma Radiation

b. X-rays

c. Ultraviolet

d. Visible Spectrum

e. Microwave

f. Infrared (IR)

g. Radar and radio waves

The primary frequencies that apply to radar are those found in the microwave region of the EMS.

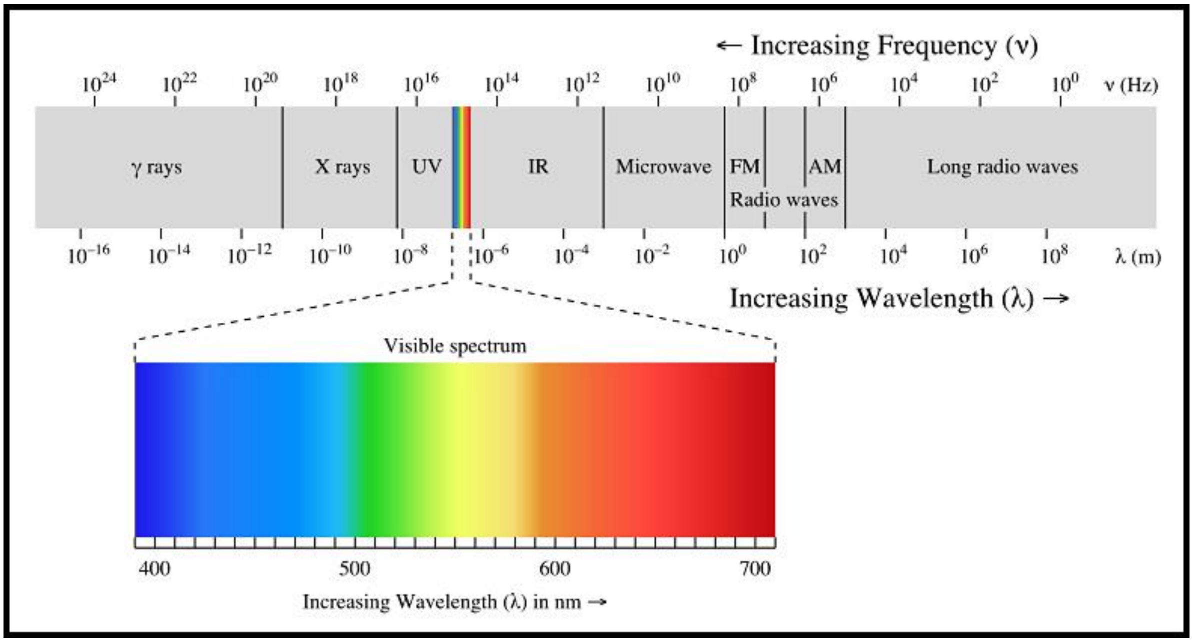

Figure 1-1 Electromagnetic Spectrum

2. EM Characteristics.

EM energy (Figure 1-2) can be broken down into the following characteristics:

a. Cycle

b. Frequency

c. Wavelength

d. Amplitude

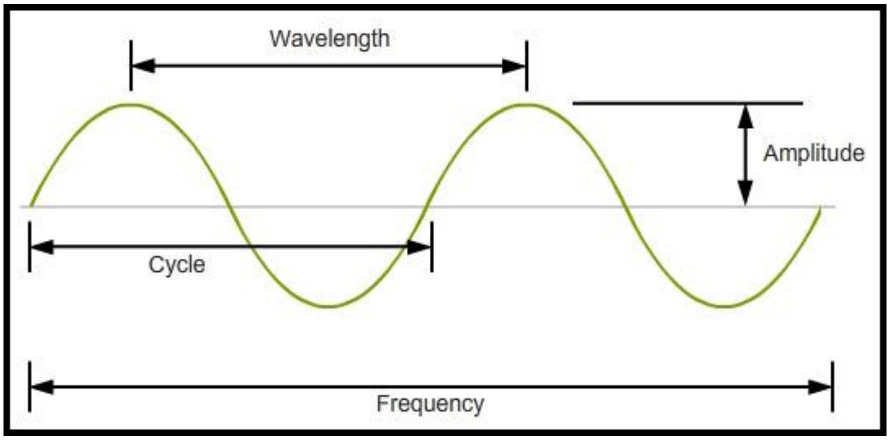

Figure 1-2 EM Characteristics

3. Cycle

An EM wave is a repeating pattern. It repeats itself in a periodic and regular fashion over both time and space. The wave cycle is one spatial repetition of the wave. It is one complete oscillation of the wave.

4. Frequency

The frequency of the wave is the measure of the periodic oscillations of the wave over time. It is the number of times that the wave repeats in a given amount of time. Frequency can be applied to EM waves, sound waves or even waves on the beach. Frequency is normally stated in terms of cycles per second (cps), and the unit of measure is hertz (Hz). One Hz is equal to one cycle per second; 60 Hz is equal to 60 cps.

To determine the frequency of a wave, a measurement of time is taken between corresponding points on a wave. Applying the knowledge that frequency is the number of repetitions (cycles) each second, the frequency in Hertz can be found. For example, if one cycle of a given wave takes 0.25 seconds to complete, the frequency can be calculated as follows:

$$f = 1/time = 1\ cycle/0.25\ seconds$$

$$f = 4\ cycles\ per\ second = 4\ Hz$$

5. Wavelength

The wavelength is a measure of the distance travelled by the wave before its oscillation pattern repeats. It is equal to the distance the energy wave will travel during the time required for one complete wave cycle. The peak is the top of the wave while the trough is the bottom. Wavelengths can be measured from midpoint to midpoint, peak to peak, or trough to trough. In fact, the wavelength of a wave can be measured as the distance from any point on a wave to the corresponding point on the next cycle of the wave.

Wavelength and frequency are inversely proportional. As the frequency increases, wavelength decreases, and vice versa. Higher frequencies (shorter wavelengths) tend to be used for directional and navigational radars such as ground mapping and fire control. Lower frequencies (longer wavelengths) tend to be used for early warning and ship’s navigation due to their longer signal strength and range.

6. Amplitude

Amplitude is a measure of the maximum positive displacement of the wave. It is normally measured from the null point to the peak, but can be measured from null point to trough.

7. EM Propagation

EM energy propagates at the speed of light. As with light energy, when EM radiation strikes something, it undergoes one or more of four processes (Figure 1-3):

a. Reflection – surface turns back EM radiation

b. Absorption – substance absorbs EM radiation

c. Transmission – EM radiation passes through the surface

d. Refraction – EM waves bend when passing through substance, caused by changes in medium's density

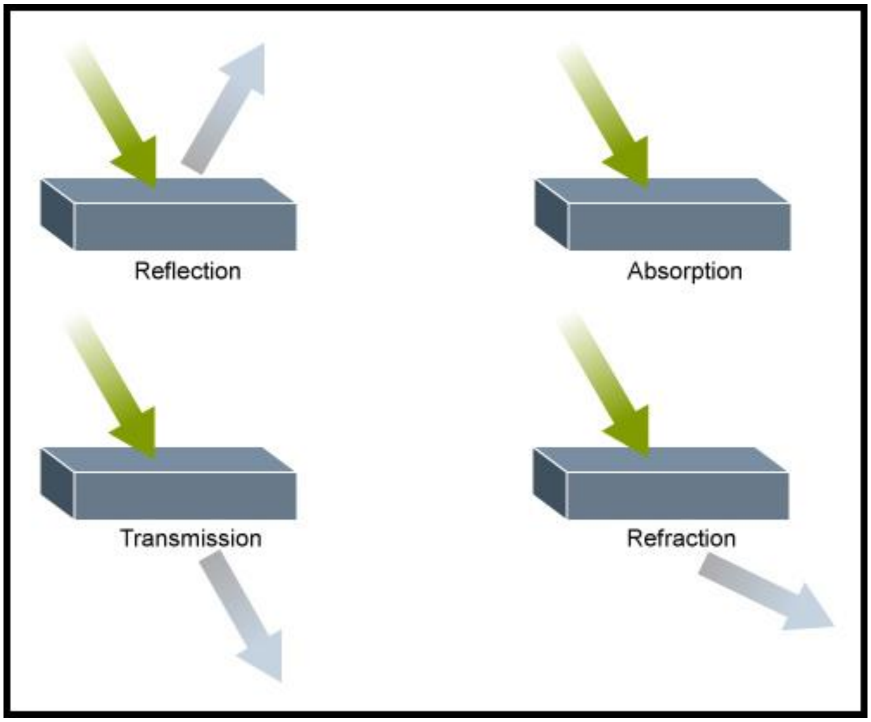

Figure 1-3 EM Propagation

102. RADAR FUNDAMENTALS

Radar is an acronym for **RA**dio **D**etection **A**nd **R**anging. Radar energy is EM energy (in the RF range) and therefore has the same properties as light; it travels at the speed of light in a straight line path and is reflected by physical objects. However, there is one important difference: radar requires the existence of a radio source whereas light requires a light source.

Radar detects the presence, direction, altitude, and distance of objects by using focused EM energy. Radar equipment transmits and processes the received energy reflected by those objects. Since metallic objects are the best reflectors of electromagnetic energy, ships, aircraft, and vertical structures provide strong echoes. In combat environments, radar is used for hazardous weather detection, navigation, air-to-ground targeting, and air-to-air targeting.

1. Radar Categories

Depending on how it is used, a radar system can be classified into one or more of the following categories:

a. Air search – provides extremely accurate information in regards to target location by leveraging range, bearing and elevation information. They are 3D capable, can be used to direct fighter aircraft intercepts, and are high frequency/short range.

b. Early warning – long range radar used for initial detection and advanced early warning of threats at range. They operate at low frequencies to obtain these long range capabilities and require large power outputs. Positions reported by these systems are not exact, however they serve the purpose of early detection.

c. Surface search – primarily used to scan the surface of the earth for ship or ground contacts. They are used by ships as a navigational aid and operate at a higher frequency and greater accuracy than early warning radar.

d. Airborne search – radar systems that are size and weight limited due to aircraft restrictions. They have limited range capability compared to land-based counterparts. These systems generally provide high target accuracy, radar navigation, ground mapping/terrain avoidance and air-to-air (A/A) search (Figure 1-4).

e. Fire Control – radars used to control the guidance of weapons. These systems operate at higher frequencies due to precision guidance and target resolution requirements.

f. Identification – radar system specialized to identify specific aircraft. They have special equipment (IFF) on aircraft that when interrogated, respond to the interrogation pulse with a transmitted response pulse.

Figure 1-4 Airborne Search Radars

2. Joint Electronics Type Designation System

The military uses the Joint Electronics Type Designation System (JETDS) to classify all electronic equipment, including radars. JETDS identifies systems with a sequence of letters and digits prefixed by "AN/." The JETDS convention utilizes three letters after the AN/ prefix followed by a hyphen and a number. Some systems will have an additional letter following the numeric portion which generally reflects the hardware/software version or variant. The JETDS classification chart is included as Appendix A of this FTI.

The three letters in a JETDS designation describe the equipment. The hyphenated number is assigned sequentially with higher numbers indicating newer systems. For example:

a. The AN/APG-73 is an airborne (A) radar (P) used for fire control (G).

b. The AN/AAQ-28 is an airborne (A) infrared (A) combined purpose (Q) targeting pod.

Some systems have a final letter following the numeric. If present, this final letter typically indicates the hardware/software version or variant.

3. Basic Radar Concepts

Basic terms used in radar discussions are as follows:

a. Echo – returned/reflected energy from the radar hitting an object

b. Beam – focused energy that the radar's antenna transmits into space

c. Contact – an echo seen on a radar target scope; it represents what is thought to be the return signal of a target

d. Target – a specific object of radar search or detection; a contact of interest

e. Azimuth – the angular distance from a reference point, usually the aircraft datum line, specified in degrees (normally it is degrees left or right of the nose centerline)

f. Range – the distance in yards or nautical miles between the radar antenna and a given contact

g. Slant range – the line of sight path between the radar and the contact, altitude dependent; slant range is normally associated with a ground target (as aircraft altitude increases, slant range increases)

4. Radar Beam Characteristics

The radar system must have the ability to transmit and receive energy in a controlled manner. The radar antenna forms the energy into a narrow beam called the main beam. Since the main beam only illuminates a small area, the radar antenna moves the beam horizontally and vertically in order to detect contacts. The true shape of most radar beams is conical. Therefore, the beam is smallest close to the antenna where the beam originates (Figure 1-5). As energy travels farther and farther away, it occupies a larger volume while keeping its original shape.

Concentrations of energy build up around the main energy beam. These byproducts are called sidelobes, with the strongest ones oriented perpendicular to the main beam. Generally, higher antenna efficiencies produce smaller sidelobes.

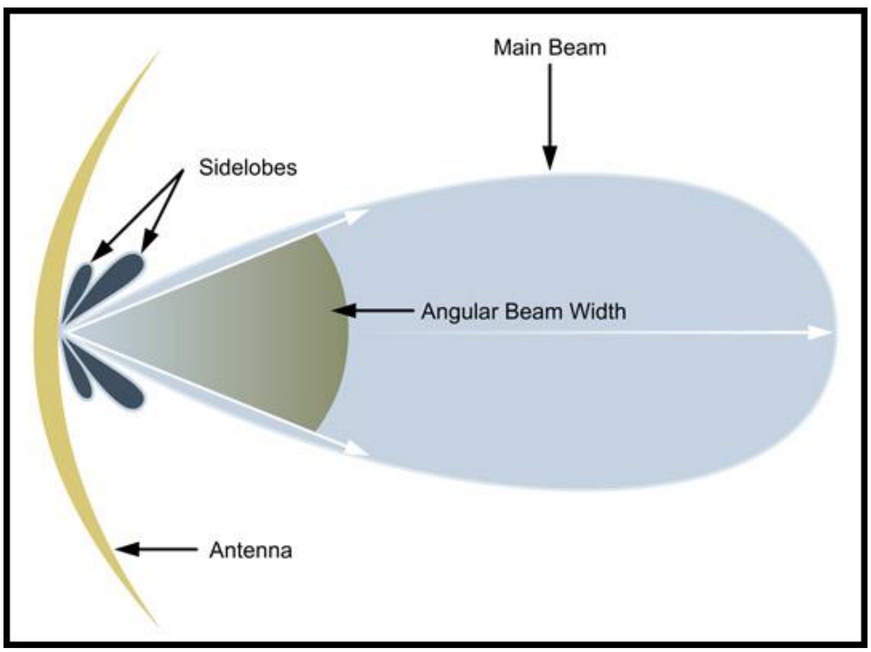

Figure 1-5 Radar Beam

5. Azimuth Resolution

Radar beam parameters are important when discussing azimuth resolution. Azimuth resolution is the ability to distinguish individual targets on different azimuths (bearings). To distinguish contacts at the same range but different bearings, contacts must be separated by a distance greater than the width of the beam at the contact area. As target range increases, so does beam width. Therefore, targets that are farther away from the radar source must have greater angular separation than targets at closer ranges in order for the radar to see them individually.

6. Radar Range Mile

As previously mentioned, the reflected radar energy returns along the same path as the source transmitted energy. The energy contained in the returning echo is much less than the original energy contained in the transmitted pulse. The returning echo or "paint" is received by the radar system, internally processed, and presented on the display as an image positioned relative to the source radar.

Knowing that EM energy travels at the speed of light (162,000 NM per second), we can deduce that EM energy takes 6.18 microseconds to travel 1 NM. Since the radar "echo" must travel to the target and back to the radar receiver, 6.18 is multiplied by two. The resulting 12.36 microseconds is known as a radar range mile. The distance to any target, measured in nautical miles, can be determined by dividing the elapsed time during a round trip of a radar pulse by the radar range mile (12.36 ms).

103. RADAR ENERGY TRANSMITTAL FORMS

There are two forms in which radar energy can be transmitted: Pulsed and Continuous Wave (CW)

1. Pulsed

The basic principle of pulsed radar requires the transmitter to send out bursts of energy with a rest period between bursts while the energy travels out to the target. During the period in which the transmitter is at rest, the radar receiver is "listening" for echo signals which would indicate a reflecting source. This system of transmit-receive-transmit allows for just one antenna to be used, sharing duties with both the transmitter and the receiver.

There are two categories of pulsed energy forms:

a. Pulse – The radar system generates a powerful single pulse of energy and has an associated waiting period to receive the returned energy

   i. Single antenna used to transmit and receive (the radar cannot transmit and receive simultaneously, thus the "waiting period")

   ii. Radar transmits pulse and marks the time of transmission

iii. System receives echo from contact which is used to determine bearing information

iv. System computes distance to target based on the time between transmission of the energy pulse and reception of the echo return

b. Pulse-Doppler (PD) – Transmission and reception are similar to the Pulse system, but the PD system distinguishes contacts by the frequency shift of the echo rather than the time between pulses.

2. Continuous Wave

A Continuous Wave (CW) radar system uses a continuous transmission of energy from one antenna, while using a separate antenna to receive the returned echo. Because the transmitted energy wave is not interrupted, CW provides very accurate azimuth and elevation measurements of a target. This form of energy transmission is often used to guide missiles to impact using fire control radars. Another important use of CW systems is the Radar Altimeter (RADALT) which uses a CW signal that is frequency modulated (FM). This FM signal allows for a high level of accuracy in determining range, or in the case of the RADALT, altitude.

a. Accurate measurement of azimuth and elevation

b. Uses include missile guidance (fire control radar) and RADALTs

3. Doppler Effect

Pulse-Doppler radar works off the principle of frequency shift known as Doppler Effect. This effect is the observed change in frequency of a wave for an observer moving relative to the source. It is commonly heard.

A common example is the frequency shift heard as a train passes a station. As the train approaches, the frequency heard appears to compress and increase. As the train passes and moves away, the sound appears to decrease in frequency. Echoes returning to the radar from an approaching contact will be higher in frequency than the original transmission. Conversely, echoes returning to the radar from contacts moving away will be lower in frequency.

When applied to radars, the Doppler Effect can be used to accurately determine the velocity of a target. When the target is moving toward the radar, each successive wave crest is returned from a position closer to the radar than the previous wave. Therefore, each wave takes slightly less time to reach the radar receiver than the previous wave. The time between the arrivals of successive wave crests at the radar is reduced, causing an increase in the frequency. If the target is moving toward the radar, the distance between successive wave fronts is reduced so the waves compress resulting in an increase in frequency. Conversely, if the target is moving away from the radar, each wave is returned from a position farther from the receiver than the previous wave, so the arrival time between successive waves is increased thereby reducing the frequency.

The end result of the Doppler Effect may result from motion of the radar or motion of the target, or both. The radar processor uses the aircraft airspeed and the frequency shift of the returned signal to accurately determine the speed of the target.

104. PULSE CHARACTERISTICS

Four basic terms describe the components of pulsed radar systems:

a. Pulse Width (PW)

b. Pulse Length (PL)

c. Pulse Repetition Frequency (PRF)

d. Pulse Repetition Time (PRT)

In order to fully understand radar operation, a solid understanding of these terms is required.

1. Pulse Width and Pulse Length

Pulse width (PW) is the time required to transmit one pulse of radar energy (duration of the pulse). This represents the time the radar is transmitting vice receiving, or “listening” for radar returns (Figure 1-6). Varying the PW allows optimization of the radar’s range resolution and enhances minimum range performance.

Pulse length (PL) is the distance from leading edge to trailing edge of the radar pulse as it travels in space (Figure 1-6).

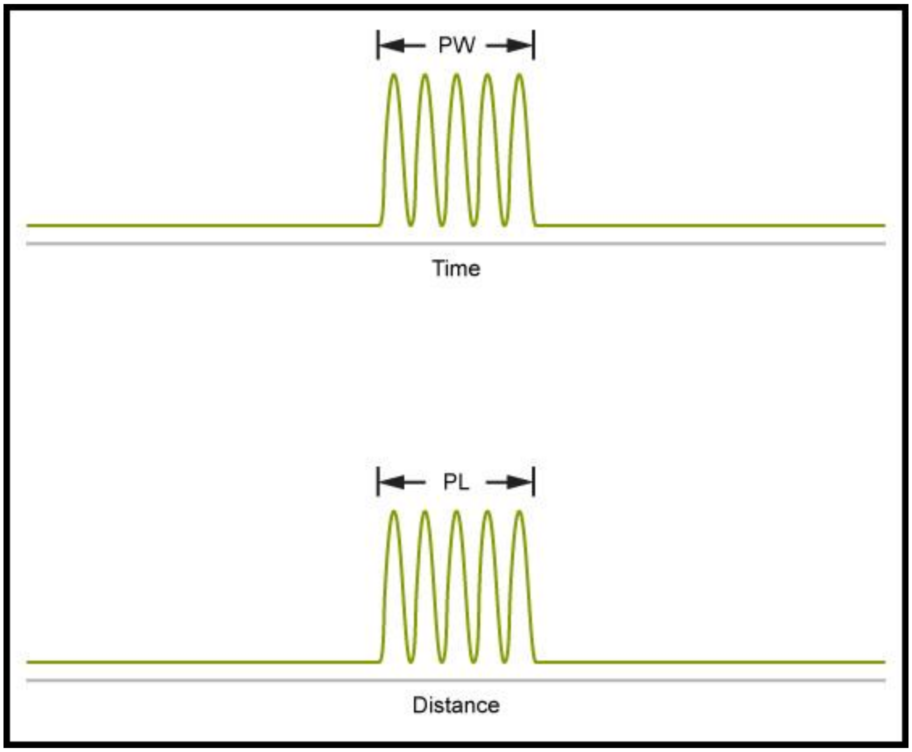

Figure 1-6 Pulse Width and Pulse Length

The PL can be calculated by using the calculation:

Distance = Rate * Time

PL = (Speed of the radar energy) * (PW)

PL = C * PW

To detect a radar target, a pulse must travel from the transmitter to the target and return to the antenna. Since the antenna is shared by both the transmitter and receiver, a target return will not be seen if a pulse is still being sent out because the receive is at rest. PL determines this minimum range as well as the range between separate targets at which each individual target can be detected (range resolution). The minimum range (R_{MIN}) of the radar corresponds to the minimum distance the receiver can see the target. In order to detect a target at the closest distance in front of the aircraft (minimum range), the length of the pulse must be such that the transmitter is turned off just prior to the return of the echo to the antenna. This range is a function of pulse length because the receiver is not turned on until the pulse has been transmitted. The minimum range is equivalent to the distance at which one half of the pulse has been returned from the target while the first half of the pulse is still approaching the target. In other words, the front of the pulse is moving back toward the receiver while the tail of the pulse is still moving toward the target. The end of the pulse represents the time the transmitter is turned off and the receiver turned on. This is the first opportunity for the receiver to see the leading edge of the returned pulse, and is therefore the minimum range of the radar:

$$R_{MIN} = 1/2\ PL$$

Therefore, the radar can only detect objects in range that are at least one half of the pulse length away.

A related concept is that of range resolution. Radar can only see individual targets that are separated by more than one-half of a pulse length, regardless of the range to the target. Range resolution determines how close in range two aircraft must fly to appear as one target.

2. Pulse Repetition Frequency, Pulse Repetition Time, R_{MAX}

Pulse repetition frequency (PRF) is the rate at which pulses are transmitted. This is the number of bursts of energy the radar releases every second. Pulse repetition time (PRT) is the total time for a complete cycle of one pulse, rest time and the initiation of the next pulse. PRT is inversely proportional to PRF:

$$PW = 1\ /\ PRT$$

The PRF will determine the maximum theoretical range (R_{MAX}) of the radar. The actual maximum range may be limited by factors such as power output, antenna type and weather factors.

The maximum time available to receive a target return is equivalent to PRT because PRT is equal to the transmission time plus rest time. The target return must arrive at the radar antenna prior to the next pulse leaving the radar. The basic equation used to calculate R_{MAX} is primarily a function of the speed of the radar energy (C) and the PRT:

$$R_{MAX} = (C \times PRT)\ /\ 2$$

The product of PRT and the speed of the radar energy are divided by 2 because the energy must travel out and back. It is important to note that the PRF of the pulse and the frequency of the radar wave are independent of one another (i.e., any frequency may operate with any PRF).

Another consideration for EM energy is that it travels in a straight line and does not bend with the curvature of the earth. Therefore, the height of the antenna and the target are factors in detection range. Radar is unable to detect a target at a range greater than the horizon unless the target is above the horizon or certain atmospheric conditions exist.

105. RADAR PERFORMANCE FACTORS

While the laws of physics govern the basic operation of a radar system, several additional factors affect the performance of a given radar system. These factors include both physical and environmental limitations.

1. EM Horizon

Because EM energy has the same properties as light, it travels in a straight line and does not normally bend or conform to the curvature of the earth. Therefore, the height of both the antenna and the target are factors that affect detection range. The distance to the horizon for a radar system, measured in nautical miles, is referred to as the radar horizon.

The radar horizon is a function of radar antenna height. A target that is beyond the radar horizon cannot be detected unless it is high enough to be above the horizon, or unless certain atmospheric conditions exist.

2. Atmospheric Factors

Particles suspended in the atmosphere can affect EM transmissions. Water droplets and dust particles absorb, scatter, or reflect energy causing less energy to strike the target. This in turn reduces the return signal making the echo smaller. This results in an overall reduction of usable range. Factors that affect the usable range include:

a. Diffusion

b. Scintillation

c. Inversion

d. Attenuation

Diffusion occurs when focused EM energy loses coherency and scatters. This is caused by particles in the atmosphere including moisture such as clouds. Diffusion directly affects the usable range of the radar system.

Scintillation refers to the rapid fluctuation and fading of an EM signal intensity caused by changes in the electron density within the ionosphere. These fluctuations are typically caused by solar winds and magnetic storms. The effects of scintillation are most prevalent near the equator, and may adversely affect Global Positioning System (GPS) navigation and targeting.

Atmospheric inversions typically occur with an increase in altitude when conditions are such that a sharp temperature increase is coupled with a sharp fall in dew point, indicating a fall in humidity. Under these conditions, EM energy can be bent back toward the earth. It can then reflect back from the earth and once again be refracted and return earthward once more. This process of refraction/reflection is known as ducting and can occur multiple times with very little attenuation. The cumulative effect of this long process can result in greatly enhanced reception distances that far exceed the radar horizon.

EM energy traveling through the atmosphere also suffers from the effects of atmospheric attenuation caused primarily by absorption of the energy by gases. This effectively reduces the overall energy and therefore reduces usable range. Attenuation is reasonably predictable at lower frequencies (below 10 GHz), but increases notably at higher frequencies. Additionally, precipitation has a significant effect on attenuation. Attenuation is four times higher in medium rain than drizzle.

As an operator, an in-depth understanding of the above factors is not required. However, a general grasp of their effects is essential in effectively employing a given radar system.

3. Physical Factors

Target resolution is a measure of the ability of a radar system to distinguish between two or more targets in close proximity, either by range or azimuth. Radar cross section (RCS) is a measure of how detectable an object is by radar. RCS does not imply a simple relationship to the physical size of the object (Figure 1-7). However, the larger targets generally have larger radar cross sections. The RCS of a target can be reduced by minimizing surface angles and using radar absorbent materials. It is determined by the following factors:

a. Geometric cross section – the cross sectional area as viewed by the radar

b. Reflectivity – the amount of radar energy that is reradiated by the target (as opposed to absorbed). This is based on the size, shape and composition of the target as well as the aspect angle of radar energy hitting the target and the radar power output.

c. Directivity – the amount of radar power that returns from the target (as opposed to scattering)

As a general rule, metals like steel, aluminum, and titanium are more radar-reflective than carbon fibers, wood or other radar absorbing materials.

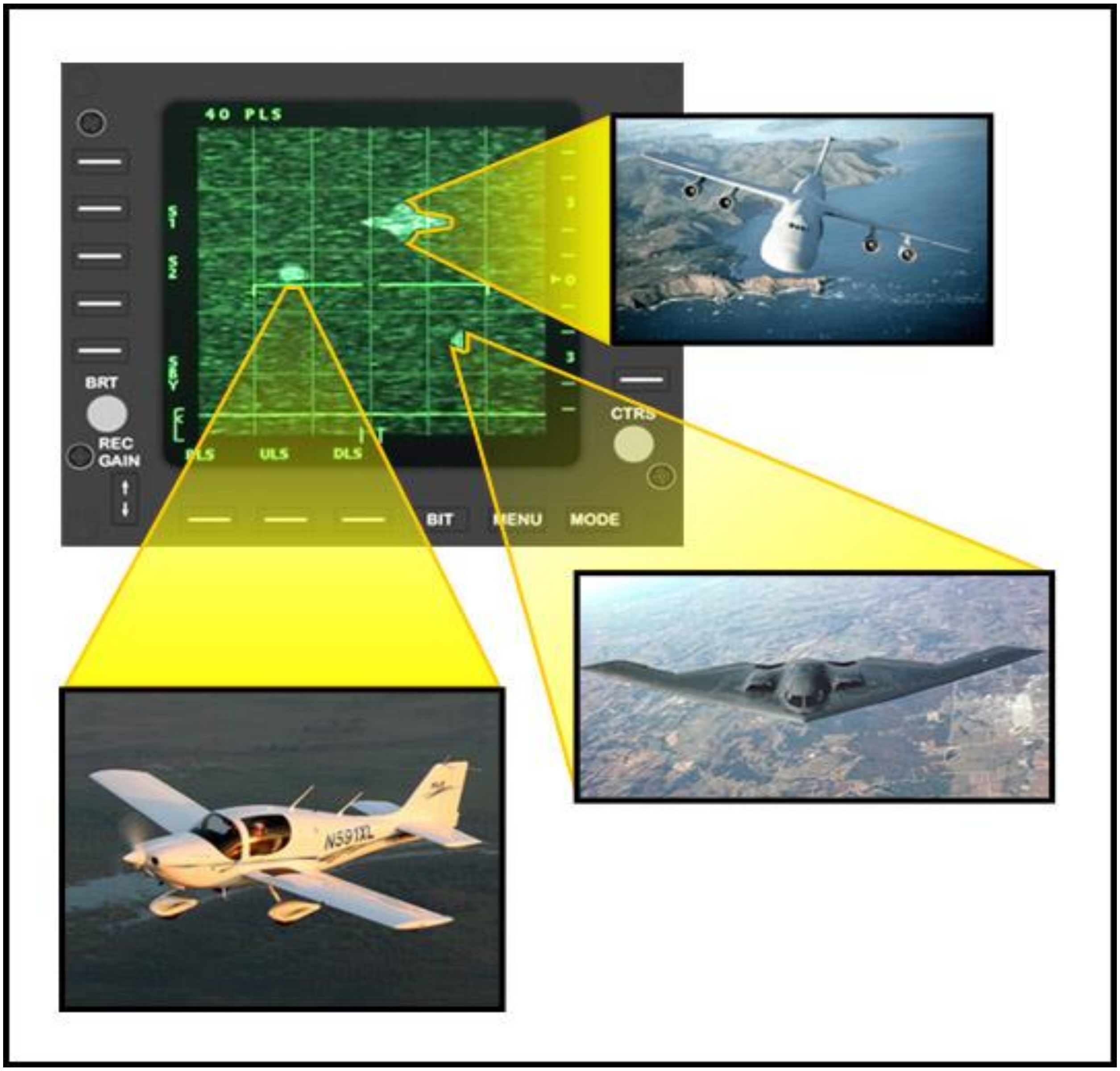

Figure 1-7 Radar Cross-Section Comparison

4. Echo Potential

Echo potential is a measure of the uncontrollable factors that affect the ability of an object to reflect RF energy. Similar to those factors that affect reflectivity, factors affecting echo potential include:

a. Size – Larger objects tend to be more reflective

b. Shape – Blunt, flat objects tend to reflect more energy than narrow, flat objects

c. Composition – Radar absorbing materials intuitively have a lower echo potential than materials that are radar reflective

d. Environment – A target standing alone in a field has a higher echo potential than a target surrounded by other radar reflective objects

When planning a radar aided navigation mission or target ingress, it is advantageous to understand the echo potential of geographical features and objects along the route as well as the target.

106. RADAR COMPONENTS

Although there are many different applications for radar, all radar systems share a common fundamental design and can be broken down into six main components. Maintenance personnel refer to these components as Line Replaceable Units (LRUs), with each component serving a distinct role.

a. Power Supply

b. Transmitter

c. Antenna

d. Receiver

e. Signal Data Processor

f. Display

1. Power Supply

The power supply provides high voltage power output for beam generation and transmission. Additionally, it provides low voltage power output to the radar system components and displays. The power supply is the electrical power generation source allowing each component of the radar system to functionally operate.

Power output is usually referred to in one of two ways:

a. Peak Power

b. Average Power

Peak Power is a term used to describe the maximum power reached during the pulse width. The amount of power radiated, averaged over the pulse repetition time (PRT) is the Average Power. The duty cycle is the fraction of time the transmitter is actually “firing.” Duty cycle is also a function of average power divided by peak power:

Duty Cycle = PW / PRT

Low average power is desirable as it allows for smaller size and lighter weight radar. High peak power is desirable for producing strong echoes. Therefore, it is advantageous to have a low duty cycle radar in an aircraft:

Low Duty Cycle = Low Average Power / High Peak Power

2. Transmitter

The transmitter generates the RF energy pulses. These pulses are transmitted at precise intervals and are routed to the antenna. Additionally, the transmitter ensures the formed pulse adheres to prescribed characteristics to include power level, pulse length, pulse width and frequency.

3. Antenna

Radar antennas radiate EM pulses from the transmitter, transmit and receive radar signals, concentrate and focus energy in specified directions of free space and scan the horizontal and vertical planes. Four basic types of radar antennas accomplish all of these tasks in varying degrees:

a. Omni directional – antennas that transmit energy in 360 degrees; they do not direct energy in specified areas. Examples are CB radio, cell phones, ship antennas used for voice and data communications

b. Parabolic – antennas in the shape of a parabolic dish that focus energy in one direction. These antennas are used by early era fighter aircraft, surface based weapons systems and fire control radar systems. Scan patterns for these antennas are accomplished by physically moving the dish through the scan pattern.

c. Planar array – a somewhat advanced antenna system composed of smaller antennas working in combination to form the beam. Shaped like a flat plane, these antennas provide highly directed beams with low sidelobes and greatly improved power/efficiency compared to parabolic antennas. Antenna is physically moved to accomplish the scan pattern. Information is displayed on a PPI or B-Scope (discussed below).

d. Phased array – antenna system composed of smaller antennas like the planar array, but phased array uses an electronic scan whereas the planar uses a mechanical scan.

The military is leaning heavily toward the phased array radar when possible. Phased array can provide nearly instantaneous update rates, while using simultaneous modes of operation. They increase the power output efficiency by reducing the effect of sidelobes (stray/scattered radar energy off the main lobe or beam). They also reduce sidelobe loss from the main beam, which can be up to 25 percent of the total radiated power in other antenna types.

4. Scan Patterns

Depending on the type of radar and its use, different scan patterns are utilized. Radars such as surface and air search use a 360 degree circular scan in which the antenna is physically rotated to maintain adequate coverage within the dimensions specified by the radar beam width. While they provide 360 degrees of coverage, a limitation of circular scans is that they produce a blank area at the center of a radar tube presentation. This is analogous to the cone of confusion associated with TACAN stations. When a circular scan radar is mounted on an airborne platform, the blank area seen on display is called the altitude hole (Figure 1-8). The center of this blank area represents the point on the ground immediately below the aircraft. At low altitude, the altitude hole is relatively small, but at mid and high altitude, it is significant.

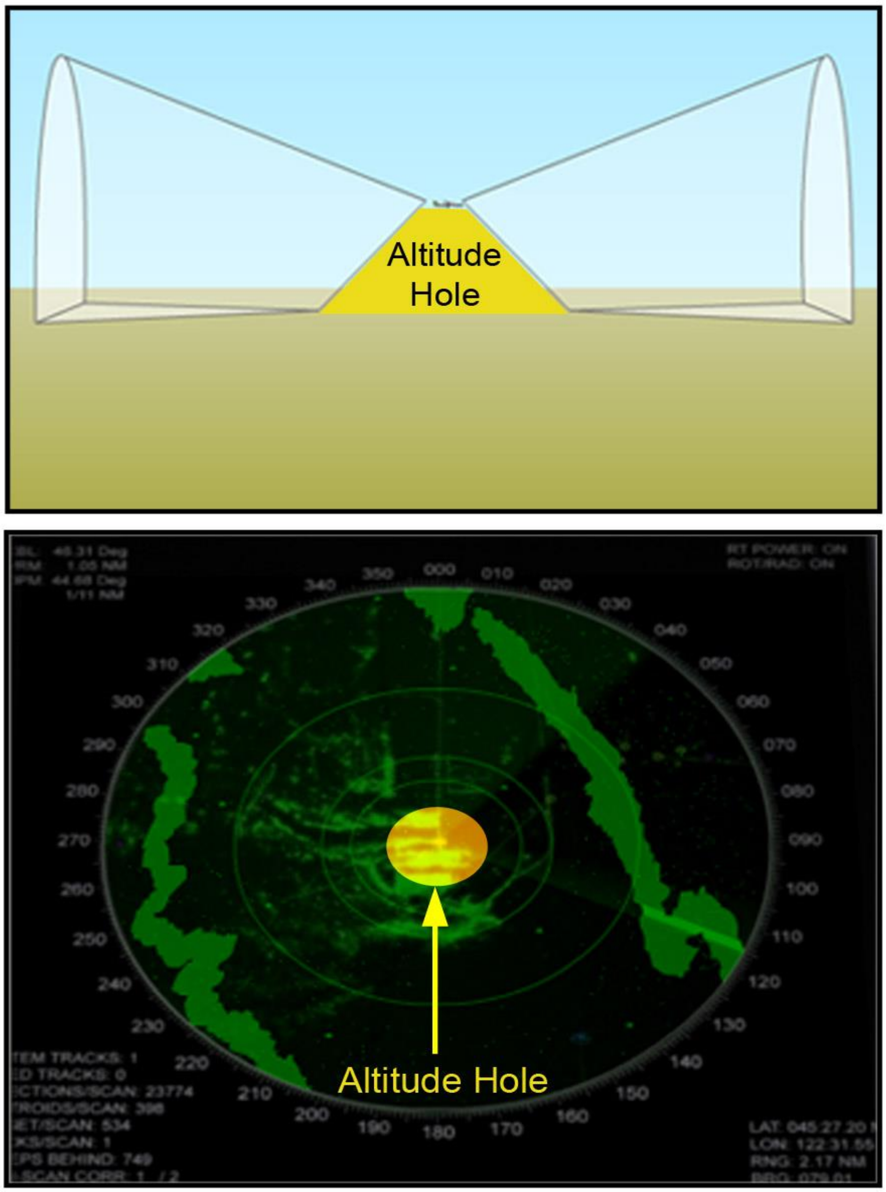

Figure 1-8 Altitude Hole with 360-Degree Scan

Fire control and airborne radars employ a bar scan movement to alter the elevation angle of the antenna. As the number of bars increases, the elevation of the radar beam increases. One bar is the simplest and most common; the radar searches at a constant elevation unless the antenna angle is manually changed by the aircrew. Multibar scan allows the radar to change elevation with every sweep in a set pattern (Figure 1-9). There is no altitude hole with this type of A/A radar.

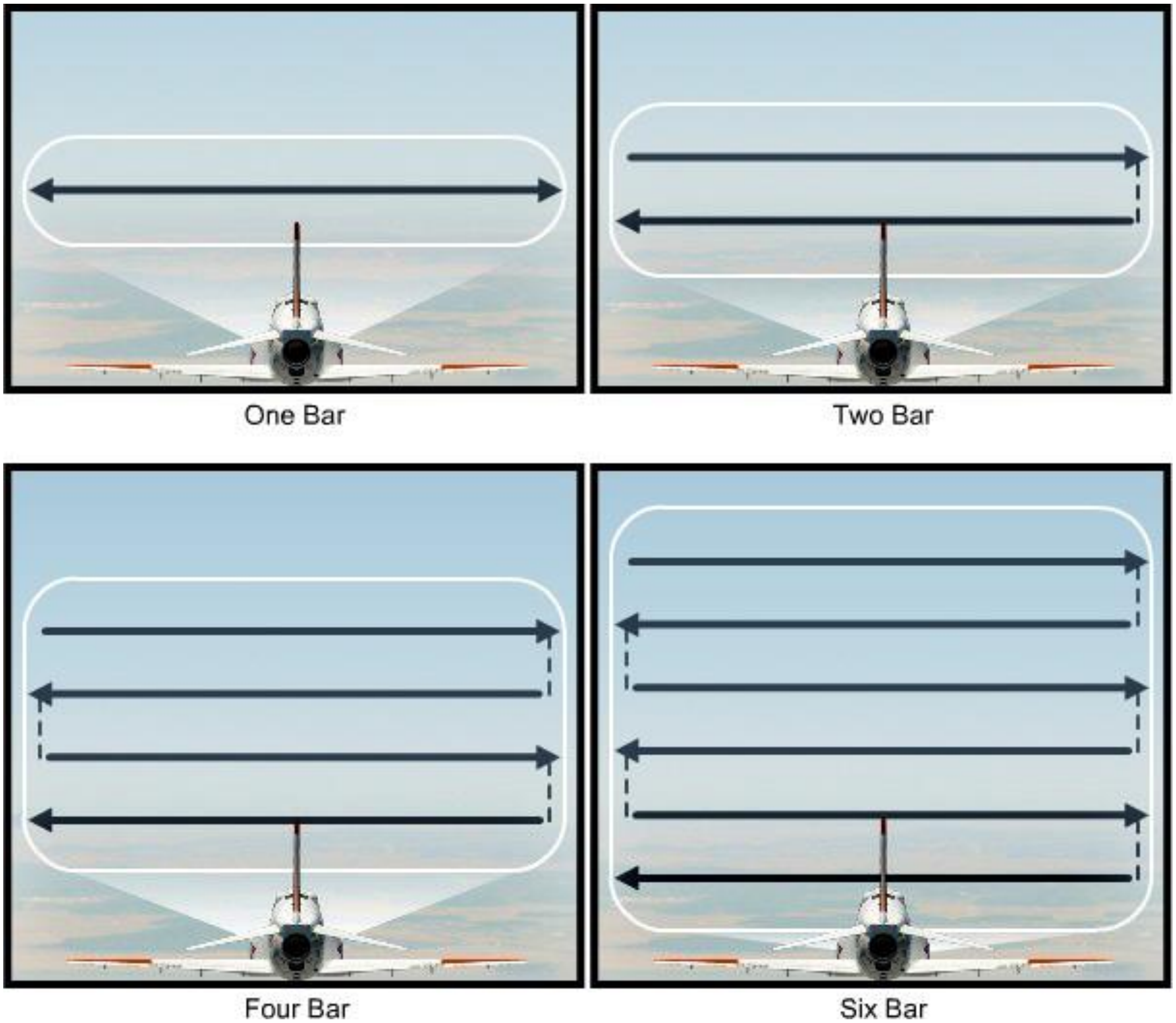

Figure 1-9 Multibar Scan Pattern

5. Receiver

The receiver receives routed RF wave energy (echoes and returns) from the antenna and converts this energy into data (video) pulses for relay to the signal data processor (SDP). The receiver also distinguishes valid returns from noise.

6. Signal Data Processor (SDP)

The SDP is considered the brains of the radar system. SDP functions include:

a. Serves as a communication link between radar components

b. Synchronizes transmitted and received signals

c. Determines which signals are valid

d. Sends information to the Multi-Function Color Display (MFCD) (radar scope) for display

7. Radar Displays

The radar display takes the video signals sent from the Signal Data Processor (SDP) and converts them into visible graphic text. This allows for an interface between the operator and the radar system. There are many different types of radar displays:

a. A scope

b. B scope

c. C scope

d. Plan position indicator (PPI)

e. Sector PPI

f. Patch map

8. A, B, and C Scopes

Figure 1-10 shows simple A scope, B scope, and C scope display formats. The A scope display presents only contact range and relative strength of the echo. Although it is the simplest of all the displays, it is not widely used because it lacks azimuth information.

The B scope is widely used in fighter aircraft because it displays both range and azimuth information for contacts.

The C scope displays target azimuth and elevation. This is useful in pursuit attack because the display corresponds to the pilot's view through the windscreen. For that reason, C scope presentations are often projected onto the windshield Head-Up Display (HUD).

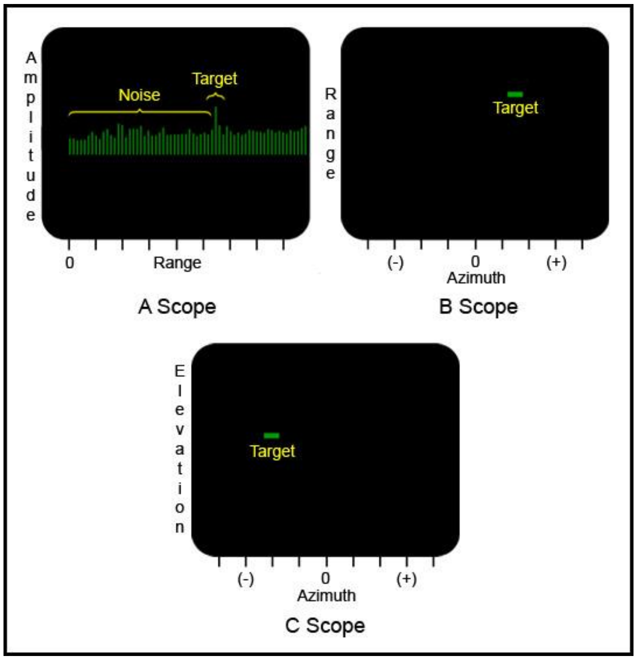

Figure 1-10 A Scope, B Scope, and C Scope

The B scope is used for the VMTS air-to-air radar display (Figure 1-11). The right side of the display depicts the range of the target from the aircraft nose; the range is aircrew selectable. The horizontal bottom of the display represents the nose of the aircraft, with contacts displayed in azimuth left or right of the nose. The azimuth scale is also aircrew selectable.

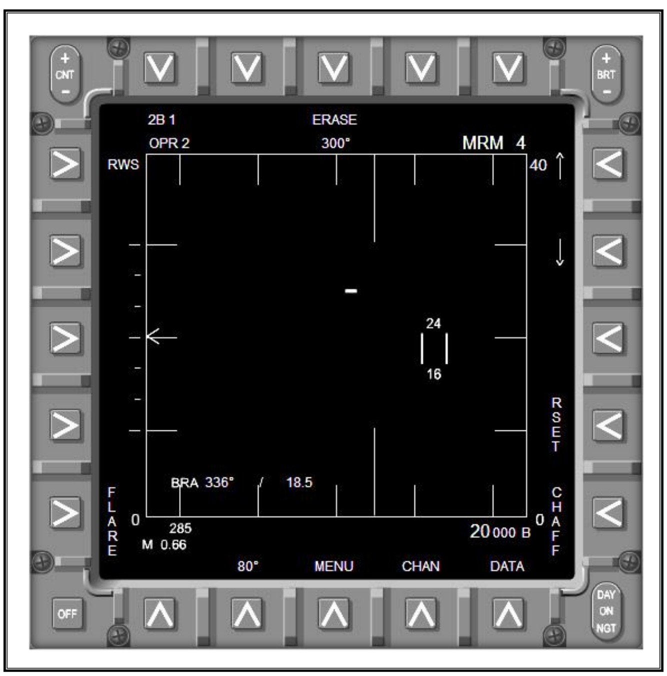

Figure 1-11 B Scope Radar Display (Azimuth Vs. Range)

9. Plan Position Indicator

The Plan Position Indicator (PPI) display is the most commonly used display format. It is a polar coordinate display of the area surrounding the radar platform. Ownship position is represented as the origin of the sweep, which is normally the center of the display. PPI uses a radial sweep pivoting about the center of the presentation. This results in a map-like picture of the area covered by the radar beam. The PPI has a long persistence screen so that the display remains visible until updated with the sweep.

The sector PPI display gives an undistorted picture of a sector the radar is scanning. Sector ground mapping radars typically use this type of display. A sector PPI display will be used in VMTS when in air-to-ground mode, simulating a ground mapping radar. Figure 1-12 illustrates the PPI and Sector PPI radar displays.

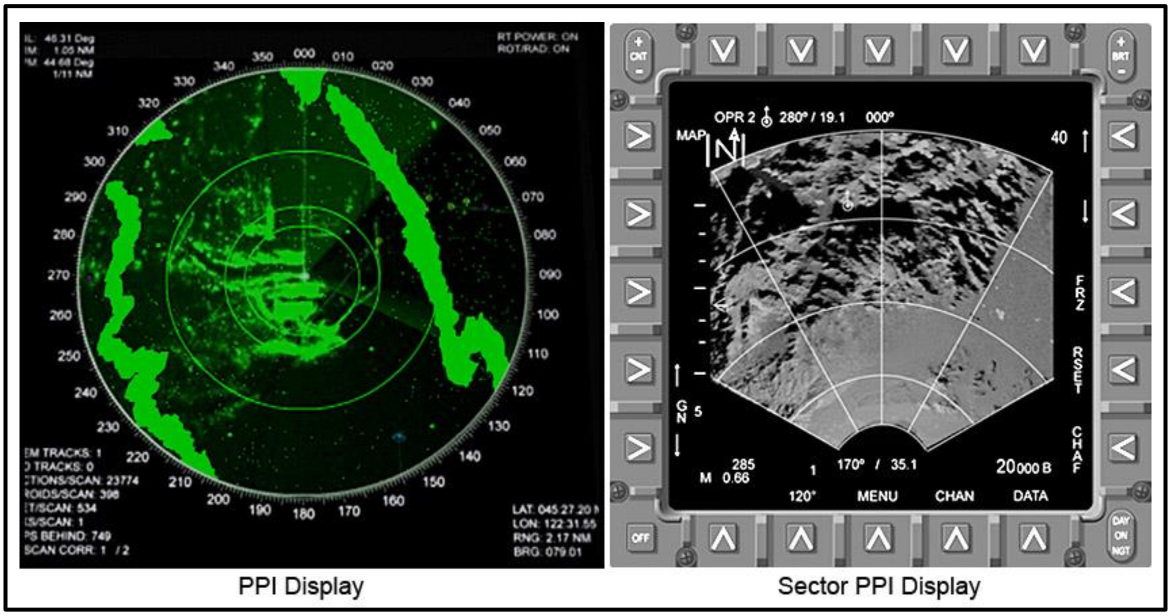

Figure 1-12 PPI Display and Sector PPI Display

Airborne ground mapping radars have an altitude hole that can be compared to a TACAN/DME "cone of confusion." Altitude hole is a function of altitude and slant range. If an aircraft is at 12,000 feet, the hole would be 2NM (12,000/6,000). The altitude hole can be seen at the bottom center of the MFCD in the T-45 Real Beam Ground Map (RBGM) (Figure 1-12 Sector PPI).

10. Synthetic Aperture Radar (SAR)

Patch map radar displays a detailed map of a specific area at a given range and azimuth. High resolution Synthetic Aperture Radar (SAR) typically uses a patch map display (Figure 1-13).

Figure 1-13 Patch Map

SAR is a type of high-resolution radar used for ground mapping; it takes advantage of the aircraft's forward velocity by sending out multiple pulses. Each time the antenna transmits a pulse, the aircraft has progressively moved forward along the flight path. The aircraft's onboard computer compiles the multiple radar images, which effectively produces a synthesized image of the area. These high resolution images are used for precise radar targeting. Air-to-ground SAR applications include:

a. Doppler beam sharpening (DBS) – provides fine resolution of a target area by using an extremely narrow beam (target acquisition)

b. Ground moving target indicator (GMTI) – displays moving target information

c. Terrain Avoidance (TA) – specialized radar mode used to maintain a constant altitude when flying low

d. SAR strip map and SAR spot map provide high resolution images used for precise radar targeting

11. Inverse Synthetic Aperture Radar (ISAR)

ISAR uses the motion of an object to develop an image. It detects minor variations in a moving target and uses an algorithm to generate an image. Aircrews typically employ ISAR systems for long range imaging and identification of moving targets, especially on ships and surfaced submarines. Radar image quality is often sufficient enough to distinguish between various missiles and aircraft types. Figure 1-14 shows an ISAR radar image and its corresponding target.

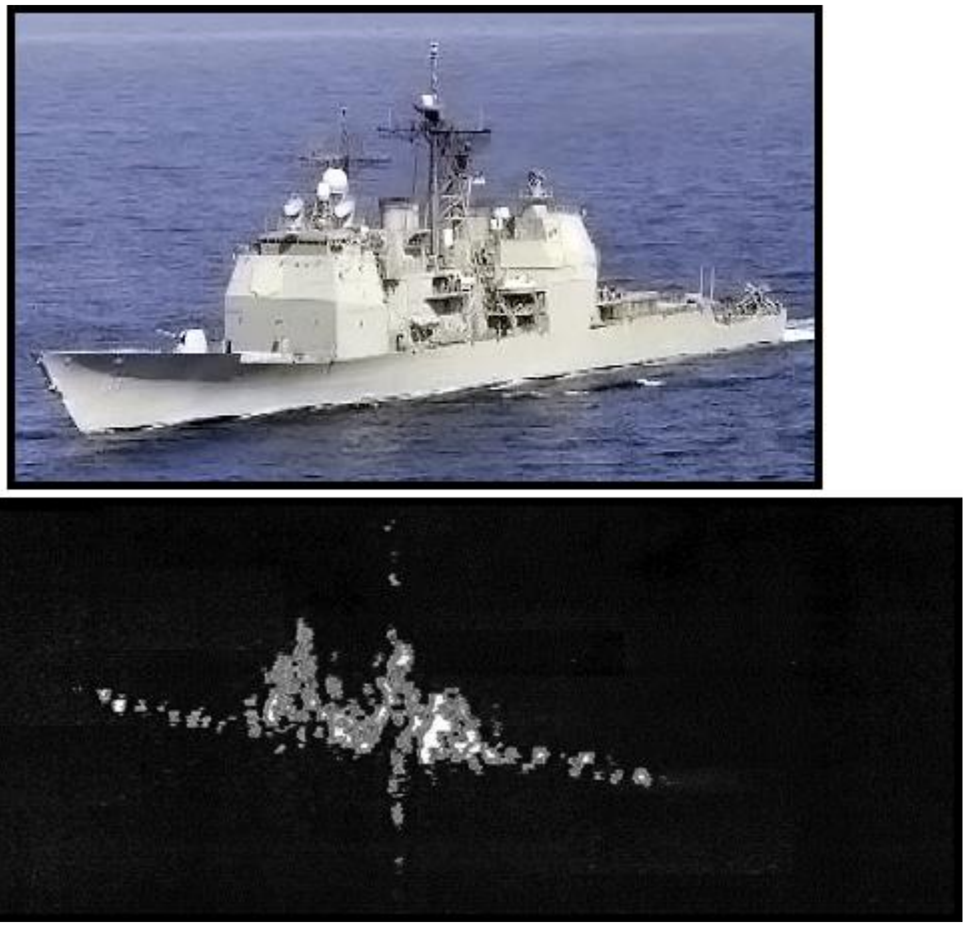

Figure 1-14 ISAR Image

CHAPTER TWO
T-45C VIRTUAL MISSION TRAINING SYSTEM AND 2F205 OPERATIONAL FLIGHT TRAINER (OFT) RADAR SYSTEMS

200. INTRODUCTION

The purpose of the T-45C Virtual Mission Training System (VMTS) is to expose Student Naval Flight Officers (SNFOs) to the previously described concepts and to more effectively train them in the use of air-to-ground (A/G) and air-to-air (A/A) radar operations and simulated weapons employment. This is accomplished through a system that emulates a mechanically scanned radar system such as the APG-73, which is found in most F/A-18F Super Hornets. VMTS is not an actual aircraft radar transmitting system. Rather, it is a simulation of a radar transmitting system.

The Operational Flight Trainer (OFT), device 2F205, provides additional functionality and capability to supplement flight training in VMTS. Although both systems function in a very similar manner, the OFT provides additional capabilities in both A/A and A/G training.

201. VIRTUAL MISSION TRAINING SYSTEM (VMTS) OVERVIEW

The T-45C VMTS supports realistic training in sensor management and control, weapons employment, situational awareness, aircrew workload, command & control, and crew resource management. VMTS supports both stand-alone internal aircraft training against virtual targets as well as cooperative multi‒participant external training with one or more VMTS aircraft and one or more VMTS Instructor Ground Station (IGS). The IGS can be used to simulate air intercept control (AIC) as well as to uplink and control virtual targets displayed on the VMTS radar attack display.

The T‒45C VMTS provides onboard simulation of a multi-mode, coherent, X‒band, fire control radar capable of employing either a high, medium or interleaved medium/high pulse‒repetition frequency (PRF). The radar antenna models a mechanically scanned antenna with a 3.2° beam width, mounted on 70° gimbals and capable of scanning at 65°‒75° per second depending on mode. The radar models performance effects from natural phenomena such as range attenuation, atmospheric attenuation, horizon effects, target scintillation and occulting, ground return clutter, beam shadowing, far shore brightening, system noise and antenna scan instability. The radar also models A/A detection and tracking performance based on assignable target Radar Cross Section (RCS) profiles, which vary dynamically with target aspect angles. VMTS also provides for simulation of A/A medium range and short range missiles (MRM and SRM, respectively).

VMTS integrates stored data and algorithms with internally generated or externally linked threat data in order to emulate tactical radar and radar warning sensor presentations. Surface and air threats can be uplinked to the VMTS aircraft from the IGS or created and modified in the cockpit. Simulated radar warning receiver threat indications are displayed on a situational awareness display in the cockpit MFCD via the VMTS situational awareness (SA) page. A complete discussion of VMTS operation in the T-45C aircraft can be found in the T-45 NATOPS.

There are five training mission scenarios, or use cases, for which VMTS can be used to train. These are:

a. Case 1 – Stand-alone, single-ship intercepts versus on-board generated virtual targets

b. Case 2 – Single-ship, networked, intercepts against another VMTS equipped aircraft

c. Case 3 – Single-ship, networked intercepts using the IGS to generate virtual targets

d. Case 4 – Multi-ship, networked intercepts using IGS(s) generated virtual targets

e. Case 5 – Stand-alone, single-ship, A/G radar operations

The VMTS system will provide an airborne virtual radar environment that supports training of:

a. Radar Mechanics

b. SNFO workload

c. Situational Awareness

d. Sensor Management

e. CRM

These training objectives are accomplished through planned mission scenarios designed to train to more than one of these tasks, simultaneously.

1. VMTS Equipment and Installation

VMTS installation in the T-45C requires the addition of component hardware in the aircraft, consisting of a processor, data link module, antenna, and installation of in-cockpit Hands On Throttle And Stick (HOTAS) controls, including a Radar Hand Controller (RHC) in the aft cockpit. Figure 2-1 illustrates the location of the associated VMTS hardware mounted in the aircraft other than cockpit modifications.

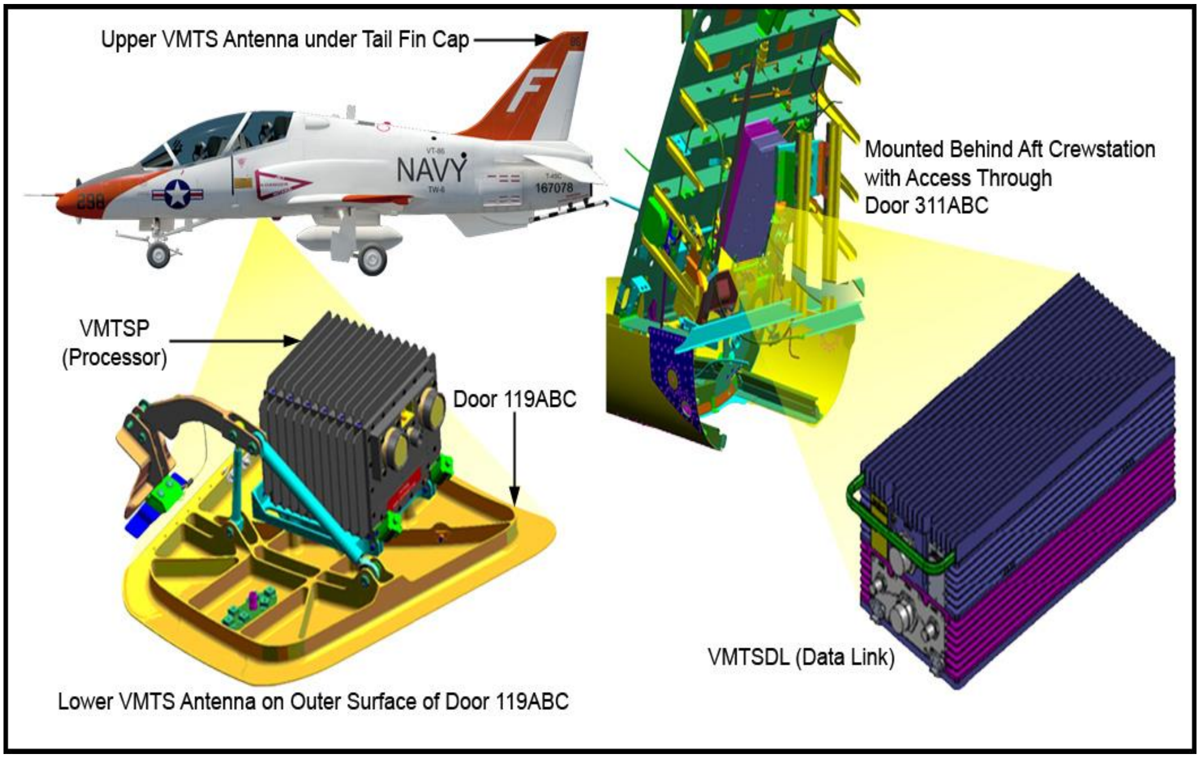

Figure 2-1 VMTS Hardware Installation

The installed aircraft hardware performs the following functions

a. VMTS Processor (VMTSP). The VMTS Processor (VMTSP) hosts radar/threat/weapon performance models, performs all VMTS calculations, processes all VMTS commands, outputs all VMTS subsystem information, and generates the radar video for display on an MFCD. The VMTSP also stores the Virtual Target and Surface Threat (VTST) database that contains pre−planned virtual air and surface threat profiles, a configuration file that contains pre−planned default values for pop−surface threat profiles, and the virtual terrain database for use with the A/G radar. To provide quick access, only VTST data is transferred to Mission Data Processor (MDP) memory after aircraft start-up.

b. VMTS Datalink (VMTSDL). The VMTS Datalink (VMTSDL) provides L−band RF datalink communication to exchange essential VMTS data at ranges of 60 NM or more between aircraft and of 100 NM or more between aircraft and IGS. The VMTS supports multiple networks operating to within 1 NM of separation without degradation from mutual interference. Essential VMTS data consists of member ID, position and velocity data, radar simulation selections and statuses, and VMTS subsystem selections and statuses. The VMTSDL operating frequency band is restricted automatically in order to protect aircraft GPS signal reception, which also occurs in the L−band.

c. VMTS HOTAS Controls. VMTS HOTAS controls consist of a modified throttle grip with new control switches, new functions adapted from the existing control stick switches, and a new RHC in the aft cockpit. Radar related HOTAS functions are only available when the VMTS Radar display is selected. Refer to NATOPS for complete descriptions of additional HOTAS functionality.

The aircraft hardware communicates with an IGS via data link. The IGS provides VMTS mission monitoring capabilities and support generation of virtual targets and threats.

2. VMTS Integration

The VMTS system is fully integrated with the T-45C and uses data and functions present in existing T-45C subsystems:

a. VMTS uses a Digital Video Recorder/Processor (DVRP) in place of a Video Cassette Recorder (VCR) to record time-tagged data for post-flight mission analysis. Recorded data includes cockpit audio, video, and simulated sensor and threat information.

b. VMTS requires accurate GPS position, velocity and time data from the GPS/Inertial Navigation Assembly (GINA) in each participating aircraft in order to accurately correlate cockpit A/A radar cues to actual out−of−the−window aircraft positions, and to correctly position A/G terrain data relative to the actual ownship location. VMTS also requires accurate time updated by GPS time signals in all participating aircraft in order to synchronize datalink messages.

c. VMTS integrates new Radar Warning Receiver (RWR) aural alert tones with existing TACAN, ILS and UHF tones in the aircraft Intercommunication System (ICS), controlled by a single RCVR master volume control.

3. VMTS Radar Modes of Operation

The radar operates in either A/A or A/G modes, with A/A radar available in A/A and NAV master modes and A/G radar available in A/G and NAV master modes.

a. The A/A radar supports:

i. Training of target search, acquisition, track and attack via realistic presentations of target returns supported modes include:

(a). Range While Search (RWS)

(b). Velocity Search (VS)

(c). Track While Scan (TWS)

(d). Single Target Track (STT)

(e). Air Combat Maneuvering (ACM) Wide Acquisition (WACQ)

(f). ACM Boresight (BST)

(g). ACM Vertical Acquisition (VACQ)

ii. Simulated weapons with SRMs, MRMs and A/A gun functions

iii. Virtual Target (VT) presentations using stored, internal performance algorithms or accepting VT presentation from external sources. Standalone training is supported by internal VT presentations or from IGS inputs. Cooperative training is supported by any mix of real aircraft and external VT presentations.

b. The A/G radar supports training of basic tactical ingress and egress navigation via realistic presentations of Real−Beam Ground Map (RBGM) terrain returns generated using an internal digital terrain database with material−specific definitions. A/G weapon modes are limited to those of the T-45C aircraft.

4. VMTS Electronic Warfare (EW) Operation

The VMTS RWR simulation models all-aspect detection of generic air and Surface Threat (ST) emitters with fixed antenna patterns and simple critical in-range signal strength models. Critical threat locks are cued in bearing and range, when available, by a combination of aural and display alerts. For air threats, locks are initiated during internal training by manual cockpit selections, or during external training either by manual ground instructor selections or real aircraft radar selections that are datalinked to the ownship.

For surface threats, locks are initiated during internal training either by manual cockpit selections or by penetration of pre−planned threat rings, and during external training by manual ground instructor selections that are datalinked to the ownship.

VMTS RWR indications are displayed on the SA page with a direction-of-arrival (DOA) strobe and a threat symbol. The SA display combines the functionality of the EW display and the Horizontal Situation Indicator (HSI) into a common display. The VMTS SA display is very similar to those currently in use in the F/A-18 and is shown in Figure 2-2. RWR aural alert volume may not always be at the same volume as the wheels−up warning alert. An air radar RWR alert consists of a 555 Hz tone alternating on and off each for 0.08 seconds in duration. A surface emitter RWR alert consists of alternating 455 Hz and 555.

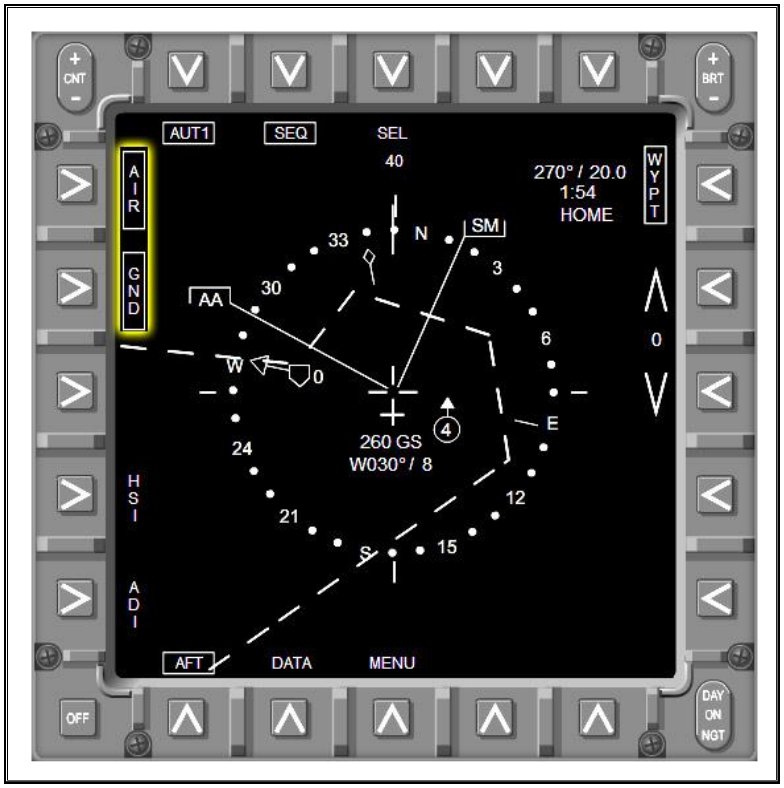

Figure 2-2 VMTS SA Display

As shown, the fighter has waypoint steering information, sequence information, auto sequence option and range selection options as in the HSI. As with the OFT, either AIR or GND can be boxed to select the desired threat warning type. VMTS EW symbols are simplified and shown below in Figure 2-3.

Symbol	Meaning
┌┐	Air Threat
└┘	Ground Threat

Symbol	Meaning
AA	Air Threat (any range)
SL	Surface Long (>25NM <40NM)
SM	Surface Medium (>10NM <25NM)
SS	Surface Short (<10NM)
U	Unknown Emitter

Figure 2-3 VMTS EW Threat Symbology

The SA display allows the fighter to reference one display for route/area management, waypoint steering, GEOREF and EW information, making it a much better display than the HSI or EW display during an intercept. The only disadvantage of the SA page is that chaff cannot be dispensed from the SA page. This must be done from the attack display.

VMTS EW operation differs from the OFT. In the VMTS:

a. Air threats:

i. Top four priority air threats are displayed

ii. Only lethal threats are displayed (AI/STT Lock)

iii. Steady threat symbol and DOA strobe

iv. The Air Long threat symbol is AA (vice AL as in the OFT)

b. Ground threats:

i. Top five priority surface threats are displayed

ii. Only critical threats are displayed (Missile Launch)

iii. Flashing threat symbol and DOA strobe (SS, SM, SL)

202. VMTS INITIALIZATION

In order to use the VMTS, it must first be formatted and initialized.

1. VMTS MFCD Menu Options

For VMTS Menu options include (Figure 2-4):

a. STRS – stores format (SRM and MRM types)

b. BIT – built-in test display

c. TRNG – training format for addition of RDR degrade sublevel

d. VMTS – VMTS data link control format

e. SA – situational awareness format

f. RDR – radar format selection, which is crossed out if VMTS is OFF or degraded

g. INST – instructor format selection, which is crossed out if VMTS is OFF or degraded

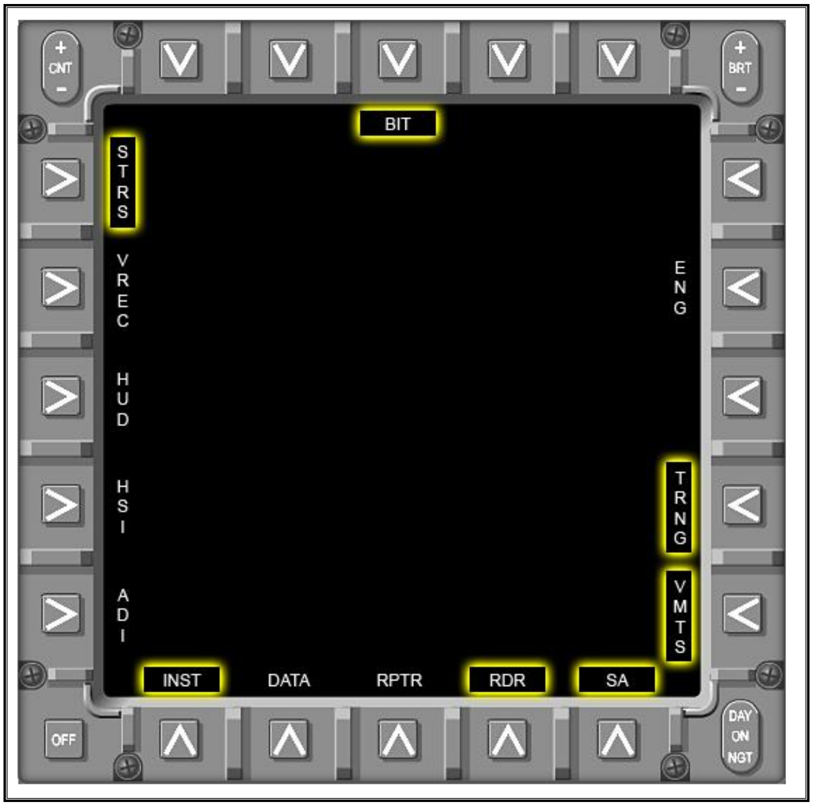

Figure 2-4 VMTS Menu Format Selection

2. Power Controls and BIT Status

   a. VMTP PWR – option controls the power to the VMTSP (processor)

      i. Initializes unpowered

      ii. “Box” PWR (PB 19) to power up VMTSP (Figure 2-5)

   b. DL PWR – option controls power to the VMTSDL (data link)

      i. Displayed when VMTSP powered and communicating with MDP

      ii. Power “boxed” (PB 17) when VMTSDL powered

   c. BIT (Built in Test) status reported by WRA for VMTSP and VMTSDL

      i. VMTSP – initially blanked 30 seconds after power up

      ii. VMTSDL – initially blanked 45 seconds after power up

      iii. Also available with weight-off-wheels

AUTO option – initiates the automated IBIT, which commands concurrent BITs of:

d. MDP

e. GINA

f. ADR

g. DVRP

h. MDL

i. VMTS (both VMTSP and VMTSDL)

j. RALT

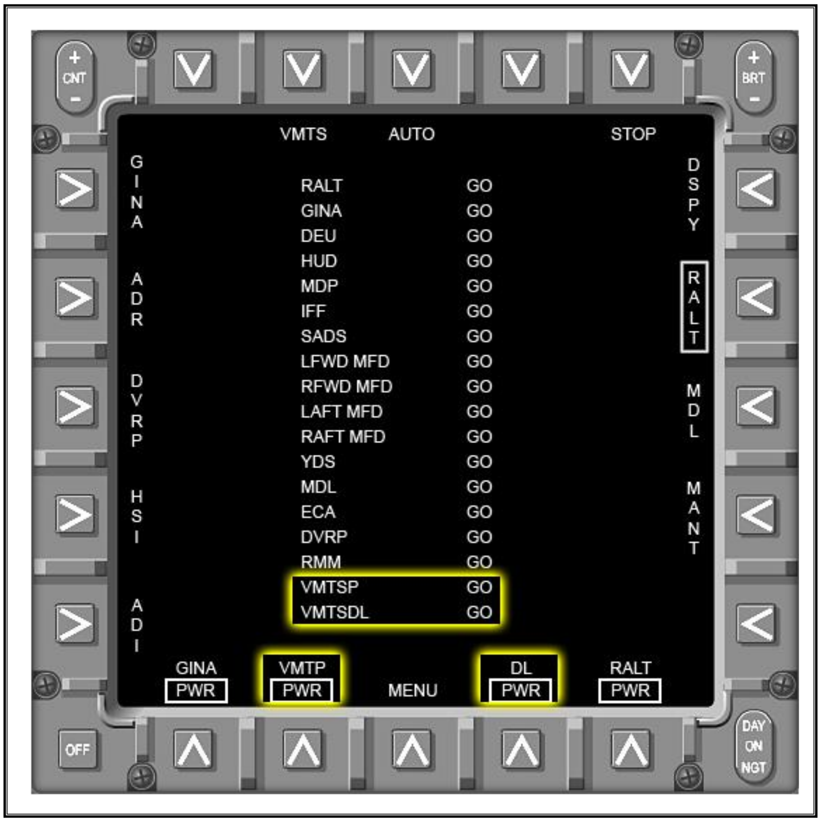

Figure 2-5 BIT Page, VMTS Power Controls, and BIT Status

3. IBIT

Selecting the VMTS option commands the VMTSP into IBIT. The VMTSP commands the VMTSDL IBIT as long as VMTSDL is powered up. A video test pattern will be displayed on the RADAR page if selected. Selecting STOP will halt the IBIT in progress. Aircrew should command a VMTS BIT (PB 7) after VMTSP and VMTSDL BIT are initially powered up (BIT GO). The initial Power up BIT does not BIT the entire VMTS system. Aircrew need to be familiar with the BIT status of the system. The following acronyms, listed in priority order, may be displayed for VMTSP status:

a. OFF – Equipment not powered on

b. IN TEST – Equipment is in test

c. OVRHT – Equipment overheat is detected

d. DEGD

    i. BIT failure

    ii. No response on either bus within 30 seconds of power up

    iii. Loss of communication after power up

    iv. Shutdown due to overheat

e. DEG AUDIO – VMTSP audio card failure (RWR audio output failure)

f. OPGO – Equipment responding on only one 1553 bus and no other BIT failure indications

g. GO – Equipment operating normally

The following acronyms may be encountered with VMTSDL status:

a. OFF – Equipment not powered on

b. IN TEST – Equipment in test

c. DLCOM – VMTSDL not communicating with VMTSP after 45 second power up

d. OVRHT – Equipment overheat detected

e. DEGD – Displayed in the event of:

    i. BIT failure

    ii. No communications with VMTSP and no IN TEST

    iii. Shutdown due to overheat

f. DEGD PPS – PPS not available as required (UTC valid)

g. DEGD ANT – Both antennas failed

h. DEGD ANT 1 – Lower antenna failed

i. DEGD ANT 2 – Upper antenna failed

j. GO – Equipment operating normally

In addition to appearing on the BIT display status, a system malfunction will also be displayed as either a VMTSP or VMTSDL cue in the MFCD (Figure 2-6). VMTSP indicates a degrade, overheat, or audio degrade while VMTSDL indicates a degrade or overheat. The Advisory Window will continue to display until the condition/malfunction is corrected or REJ (PB15) is selected. Advisories will not be displayed on the HUD.

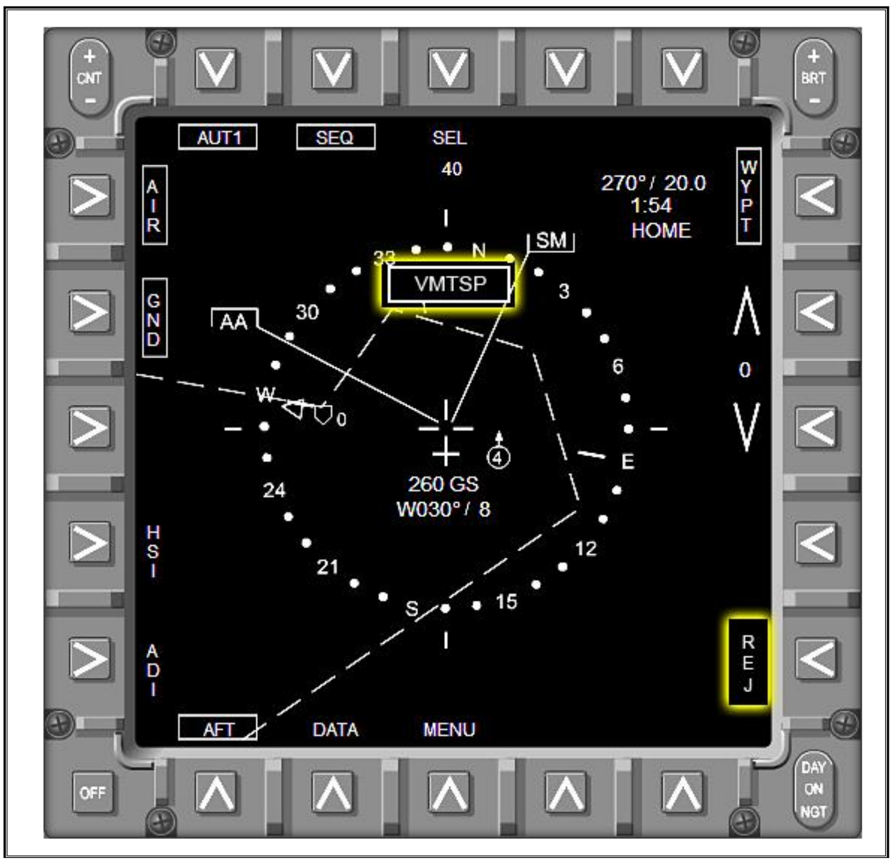

Figure 2-6 MFCD VMTS Advisory Window

The radar training sublevel display provides instructors the ability to induce typical fundamental radar failures into the VMTS simulated radar which impact radar performance and display cueing. These failures include (Figure 2-7):

a. Mode failure

b. Channel failure

c. Transmitter failure (TX)

d. Receiver failure (RX)

e. Antenna failure

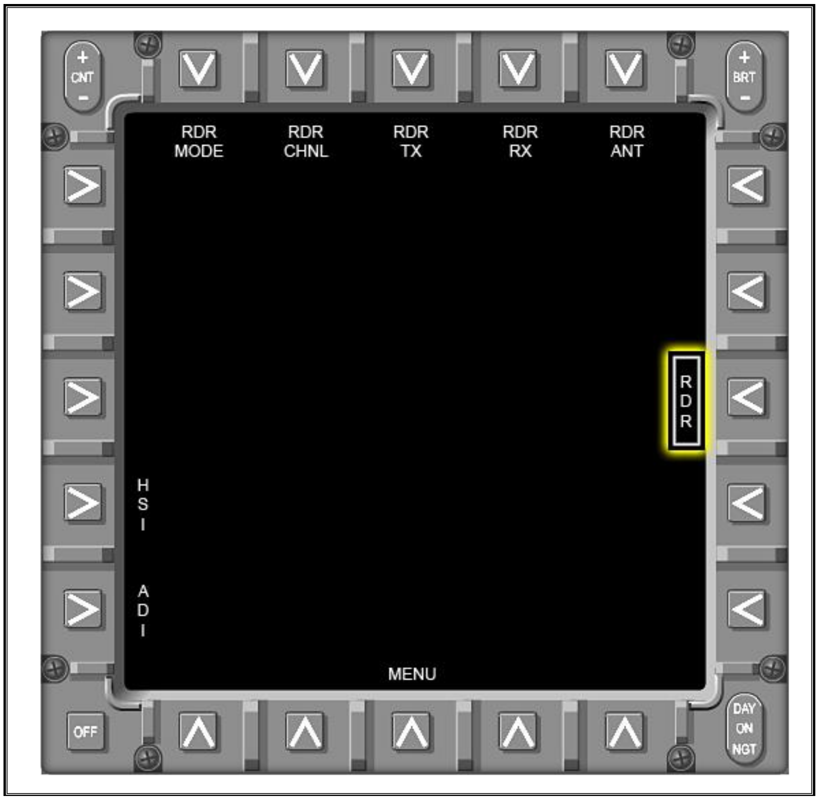

Figure 2-7 Radar Training Sublevel Display/Failure Options

4. VMTS Initialization

After startup, with the generator on line, the following steps are performed to power up the radar:

a. Select (box) VMTSP PWR and VMTSDL PWR via the BIT page

b. Perform VMTS preflight checks and verify operational status is GO for VMTSP and DL

i. When operating within a VMTS network, confirm A/C D/L communication with other network members on the D/L display

c. Verify correct VMTS database configuration

d. Select RDR option from the MENU format and observe the following:

i. Radar data sublevel is directly displayed (Figure 2-8)

ii. Radar simulation initializes OFF

iii. No transition through top level

iv. No DATA option/selection box

v. No RDR related options or cues (A/A scales and grids only)

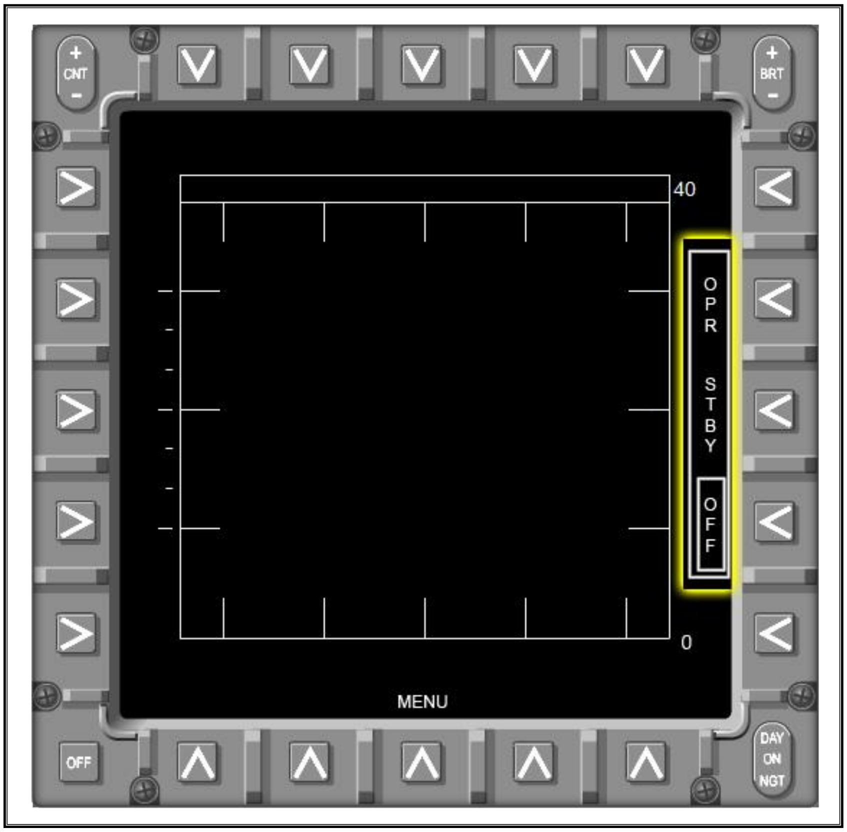

Figure 2-8 VMTS Radar Initialization

e. Select radar power to operate (OPR)

f. Run radar IBIT and confirm radar preflight status

g. Set up initial radar operating parameters and master mode as required

h. Set up sequence for route (A/G event as required)

i. Select SIM mode from Stores page for simulated weapons employment

5. VMTS Radar Default Initialization Parameters

Upon selection of OPR, the radar switches from off to operate based upon the Master mode selected:

a. NAV master mode defaults to RWS, MRM

b. A/G master mode defaults to RBGM

c. A/A master mode defaults to RWS with selected weapon (or MRM default)

203. OFT SYSTEM OVERVIEW

The device 2F205 operational flight trainer, or OFT, is designed to incorporate radar training system with enhanced capabilities over those in VMTS into a fully functional T-45C simulator. The 2F205 consists of an Operational Flight Trainer (OFT) and a Debrief System. The OFT provides training to students in the fundamentals of aviation, navigation, communication, systems function and management, crew resource management, radar system employment and leadership. The OFT supports learning objectives related to cockpit procedures/checklists including normal and emergency procedures of aircraft systems, controls, and instruments, communication, navigation, and instrument flight procedures.

1. OFT Stations

The OFT consists of a student station, observer station and instructor operating station (IOS). The SNFO should note the following about each location.

a. Student Station – includes simulator control panel for control of the simulation and a Handheld Controller used to control the IOS when an instructor is not present.

b. Instructor Operating Station – Includes two seats and five monitors to support simulator operations with one or two instructors. The five screens are:

i. Switch repeater monitor – displays cockpit indications and forward cockpit switches not accessible from the student station rear cockpit. Student Station switch movements are indicated by a momentary green box around the affected switch.

ii. Instructor Monitor – provides interaction with IOS applications to control the simulation. It also provides 2D and 3D map views as well as control of weather, lighting and other scenario effects. Weapon reload is accomplished through this interface.

iii. Out the Window (OTW)/HUD monitor – displays a Head-Up Display (HUD) overlaid on an Out-the-Window (OTW) view, providing the instructor an additional means to fly the Ownship.

iv. Touch Screen Monitor – shows the simulated front cockpit displays. The monitor allows the instructor to interact with the student station as if in the front cockpit.

v. KVM/Operator Interface Monitor – the far left monitor at the Instructor Operator Station (IOS), the KVM defaults to a 2D map view for single instructor use. When two instructors are present, this is the primary instructor interface.

c. Observer Station – is provided for an additional person to observe training events.

2. OFT Radar System Initialization

OFT system initialization will be discussed in detail in the OFT familiarization event. Once the simulator is on, system is powered up, and a scenario is loaded the Transfer Mode Control (TMC) switch is used to enter and exit the UMFO mode. Entering training mode does the following:

a. When the TMC switch is activated aft, the left MFCD enters UMFO mode and displays the Stores or the OFT EW page.

b. When the TMC is activated forward, the right MFCD enters UMFO mode and displays the Radar Attack display.

c. To exit the UMFO mode for either display, actuate the TMC forward or aft. The display will return to the T-45C MENU display.

The displays operate independently of each other. Therefore, one display can be in the training mode while the other display is in aircraft mode.

3. OFT Training Mode and T-45 Software Integration

Integration between the training mode and the base T-45 systems is limited to those functions that are required to provide ownship position, heading, altitude, airspeed, and flight performance information to the radar and EW pages. Master mode selection is also identified.

4. OFT Specific Displays

The OFT provides for three displays unique to the OFT training mode. These are:

a. Stores Management System (SMS) Display – A planform display that includes selection of master modes and provides for the selection of training mode weapons (Figure 2-9). Available weapons include:

   i. Medium range missiles (MRM) – A/A

   ii. Short range missiles (SRM) – A/A

   iii. General Purpose (GP) bombs

   iv. Precision Guided Munitions – including target point programming

   v. Gun

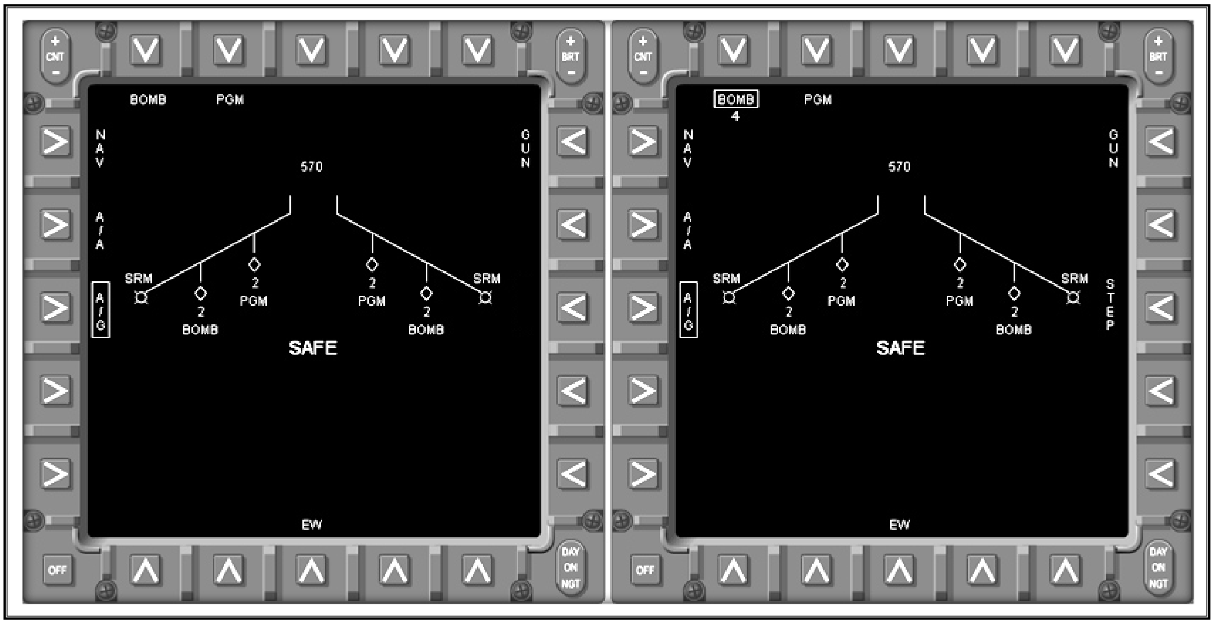

Figure 2-9 OFT SMS

NOTE

The displays show the SMS before and after bomb is selected.

b. EW Display – Displays threat type and direction of arrival (Figure 2-10). Provides for dispense of simulated countermeasures (chaff and flares). This display is accessed via the EW pushbutton on the SMS page and is, therefore, limited to the left MFCD only. OFT EW symbols (Figure 2-11) are similar to VMTS.

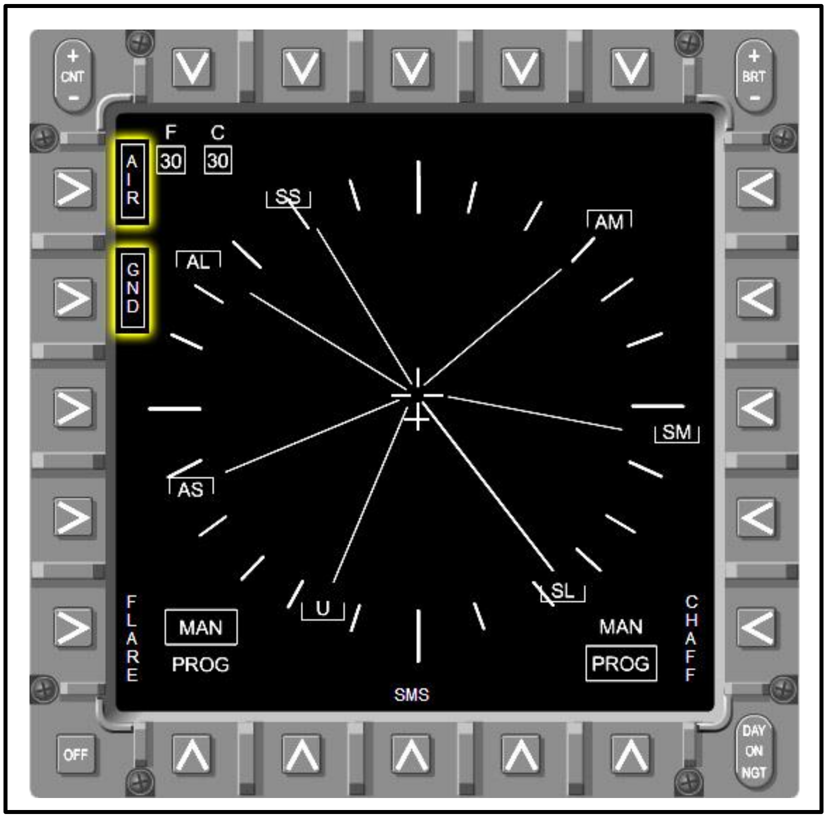

Figure 2-10 OFT EW Page

Symbol	Meaning
┌┐	Air Threat
└┘	Ground Threat

Symbol	Meaning
AL	Air (> 25 NM < 40 NM)
AM	Air Medium (> 10 NM < 25 NM)
AS	Air Short (< 10 NM)
SL	Surface Long (> 25 NM < 40 NM)
SM	Surface Medium (> 10 NM < 25 NM)
SS	Surface Short (< 10 NM)
U	Unknown Emitter

Figure 2-11 OFT EW Symbology

c. Radar Attack Display – Radar attack display of the same format as in VMTS.

In addition to modes available in VMTS, the OFT provides

i. A/A TWS expand (EXP) mode

ii. A/G EXP1, EXP2, and EXP3 patch map modes

NOTE

A complete discussion of these modes occurs later in this document.

204. RADAR HAND CONTROLLER (RHC)

The primary controller for the SNFO's interaction with the radar is the RHC.

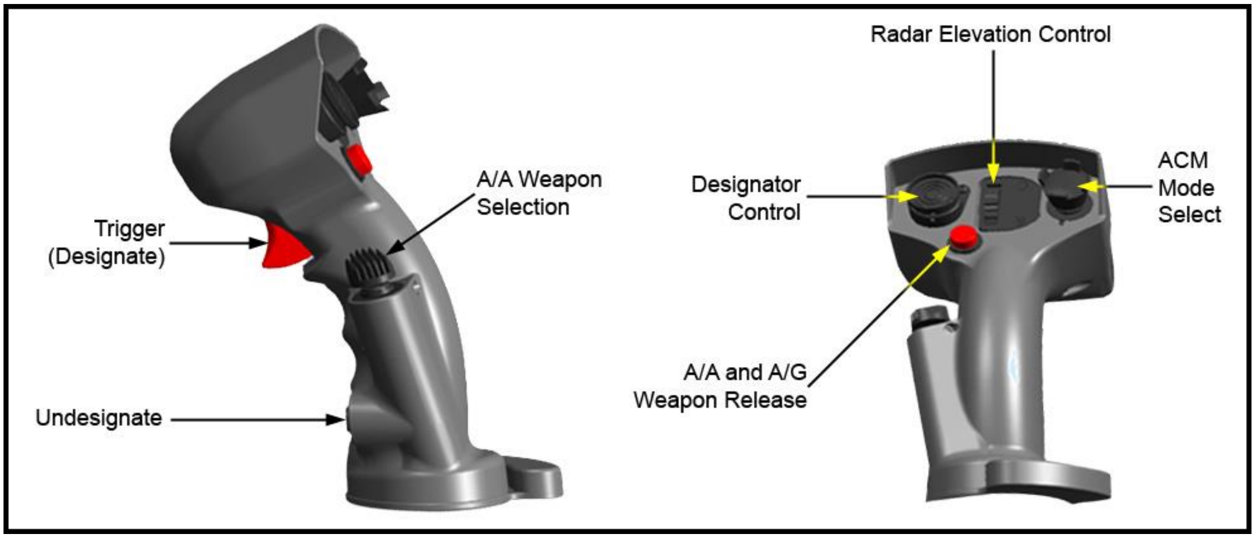

Figure 2-12 Radar Hand Controller – VMTS

As shown in Figure 2-12, the RHC is a seven switch (eight in the OFT), fixed, ergonomically designed interface device used to control radar modes and functions. The VMTS RHC has the following switches and buttons.

1. A/A & A/G Weapon Release – push button that initiates the launch or release of the selected A/G or A/A weapon.

2. Designator Control (DC) – Two axis Momentary "action" position

   a. In A/G Mode

      i. Adjusts scan azimuth center

      ii. Increases/decreases azimuth and range scales

      iii. Positions target designating cursor

b. In A/A Mode

i. Adjusts scan azimuth center

ii. Increases/decreases azimuth and range scales

iii. Trackfile designation and target acquisition

3. Radar Elevation Control – Positions radar scan elevation

4. ACM Mode Select – operates in the A/A mode

a. Forward – commands initial entry to ACM condition, boresight (BST) mode, and initializes radar for BST operation

b. Aft – in ACM condition, commands exit of ACM modes

c. Left – commands caged wide acquisition (WACQ) mode and initializes radar format for WACQ operation

d. Right – commands vertical acquisition (VACQ) mode and initializes radar format for VACQ operation

5. A/A Weapon Selection - Operates in the A/A master mode; it is used to select A/A weapons.

6. Undesignate

a. In the A/G master mode, undesignate clears A/G designations.

b. In the A/A master mode, undesignate commands break track, Return to Search (RTS), steps Launch and Steer (L&S) in the RWS and TWS modes.

7. Trigger (Designate)

a. In the A/G master mode, the trigger creates A/G designations.

b. In the A/A mode, the trigger designates trackfile/command acquisition.

8. Transfer Mode Control Switch (OFT only)

The OFT RHC is similar to the VMTS RHC, with one significant difference. The OFT RHC incorporates the Transfer Mode Control Switch on the right hand side (Figure 2-13):

a. Forward toggles right MFCD

b. Aft toggles left

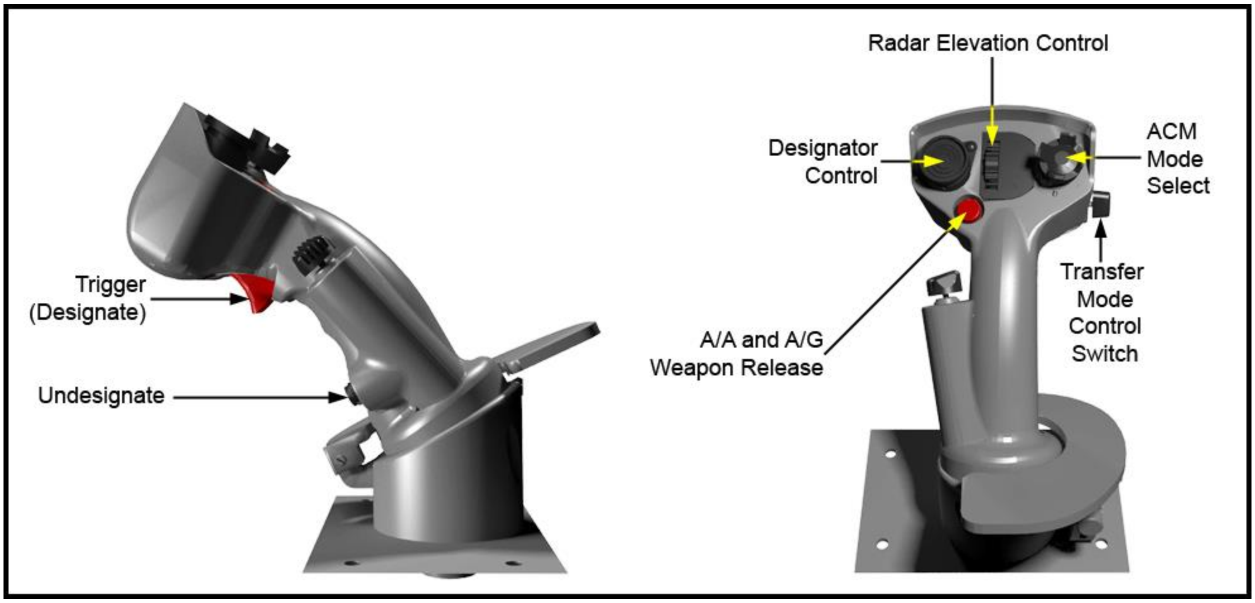

Figure 2-13 OFT Radar Hand Controller (RHC)

205. VMTS FRONT COCKPIT HOTAS

All of the controls found on the RHC can also be commanded with HOTAS. HOTAS has the following switches and buttons that are somewhat different than the RHC (Figure 2-14):

1. A/G Weapons Release – switch that releases the selected A/G weapon. In SIM mode, simulates the release of the selected A/G weapon.

2. A/A Weapons Release – trigger simulates launch of selected A/A missile or fires GUN

3. A/A Weapon Selection (Cage) – switch in A/A master mode that selects A/A weapons. It initializes the radar for each weapon and cycles through:

   a. Medium Range Missile (MRM) - (initial selection under most conditions)

   b. Short Range Missile (SRM)

   c. GUN – no impact on radar setup

Notice that the HOTAS Designator Control is on the throttle and is called the Throttle Designator Control (TDC) instead of the DC. The ACM mode select switch and the radar elevation control are located on the throttle as well, but they perform the same functions.

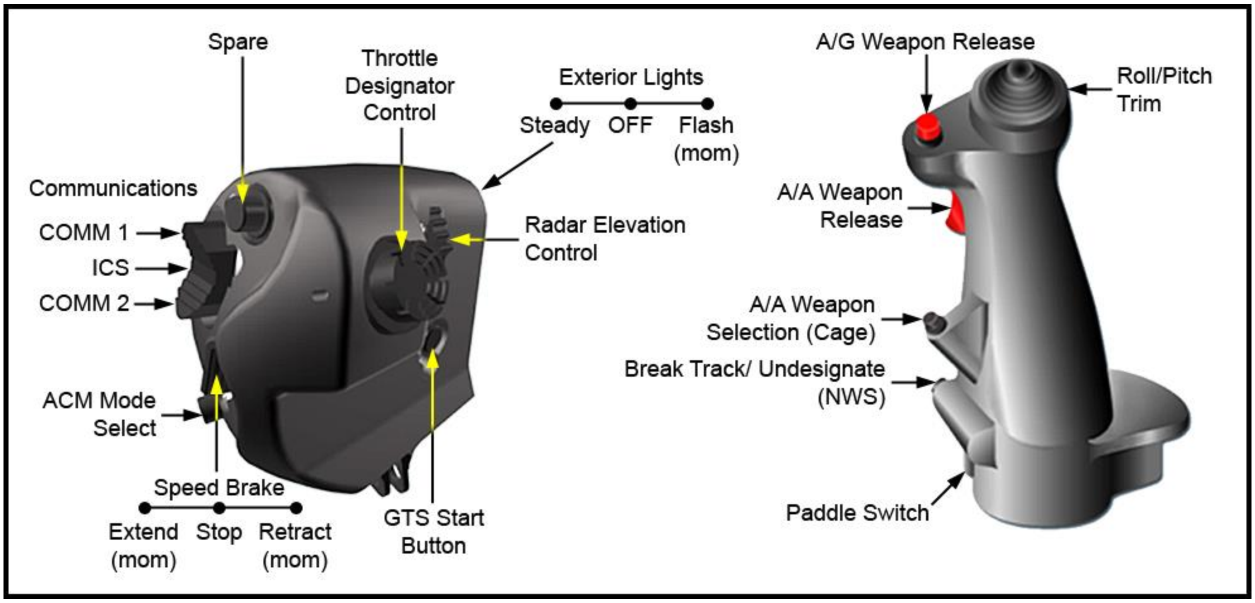

Figure 2-14 Front Cockpit Throttle and Stick Functions

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CHAPTER THREE
AIR-TO-GROUND RADAR

300. INTRODUCTION

The T-45 VMTS uses a Real Beam Ground Map (RBGM) mode to display simulated imagery. It provides the ability to perform cursor designations of displayed target areas on the A/G attack display.

301. REAL BEAM GROUND MAP (RBGM) MODES

In the VMTS, "MAP" will be displayed on the attack display to indicate this mode. The RBGM mode is active when:

1. A/G Master Mode is selected

2. Ground Data Base (GDB) is available

    a. Areas of database with no coverage will be blacked out

    b. If the GDB is invalid, a NO DATA cue will be displayed on the status field

The RBGM mode is the only A/G mode available in the VMTS. The OFT features the following A/G radar modes:

1. RBGM (MAP)

2. Sea Surface Search (SEA)

3. Ground Moving Target Indicator (GMTI)

4. Doppler Beam Sharpening and Expand 1, Expand 2 (EXP1, EXP2)

5. Synthetic Aperture Radar Expand 3 (EXP3)

In the OFT, the MAP, SEA, or GMT mode can be selected with the Radar Mode Select pushbutton. These additional modes simulate more advanced radar suites and capabilities.

Figure 3-1 summarizes the VMTS and the OFT differences.

Difference	OFT	VMTS
System Entry	Selectable but does not have navigation information overlay	VMTSP & DL PWR-up and DL Network Entry Procedures
SA Display	Not Selectable	Selectable on MFCD
EW Display	Selectable but does not have navigation information overlay	Not selectable due to EW information on SA page overlay
A/G Symbology	Target Designation Cue : + EXP Modes Selectable	Target Designation Cue : ◇ No EXP
A/A Symbology	MRM Flash Cue RCS/ASE/Dot EXP Selectable No B/E Information	MRM Flash at 5" TTI NO RCS/ASE/Dot No EXP B/E Available
Stores Display	Additional PGM, Missile Planform MRM/SRM Target Points - PP/TOO	ROKT, BMB, GUN options only
SRM Tone	Provides additional tone with SRM In LAR	HUD In LAR symbology only, no tone

Figure 3-1 VMTS vs. OFT Symbology and Function Differences

302. A/G DISPLAY OPTIONS & SYMBOLOGY

RBGM symbology and operation must be understood prior to applying A/G target acquisition procedures. Figure 3-2 illustrates the A/G attack display symbology.

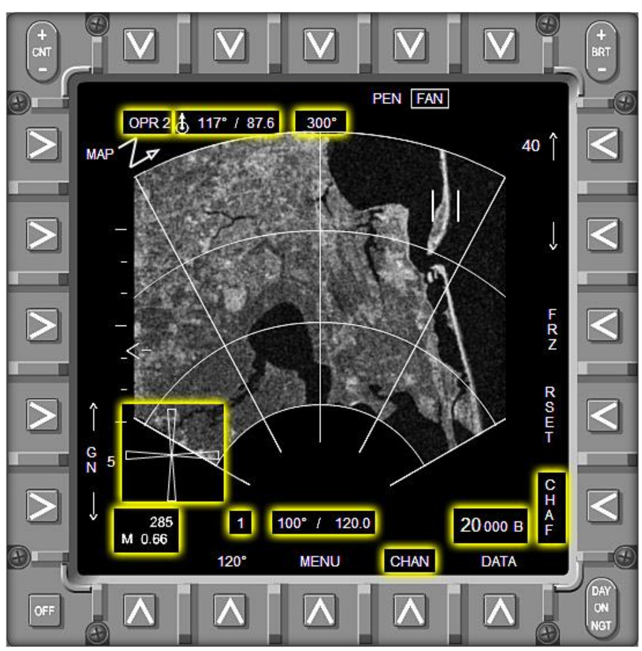

Figure 3-2 RBGM Symbology Overview

Detailed definitions of symbology and PB utilization are as follows:

1. North Arrow Cue

Stylized N with an arrow that is automatically updated and rotated by the computer such that the arrow always points toward magnetic north

2. Air-to-air waypoint (Figure 3-3)

Air-to-air waypoint, the number with a circle around it, represents the location of the selected bullseye (has an arrow pointing toward magnetic north). If no air-to-air waypoint is selected, the current waypoint selected will be shown as a circle.

3. Bullseye Bearing/Range to Cursor (top of attack display, left of aircraft heading)

Indicates the relative bearing and range (to the nearest degree magnetic) from current A/A waypoint to acquisition cursor, "bullseye to cursor." Information is the same whether there is a designation or not.

4. Bearing/Range from Ownship (bottom center of attack display)

Information displayed indicates the relative bearing and range from ownship to acquisition cursor. (cursor or target designation cue OFT only).

5. Range Scale

160, 80, 40, 20, 10, and 5 NM ranges, increased and decreased using the pushbuttons or through the Cursor bump feature (Figure 3-3).

6. Range and Azimuth Grid

Grid consists of four equally spaced range arcs. Azimuth lines are at 0, +/- 30, and +/- 60 degree increments. 0 degree line is referenced to ground track.

7. Freeze (FRZ)

Freezes/unfreezes the simulated radar video display; boxed when selected; radar antenna scanning is not affected (Figure 3-3).

8. Reset (RSET)

Reinitializes the radar gain to 5 and sets the antenna elevation for optimum coverage at the selected range and altitude (Figure 3-3).

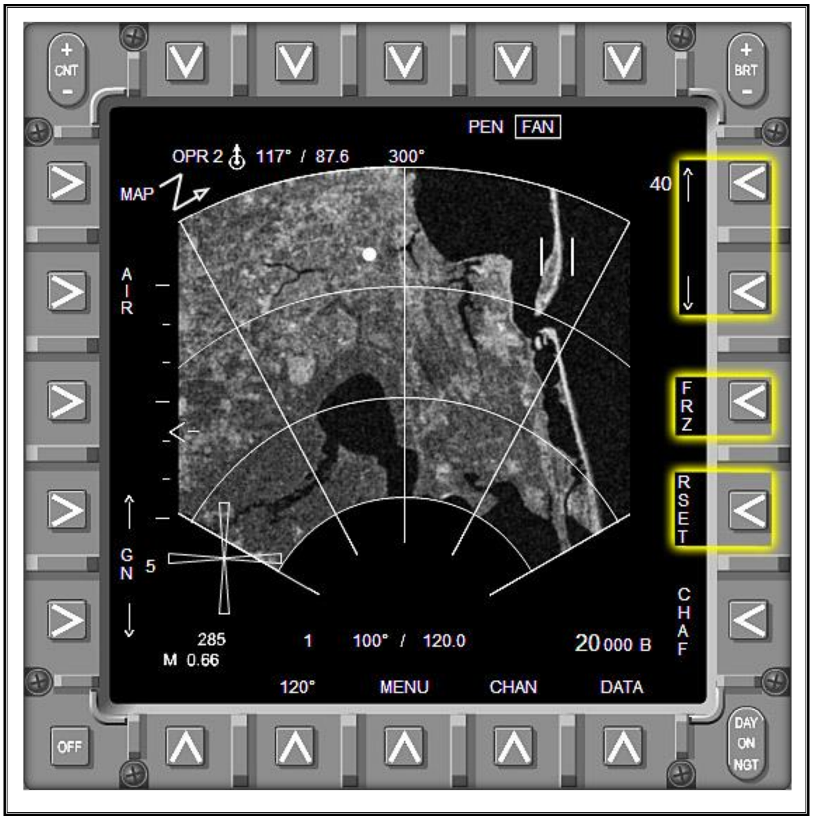

Figure 3-3 RBGM Range, Range/Azimuth, FRZ, RSET

9. Azimuth Scan selection

Options are 120, 90, 45, and 20 degrees. Scan volume may be repositioned for all selections except 120.

a. With the acquisition cursor over the azimuth value legend, 90, 45, or 20 will be selectable. TDC/RHC Trigger depressed and held causes the acquisition cursor to be removed. Azimuth scan centering cursor initializes at the center of the current azimuth scan selection (Figure 3-4).

b. TDC/DC repositions scan centering cursor within the 120 degree limits

c. TDC/RHC trigger released

d. New Radar map is generated and the acquisition cursor moves to stowed position

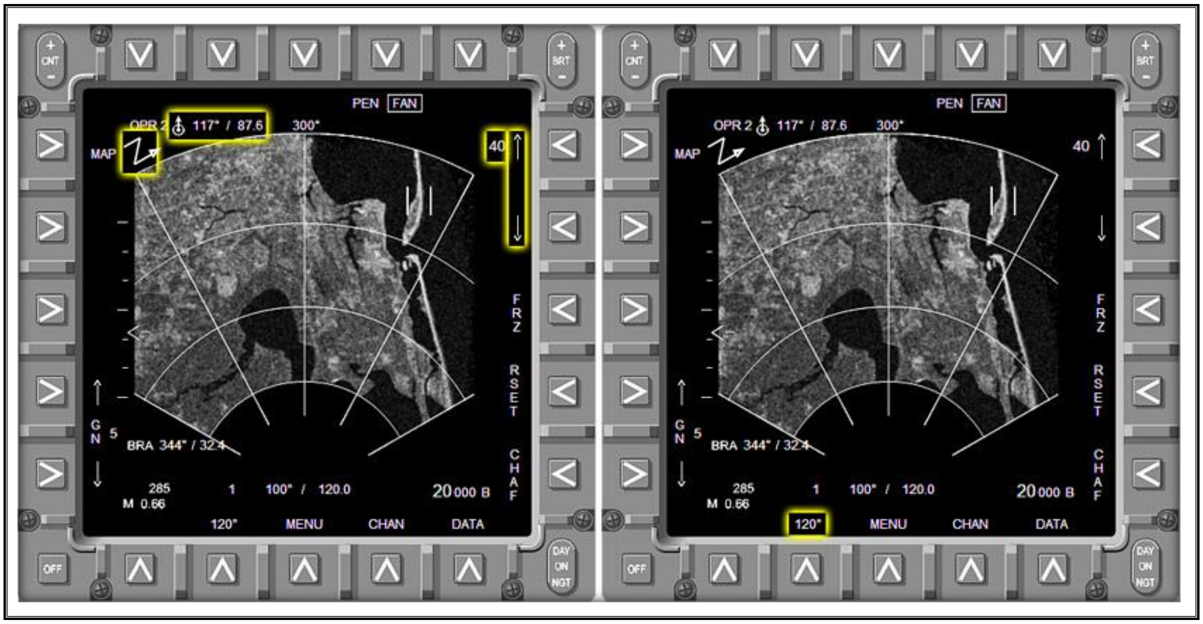

Figure 3-4 RBGM Symbology/Azimuth Scan Re-Center

10. Antenna Elevation Scale

Scale displays 60 degrees of antenna elevation, in 10 degree increments (+-30 degrees from aircraft horizon, Figure 3-5).

a. Elevation Caret – displays current antenna elevation (Figure 3-5, right image).

b. Optimum Antenna Elevation Position – symbol depicted by "–" that indicates optimum radar coverage for current range/scale and aircraft altitude. Figure 3-5 shows this position to be coincident with the radar elevation caret.

c. Antenna elevation is controlled in one of two ways:

i. Throttle quadrant with radar elevation wheel

ii. Radar elevation wheel on the Right Hand Controller

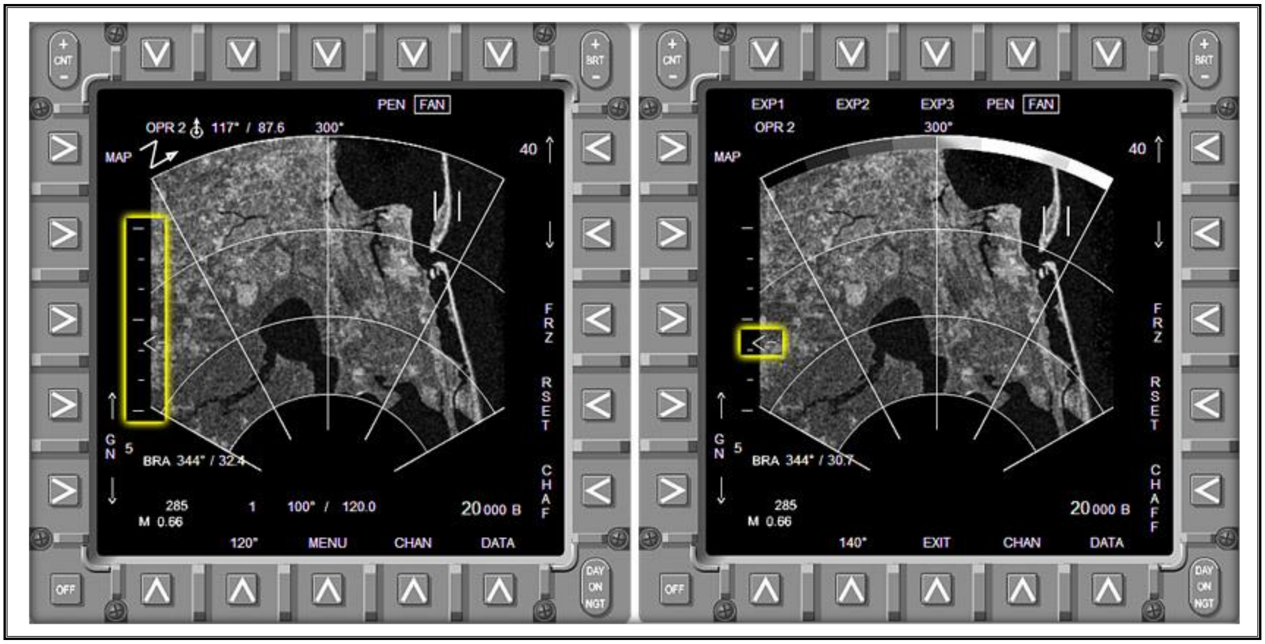

Figure 3-5 Antenna Elevation Scale/Elevation Caret

11. Gain (GN)

Displays the current gain level and is adjustable through 9 levels; default value 5 (Figure 3-7). It is important to recognize that the Gain in the VMTS aircraft functions more like brightness since actual radar energy is not being filtered with this adjustment.

12. Data Sublevel

This page can be accessed through the radar format A/G master mode, RBGM (Figure 3-6).

a. The DATA option is located on the lower right of the MFCD.

b. IBIT, STOP, BRA, and power controls are the same as in the A/A radar mode.

c. Gray scale is used to adjust the display brightness and contrast; there are 8 levels of brightness and the intensity level can be set from no return to full return.

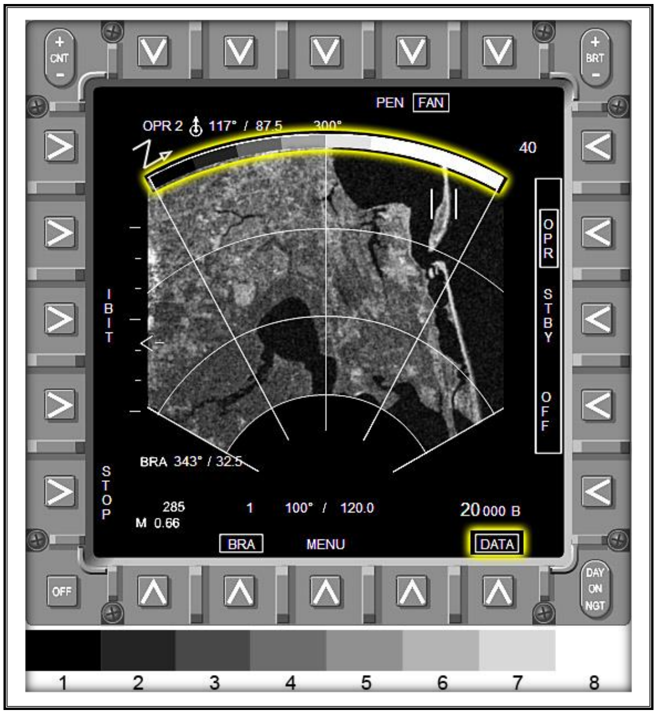

Figure 3-6 Data Page with Gray Scale

13. Aircraft Ground Track and Heading

Variations may exist between the displayed ground track map image and aircraft heading; antenna stabilization displays ground map image oriented to ground track, not heading (Figure 3-7).

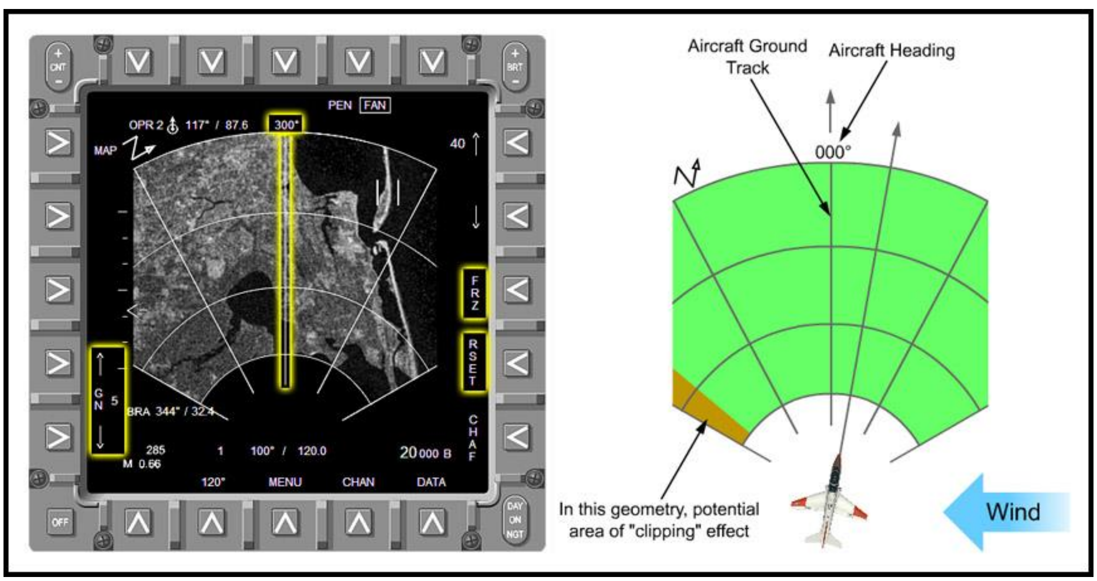

Figure 3-7 Ground Track Vs. Aircraft Heading

14. Cursor Designation

   a. RHC trigger is pulled and held, or TDC is depressed and held

   b. Acquisition Cursor is now replaced with the Designating Cursor (Figure 3-8) and may be slewed as needed to refine the position over the desired target

15. Stabilized Cue

   a. When RHC trigger or TDC is released, Designating Cursor is replaced with Stabilized Cue (Figure 3-8)

   b. Stabilized Cue can then be updated by:

      i. Re-commanding Designating Cursor (pull and hold trigger)

      ii. Updating the designation placement

      iii. Setting updated Stabilized Cue (release trigger)

   c. Aircrew clear the A/G designation by:

      i. Pilot undesignated switch

      ii. Aft crew station undesignated switch

      iii. Deselect TGT or select new waypoint on HSI

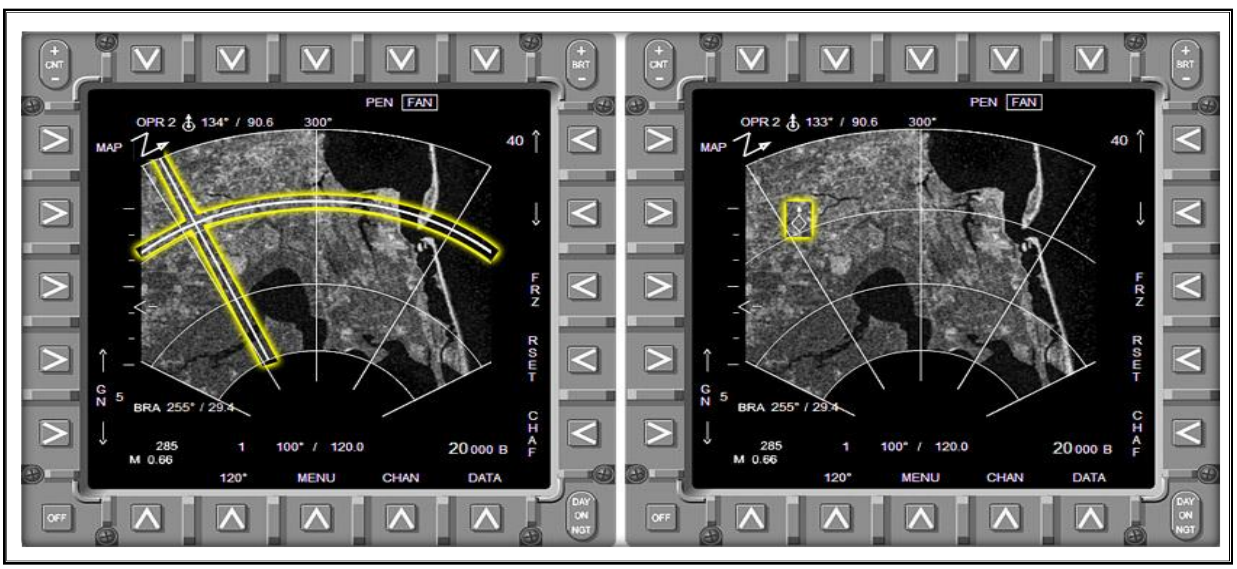

Figure 3-8 Designating Cursor/VMTS Stabilized Cue

It is important to note the system tolerances. The displayed position of a terrain feature and the calculated position relative to ownship is within 1 NM and 3 degree of azimuth on a 10 NM scope (Figure 3-9).

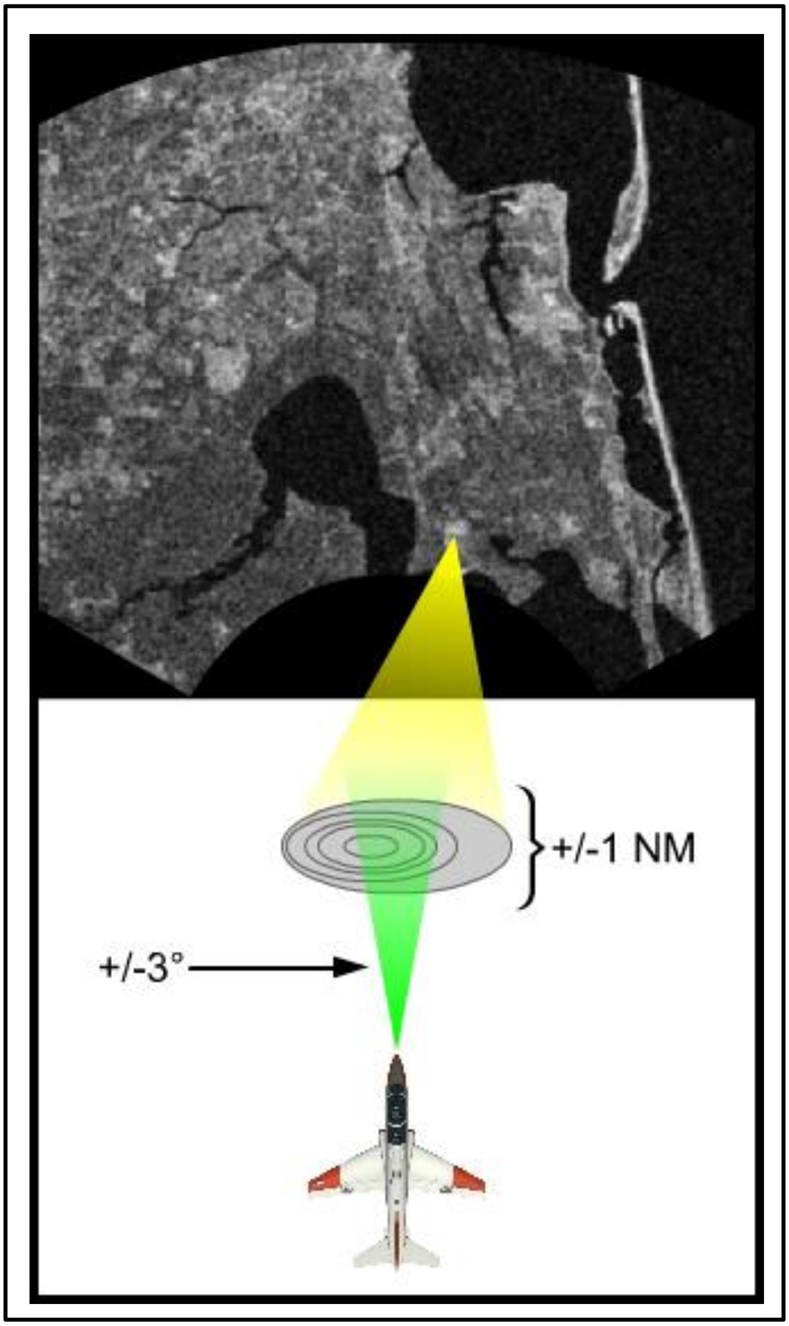

Figure 3-9 VMTS RBGM Display Correlation Tolerances

16. Expand Modes (OFT Only)

Expand modes provide the ability to refine designations by taking a smaller area of focus and expanding that area on the attack display. Expand modes can be entered with or without a designation; however, the scanned area will automatically be centered on a designation. There are three expand modes:

a. Expand 1 (EXP 1)

b. Expand 2 (EXP 2)

c. Expand 3 (EXP 3)

The first attack display (left image) in Figure 3-10 displays a radar picture on the attack display with a stabilized cue in a specific target area. The stabilized cue in this radar attack display is a small cross instead of a diamond (this is what the stabilized cue looks like in the OFT). The second attack display (right image) in Figure 3-10 depicts the radar picture of that target area in Expand (EXP 1).

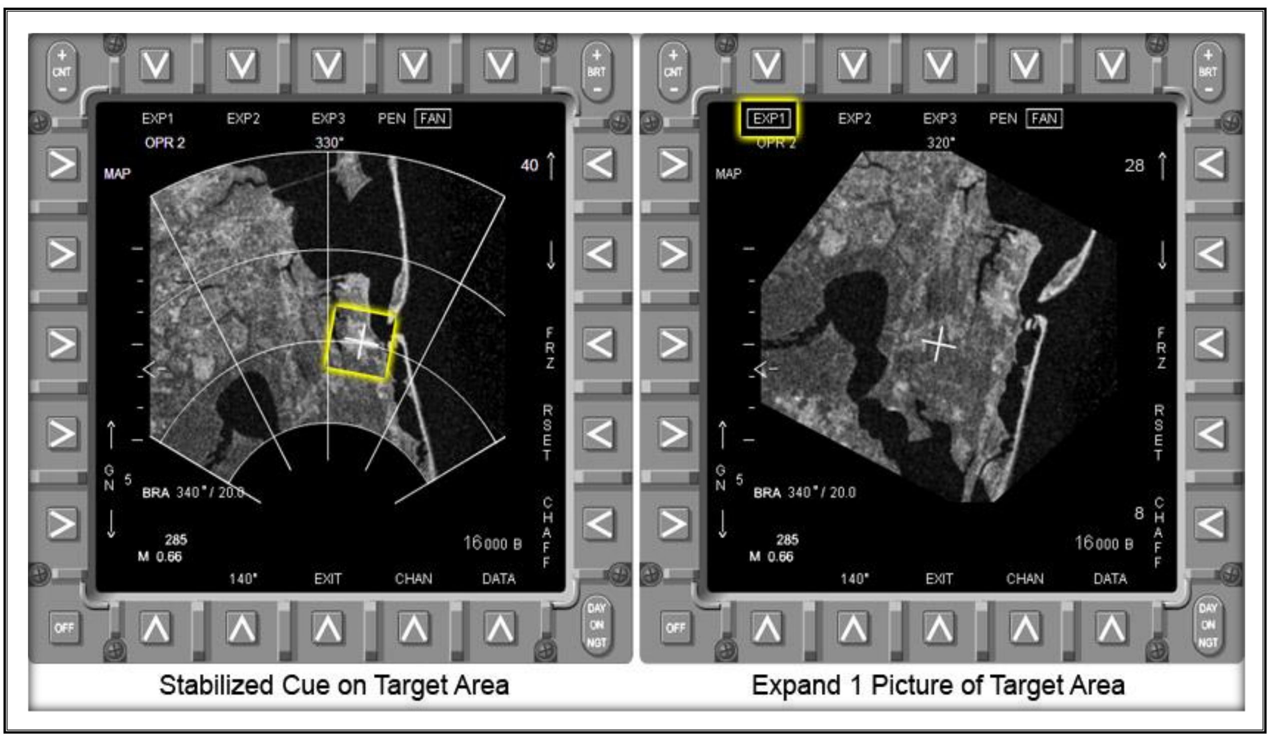

Figure 3-10 OFT EXP 1 Display

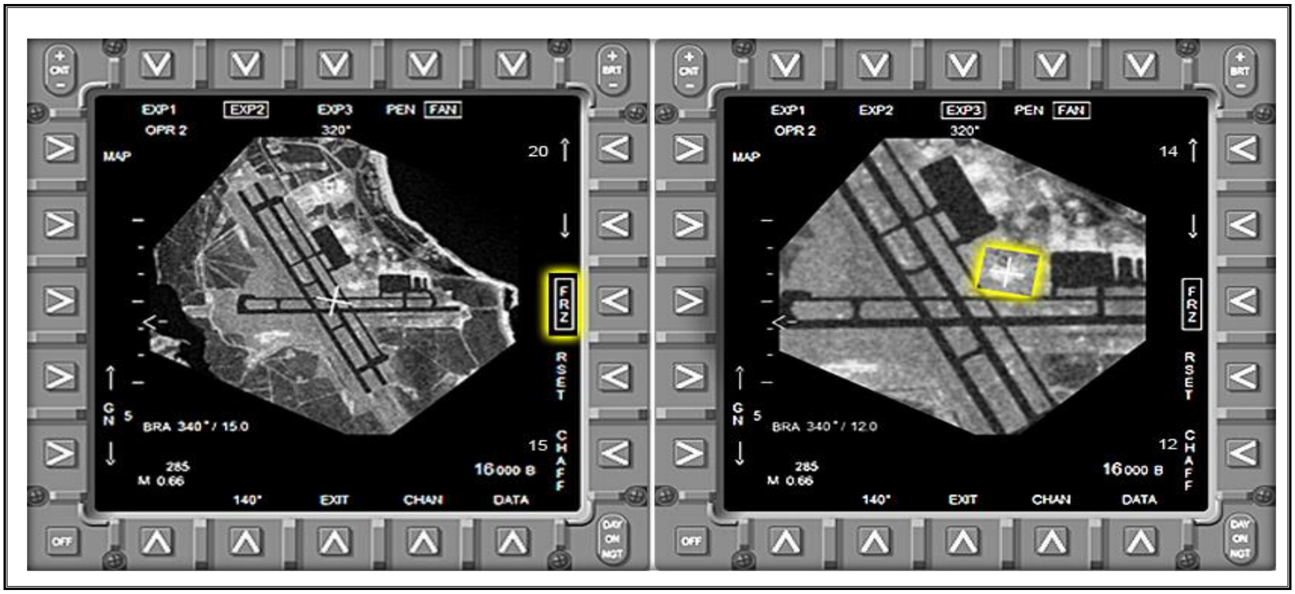

Figure 3-11 Expand 2 & Expand 3 Displays

Once the actual target or target area can be identified on the attack display, the picture can be frozen by pressing the FRZ push tile. The radar designation can then be slewed over the target or Desired Mean Point of Impact (DMPI). This is done with a full action trigger squeeze, which gives the designating cursor. The designating cursor can be slewed over the target. Release the trigger to update the designation. Figure 3-12 illustrates the FRZ and slew functionality.

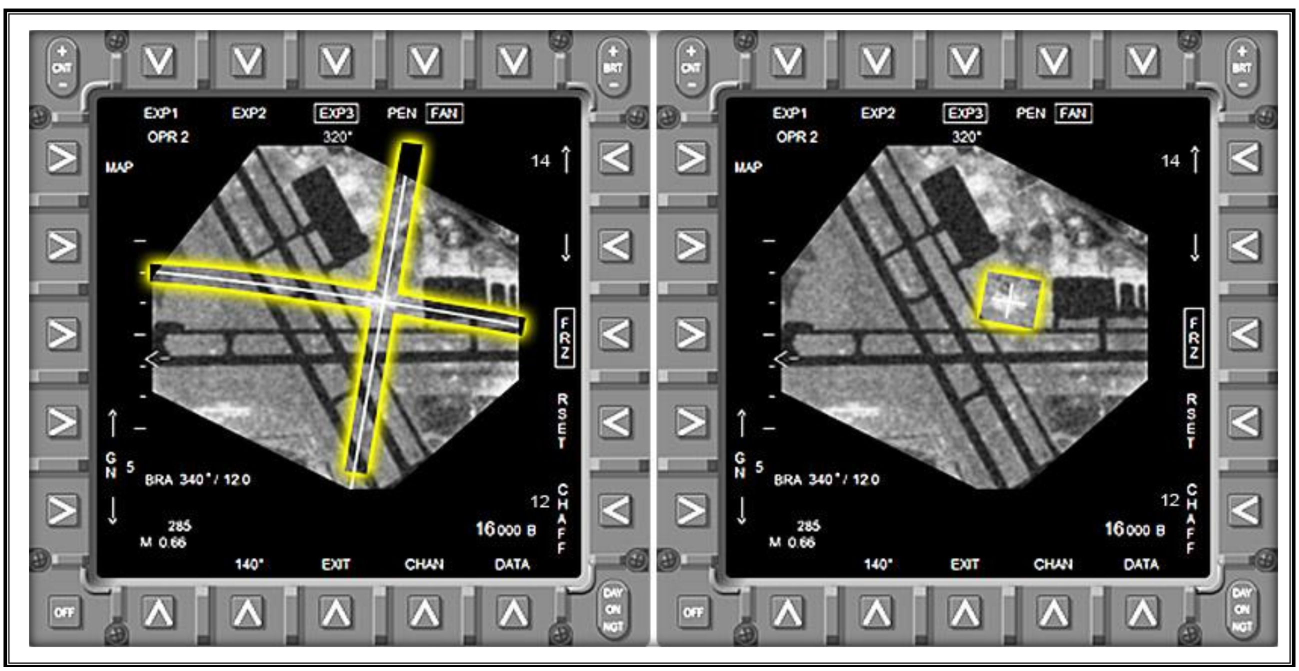

Figure 3-12 Expand 3 FRZ with Designating Cursor Slew/New Expand 3 Designation

It is not necessary to make an A/G designation to use the Expand modes. In this case, the Expand Mode (OFT) Corral option can be used to slew a "corral" over a particular area of interest. For this to be effective in finding a desired target, a thorough preflight study of the target area to include radar predictions is required. To enter EXP1 mode using corral, perform the following (Figure 3-13):

a. Slew the acquisition cursor to the target area

b. Select EXP1

c. Slew the TDC/DC, centering the corral in the desired target area, full action trigger pull and release.

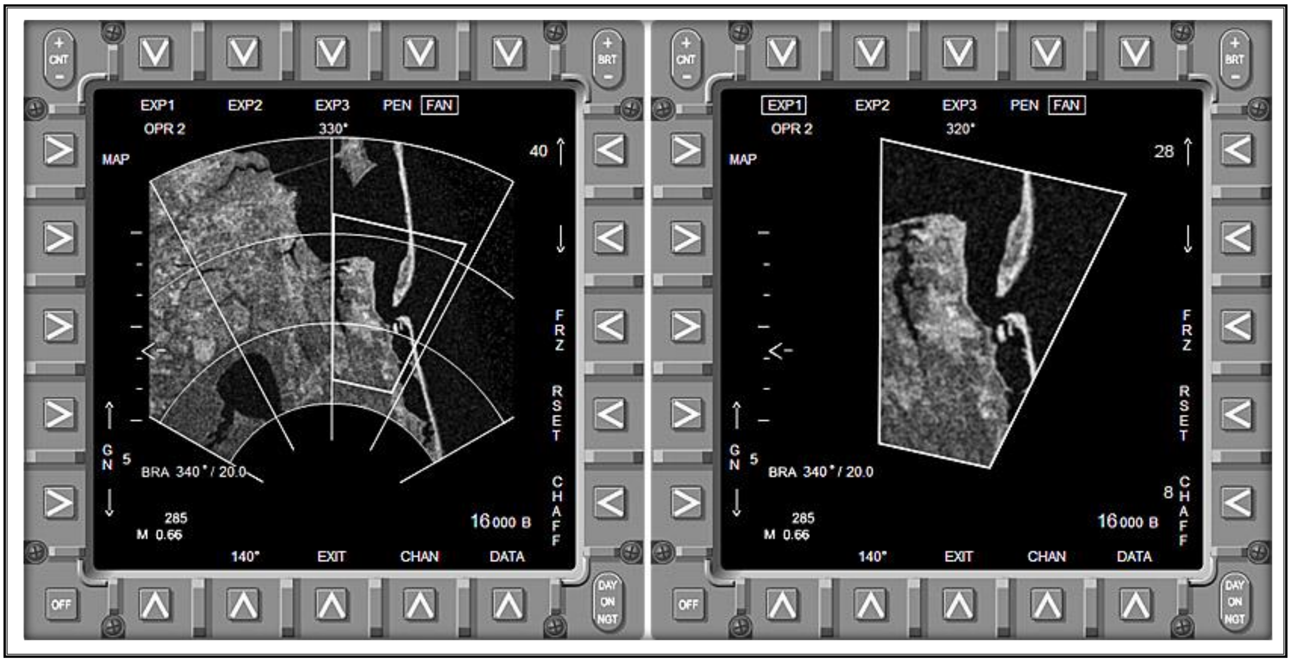

Figure 3-13 Expand 1 Mode Using Corral

The same procedure can be used for EXP 2 or EXP 3 corral (Figure 3-14). Select either mode then slew the corral over the target area and execute a full action trigger pull. If an EXP 2 refinement is not required, it can be bypassed to proceed directly to EXP 3.

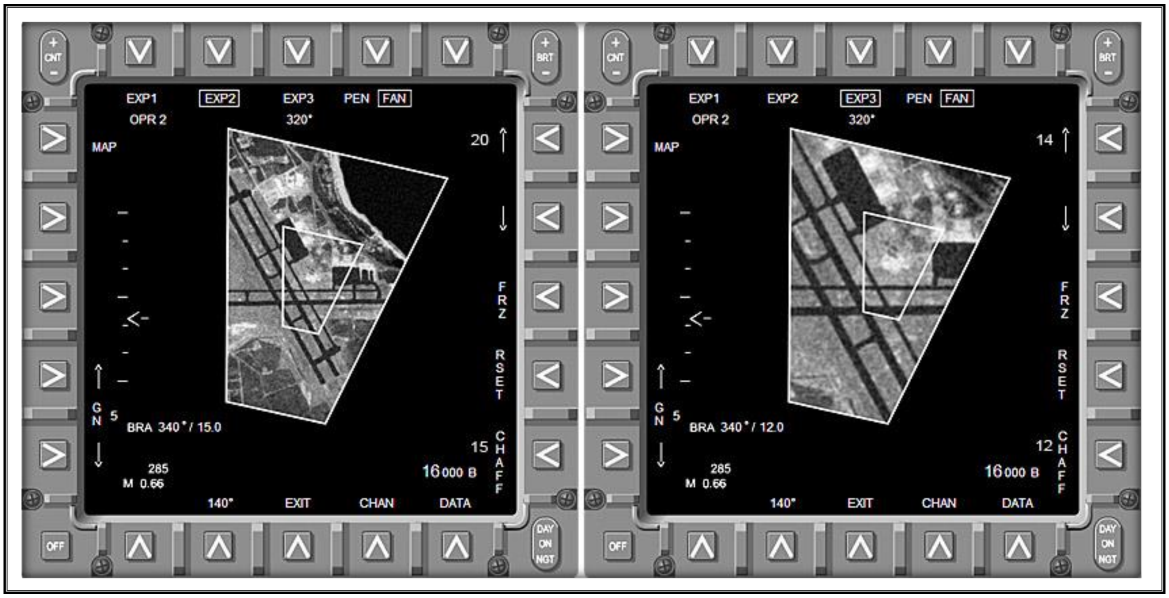

Figure 3-14 Expand 2 and Expand 3 Mode Using Corral

17. Radar Track Designations

In both the GMT and SEA modes of the A/G radar, a radar target track designation can be commanded using the following procedures (Figure 3-15):

a. Enter the GMT or SEA mode

b. Slew the cursor over the radar trackfile

c. Full action trigger squeeze

d. Slew Designating Cursor directly over target trackfile desired

e. Release Trigger

Once a moving target trackfile is created, the trackfile will show course and speed along with an aspect vector.

GMT and SEA modes will not be used at VT-86.

18. A/G and A/A Common Attack Display Symbology

There are some attack display symbols that are common to both A/G and A/A modes (Figure 3-16):

a. Maltese Cross – when displayed indicates the simulated radar is not transmitting due to weight-on-wheels or transmitter malfunction or failure

b. Ownship Data

i. Aircraft Heading – top center of attack display (Heading 000 in Figure 3-17)

ii. Airspeed/Mach number ("M")

iii. Position Figure of Merit (PFOM)

iv. Altitude (20,000 Barometric)

c. Ownship positioning

i. Bullseye to cursor – (VMTS only) top of attack display, left of aircraft heading; this readout gives the *cursor position* relative to the bullseye (reference waypoint)

ii. Ownship to Bullseye – bottom center of attack display; gives *aircraft position* relative to bullseye or designation

iii. BRA (OFT only) – when the cursor is slewed inside the attack display, the bearing, range, and altitude (BRA) from the aircraft to the curser point will be displayed underneath the cursor. This information can be used to correlate target relative position from the aircraft. If the target is a ground target, the altitude will not be shown.

d. CHAN – radar channel option allows for selection of different radar channels

e. CHAF – chaff option

f. FLARE – flare options (OFT only)

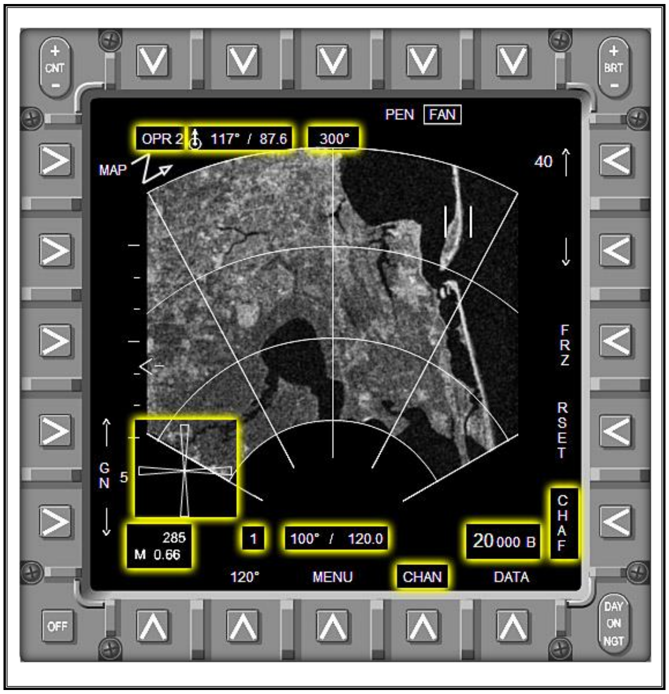

Figure 3-15 A/G and A/A Common Attack Display Symbology

Figure 3-16 summarizes the A/G attack display cursor cues.

CURSOR NAME	CURSOR SYMBOL	ENABLING METHOD	SLEWING METHOD	DESIGNATION METHOD
ACQUISITION CURSOR	II	DEFAULT CURSOR. INITIALIZATION POSITION IS IN THE UPPER LEFT CORNER OF THE DISPLAY (NEAR NORTH ARROW).	TDC/DC PIVOT ACTION	N/A
DESIGNATING CURSOR		PRESS TDC/DC ACTION INSIDE THE TACTICAL DISPLAY SELECTS THE DESIGNATING CURSOR. THE DESIGNATING CURSOR WILL INITIALIZE AT THE STAB CUE IF A DESIGNATION EXISTS AND THE ACQUISITION CURSOR IS INSIDE THE TACTICAL BORDER, OTHERWISE IT WILL INITIALIZE AT THE LAST LOCATION OF THE ACQUISITION CURSOR (IF THE ACQUISITION CURSOR IS INSIDE THE TACTICAL REGION).	TDC/DC PIVOT ACTION WHILE PRESSED	UPON TDC/DC RELEASE THE STAB CUE POPS UP AT DESIGNATING CURSOR'S CENTER AND THE ACQUISITION CURSOR IS THEN SHOWN.
STAB CUE MARKS THE DESIGNATION POINT.	◊	TDC/DC RELEASE WHEN DESIGNATING CURSOR OVER DESIRED AIMPOINT.	CAN NOT BE SLEWED	
AZIMUTH SCAN CENTERING CURSOR	/	A PRESS AND HOLD OF THE TDC/DC WHILE OVER THE AZIMUTH PB LEGEND SELECTS THE AZIMUTH SCAN CENTERING CURSOR. THE CURSOR INITIALIZES AT THE CURRENT AZIMUTH SCAN CENTER.	TDC/DC PIVOT ACTION WHILE PRESSED	UPON TDC/DC RELEASE THE AZIMUTH SCAN CENTERING CURSOR IS REMOVED AND THE ACQUISITION CURSOR IS THEN SHOWN AT THE INITIALIZATION LOCATION. THE AZIMUTH SCAN IS NOW CENTERED AT THE LAST LOCATION OF THE AZIMUTH SCAN CENTERING CURSOR.

Figure 3-16 A/G Attack Display Cursor Cues

19. Situational Awareness (SA) Page

The Situational Awareness (SA) page is a versatile display that incorporates HSI navigation information with EW information. The SA page is only selectable in the aircraft VMTS; it is not available in the OFT. The SA page can display critical surface threat symbology and lethal air threat symbology (Figure 3-19), with corresponding aural warning tones. It displays waypoint data to include the selected A/A or A/G waypoint and waypoint sequences. SA features include:

a. Warning tones that are integrated with TACAN, ILS, and UHF; they are controlled by the master volume control

b. Warning tones will be audible unless inhibited by aircrew; surface threats are alternating 455 Hz/555 Hz, each held for 0.166 seconds

c. The top active priority surface threats are:

   i. SS – Surface short range

   ii. SM – Surface Medium range

   iii. SL – Surface Long range

d. SA page GND (Ground) option is boxed when initialized and enables:

   i. Display of surface threat cues

   ii. Aural warning tones

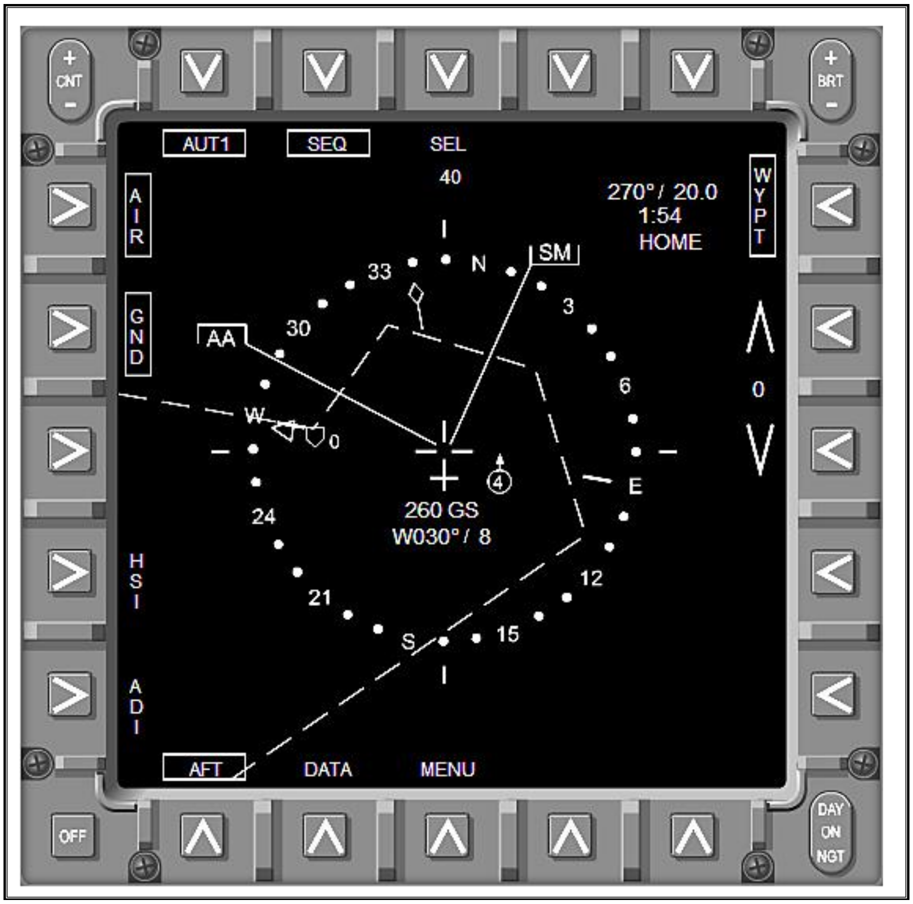

Figure 3-17 SA Page, Displays Surface and Air Threats

The SA page functionality is the same for the AIR and GND options. The SA page is accessed through the Menu format. In conjunction with the tactical attack display, aircrew will use the SA page to build and keep overall situational awareness while acquiring and prosecuting targets on the attack display. As the OFT does not have the SA page option, aircrew will be required to use both the HSI and EW pages, in concert with the radar attack display, for situational awareness.

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CHAPTER FOUR
AIR-TO-AIR RADAR

400. INTRODUCTION

This chapter introduces A/A radar concepts and fundamentals. It builds on basic radar theory previously presented and addresses A/A specific radar considerations.

401. HISTORY OF THE MILITARY APPLICATION OF RADAR

Radar was designed for military applications. Initially, radar stations, such as the Chain Home series Britain used in 1940, were used as early detection and warning of incoming enemy aircraft. As technology improved, radar was added to aircraft and by the end of WWII, specialized radar-equipped fighters were being used by the U.S. Navy and Marine Corps with positive effects. Primarily used at night, these radars required a great deal of understanding of the principles of radar to make them effective. By the Korean War, radar had evolved to the point of specialized aircraft designs to capitalize on the new technology.

Figure 4-1 F4U-5N Corsair with Early A/A Radar

402. AIRBORNE RADAR FUNCTIONS

Aircraft-mounted radar can be effectively used for mapping of surface areas as well as for target identification and attack. It is important to remember that fighter radars, by nature of their designation, are fire control radars and are not optimized for the long-range detection and tracking of multiple targets. Rather, fire control radar is designed to illuminate a target in order to calculate a firing solution to destroy a target.

Although newer radars combined many functions into one system, such as the APG-73, this radar remains primarily a fire control radar with additional capabilities. With the advent of phased-array radars like the APG-79 Active Electronically Scanned Array (AESA) in the F/A-18E/F, the lines between what fighter radar can and cannot do continue to diminish.

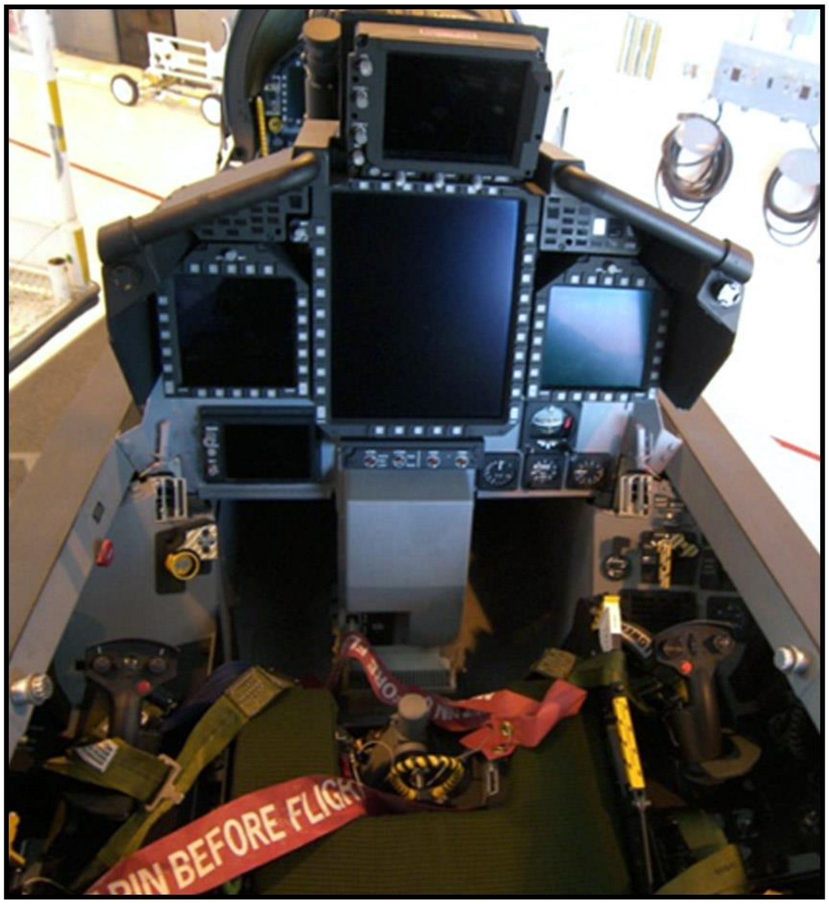

Figure 4-2 Rear Cockpit of an F/A-18F

403. ANTENNA MECHANICS

1. Pulse Radars

The first radars were pulse radars. A pulse radar operates by emitting focused radio frequency energy and then receiving, or “listening,” for the reflected return of that signal. Bearing to the target is determined by the direction the antenna is pointing and range by the time it takes for the pulse to travel to the target and be reflected back to the antenna. These returns, called “echoes” were then displayed to the operator on the scope.

The basic components of a pulse radar include a transmitter, a receiver, a time-shared antenna, signal data processor and a display. In modified forms, pulse radars are still used today by some surface-to-air systems, ground mapping, and weather applications.

Figure 4-3 Surface Based Radar and Typical PPI Scope

2. Doppler Effect and Doppler Radar Types

A Pulse-Doppler, or PD, radar emits pulses of energy, but interprets the returns in a different way. Rather than display only the echo, the PD radar evaluates the change in frequency comparing the relative velocity of the transmitter to the returned signal. This change in frequency is called the "Doppler effect."

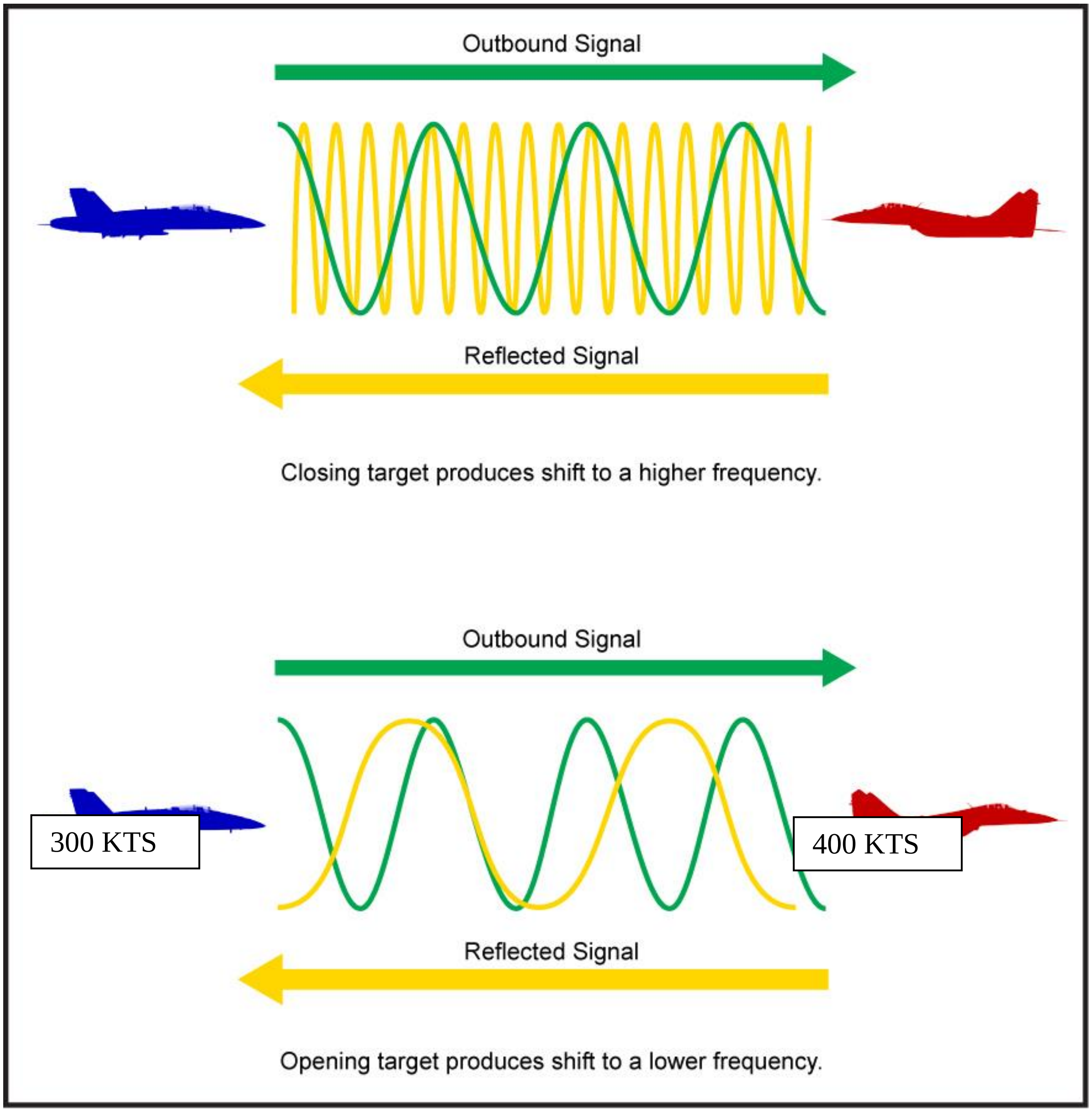

Figure 4-4 Doppler Shift

The Doppler effect is noticeable in sound waves when a vehicle such as a car or train horn passes by. As the vehicle approaches, the sound waves are compressed in frequency, raising the pitch of the sound. After the vehicle passes, the sound waves frequency is reduced; therefore, lowering the pitch of the sound. If two vehicles are traveling at the same speed, there is no change in pitch as there is no frequency change.

This same principle applies to electromagnetic (EM) waves emitted from a radar. That is, the frequency increases for approaching targets and decreases for receding targets. In a true Doppler radar, the radar only detects and displays contacts with Doppler shift in the returned energy. This limits the applications of radars that are only Doppler radars.

3. CW Radars

A subset of Doppler radars are the continuous wave or CW radars. In a CW radar, one antenna transmits a continuous wave while another receives the signal. When this is coupled with a measured shift in frequency of the transmitted signal, the result is called a frequency modulated continuous wave (FMCW) radar. This sweeping in frequency allows the system to code the time of the emitted pulse and time the return to calculate range in addition to the velocity of the detected contact. This type of system was used for target illumination for early AIM-7 Sparrow missiles as well as the Russian built SA-5 surface to air missile system.

4. Pulse-Doppler Radars

A PD radar seeks to capitalize on the properties of a Doppler radar while retaining the all aspect detection capability of pulse radar. The PD radar does this by transmitting short pulses of energy and listening for the Doppler shift in the return. As a result, a PD radar is able to use pulse theory to aid in the detection of targets and the elimination of clutter.

However, unlike a pulse radar, where the radar is looking for direct reflected energy from the target, the PD radar looks for the frequency shift in the returning signal. This means that the radar will only “see” returns that generate a Doppler shift. Where there is no Doppler shift, the radar will not “see” the target, even though it is there. There are two conditions where this can occur:

a. The contact is travelling in the same direction at the same velocity, resulting in no change in frequency in the signal.

b. The contact is perpendicular to your antenna, which results in a frequency shift equal to ground return, which is filtered out.

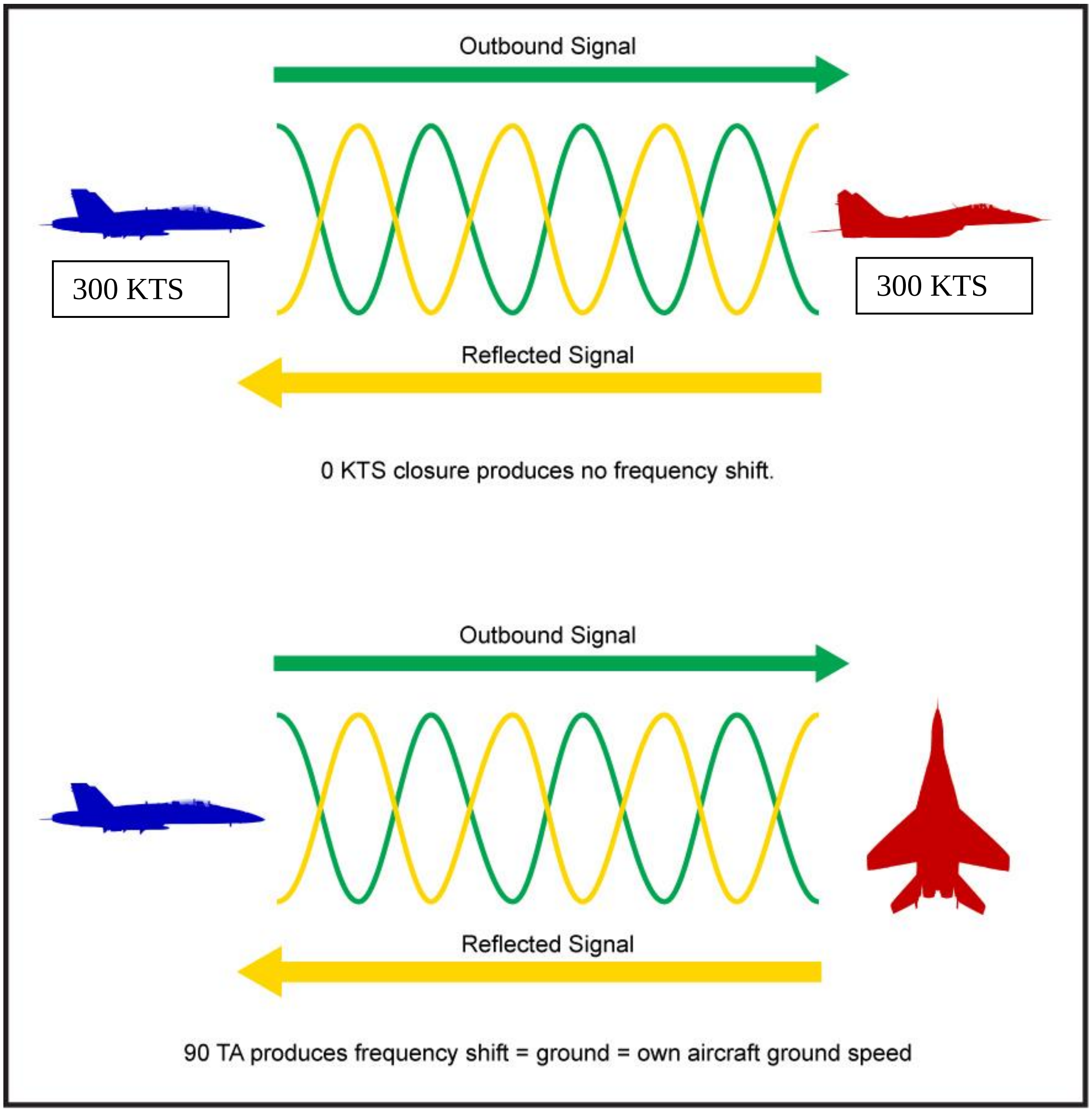

Figure 4-5 No Doppler Shift

404. PULSE AND PULSE-DOPPLER RADARS

Pulse radars have an advantage in that they “see” everything. The problem, however, with seeing everything is that it takes a very well trained operator to discriminate real returns from clutter and potential decoys, such as chaff. This makes their successful application in the A/A environment dependent on the skill of the user. Early radar equipped fighters, used pulse radars and CW illumination for radar guided missiles. Many incorporated a radar operator due to the nature of early radar systems.

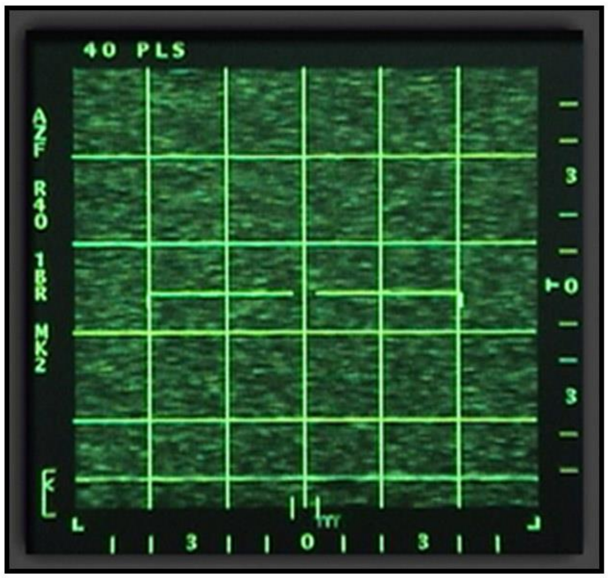

Figure 4-6 Typical Pulse Radar Display

PD radars present images on a very clear scope. These scopes are optimized for ease of use with a clear presentation of information and can be used after a limited amount of training. PD radars work well in environments with a lot of Doppler shift, such as A/A intercepts.

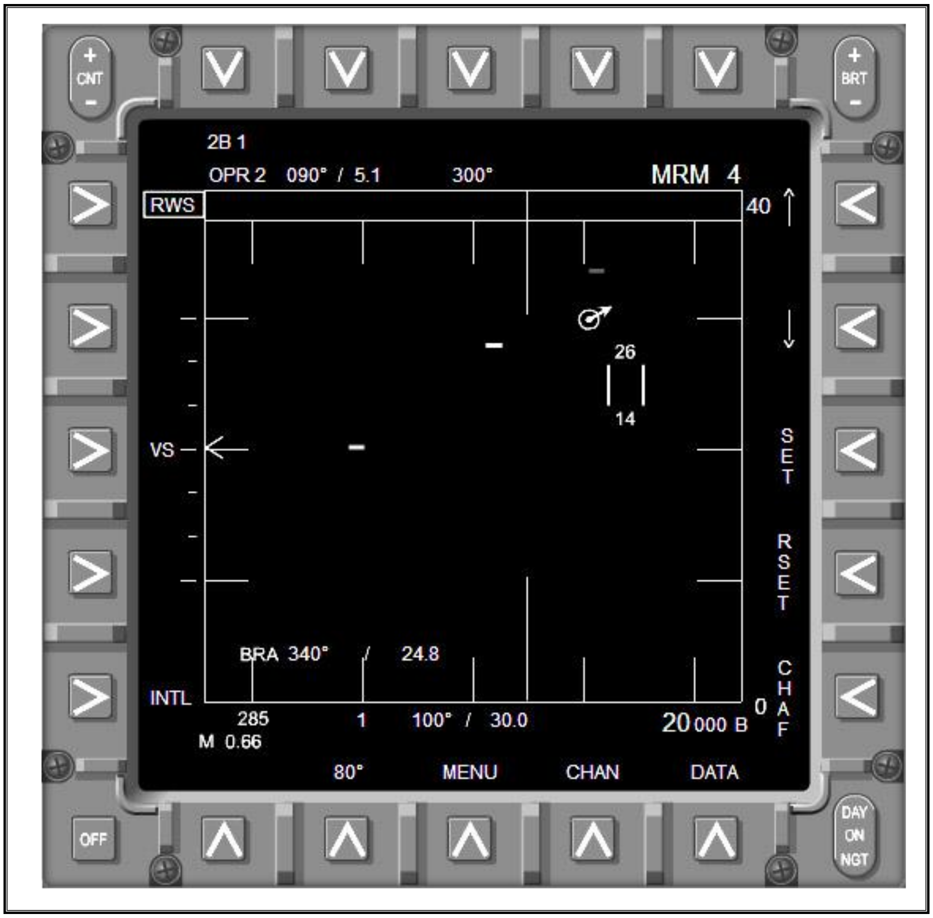

Figure 4-7 Typical Pulse-Doppler Radar Display

1. Advantages of a Pulse-Doppler Radar

In a PD radar, the Doppler effect is used to determine target parameters or aid in developing an image of ground return. This provides a number of advantages over a pulse only system, including:

a. Ability to track more than one contact while continuing to search and detect others; also called track while scan capability

b. Ability to detect moving targets on the ground

c. Ability to generate real-time spot mapping in high detail at long range through the use of Doppler image sharpening

d. Inherent resistance to chaff and some types of jamming

e. Improved detection of maneuvering targets due to highly accurate measurements of Doppler shifts

2. Clutter Determination in PD Radars

Clutter is any undesired radar returns. In the A/A environment, this means any return that does not represent an airborne object. This unwanted return includes surface returns, terrain, and environmental effects such as clouds and rain. Additionally, chaff released by hostile, or even other friendly, aircraft may clutter the display.

The primary method a PD radar uses to establish whether a return counts as clutter or as a legitimate return is through measurement of that return's Doppler velocity. Then, the radar's processors will filter out this unwanted return. This is very effective at reducing clutter but comes with a price.

3. Return Filtering

When the PD radar receives returns, it filters out frequencies that are expected from stationary objects like terrain, moisture and dust. If your ownship is traveling at 300 KTS ground speed, the return signals from these stationary objects will have a Doppler shift as there is 300 KTS of closure velocity (Vc) from your aircraft. Therefore, radar returns from objects with Vc about the same as ownship groundspeed will be filtered out, in order to provide as clutter free scope as possible. The region of velocities around ownship groundspeed that are filtered out is called the "Doppler notch."

Filtering the Doppler notch provides for a very clutter free radar display for the operator, since all targets with velocities outside the notch are recognized immediately as targets. However, if a target is at an aspect of 90 degrees TA to the antenna, then its return gets filtered out, even if the return is received.

If a target is moving away from you and is also co-speed, there will be no Doppler frequency shift (see Figure 4-5); however, these frequencies are not filtered out, so the returns will be displayed.

Most modern fighter radars have selectable radar settings, which helps enhance PD in any situation while eliminating false tracks.

405. A/A TARGET DETECTION

1. Probability of Detection

Probability of detection, or P_D, is the range at which the radar has a 90 percent probability of getting a return from a particular contact. As a radar operator, the SNFO's job in the A/A environment is to operate the radar in such a way that maximizes the PD for what the operator is searching for or expecting to detect. An SNFO must have an understanding of the factors that affect $P_{D,}$ which include PRF, bar scan, radar cross section (RCS), clutter effects, and the Doppler notch.

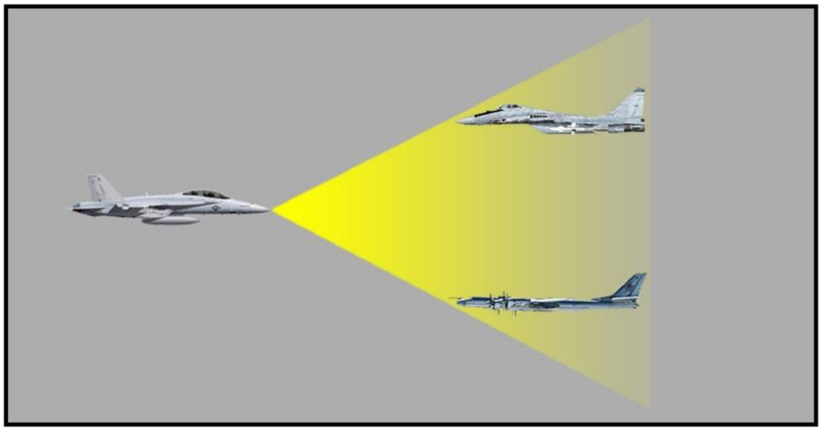

Figure 4-8 Physical Size Does Not Matter In A PD Radar

A well-trained operator can manipulate radar controls to account for all those factors except RCS and any clutter filtering logic built into the radar.

2. PRF and Duty Cycle

As previously stated, PRF is a measurement of how many pulses per second the radar transmits. The percentage of time sharing between transmitting and receiving is called the radar’s duty cycle. There are three types of duty cycles; low, medium, and high. Each duty cycle has its own important employment considerations.

3. Low PRF (LPRF)

Low PRF is an all aspect duty cycle and is defined as a 1 percent transmit and 99 percent receiving time sharing. It is often used in A/G modes. Low PRF offers all aspect contact with no filters, good range resolution due to shorter transmission times, and less sidelobe clutter; however, these advantages come with the drawbacks of low power out and therefore short detection ranges.

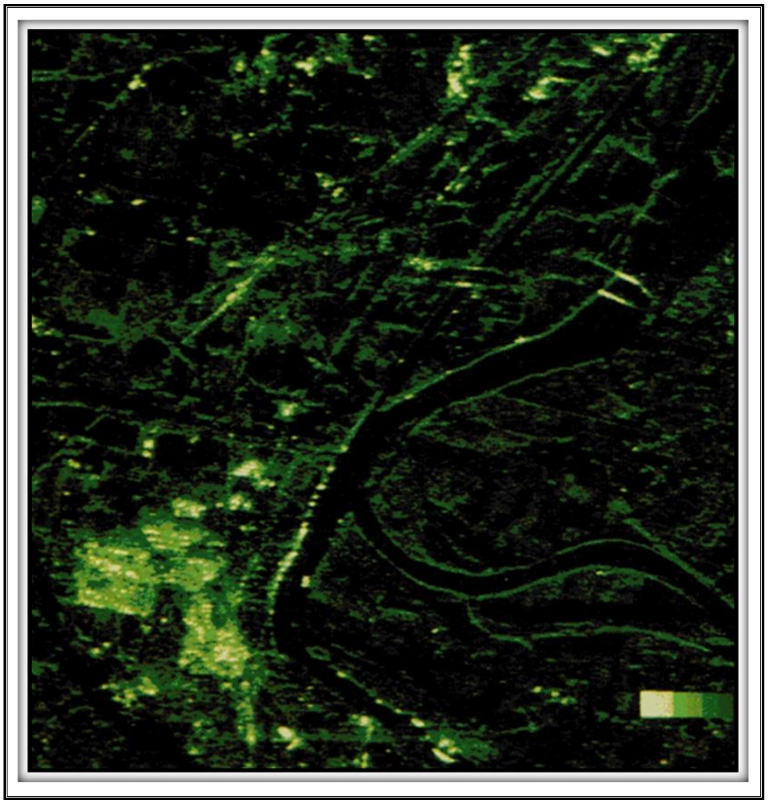

Figure 4-9 Ground Map with Low PRF

4. Medium PRF (MPRF)

Medium PRF duty cycle is a 10 percent transmit and 90 percent receive time sharing scheme. This provides nearly all aspect contact detection, but requires some filtering. It additionally provides for medium power out, the detection of fighter-sized contacts at medium ranges with moderate relative Doppler velocities.

Medium PRFs drawbacks include the use of Doppler filtering to eliminate clutter around ownship speed, which eliminates some targets in the "notch," medium clutter reception, and moderate range resolution ability.

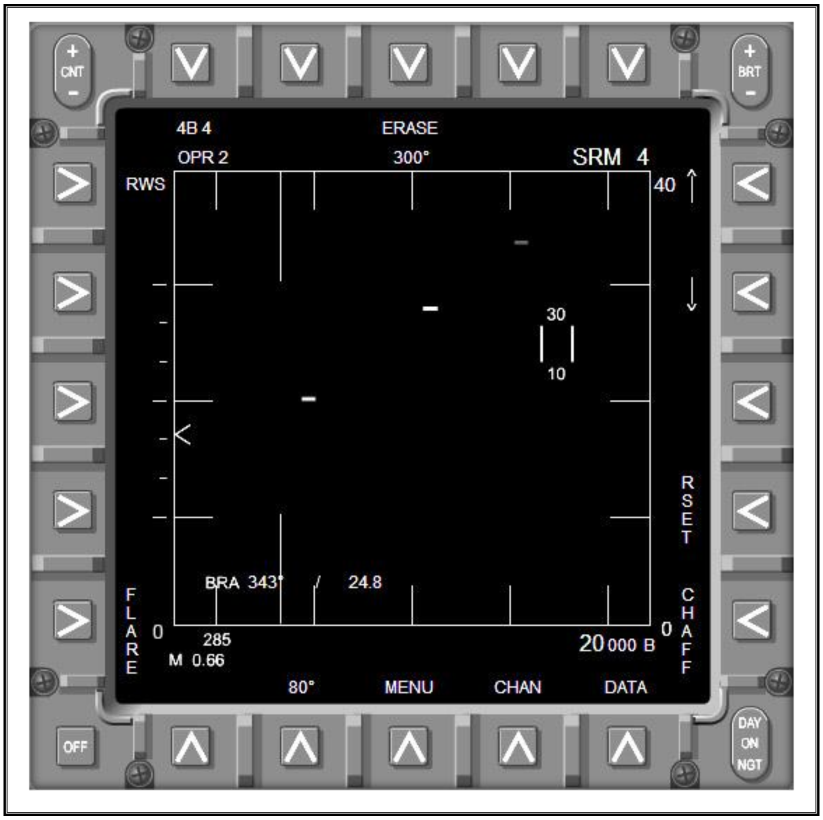

Figure 4-10 Typical PD MPRF Screen

5. High PRF (HPRF)

High PRF duty cycles are represented by a 30-percent transmitting and 70-percent receiving time sharing scheme. HPRF provides for the longest range detection due to higher average power out and is used in situations and modes where long range detection is required.

HPRF has distinct disadvantages, however, including the need for high closure rates, detection of more clutter due to higher power out and poor range resolution due to increased pulse time.

6. Bar Scans, Frame, Frame Time, and Dwell Time

Recall that A/G radar uses a single bar scan to paint the ground and create a map of the ground. In an A/A radar, the elevation of the antenna is changed at the end of the azimuth sweep in order to cover more airspace. Each sweep in azimuth constitutes a bar, and the number of bars in the scan constitute the bar scan. One complete scan of all bars is called a frame. The time it takes the radar to complete one frame is called the frame time. Frame time depends on the number of bars selected, the azimuth of the scan and the azimuth scan rate of the radar.

The amount of time a radar spends on a target is called dwell time. The longer the frame time, the longer the period between dwell times. Since the radar can only get actual target information during a dwell time, longer frame times mean that the time between dwells is longer. As a result, the radar updates the target information less frequently and the radar processor's extrapolated information becomes less accurate.

Frame time should be taken into account in A/A planning, especially when using large azimuth, multi-bar scans, because a target can maneuver significantly dwell times in long frames. This relationship and visualization is important to understand because all modern fighter radars use multi-bar scans.

7. Interleaving PRF to Enhance P_D

Most modern fighter PD radars use some kind of an interleaving scheme to counter the negative aspects of medium and HPRF. Interleaving means that the radar ensures that if a bar is scanned in medium PRF in the current frame, it will be scanned in high PRF in the next frame and vice versa. This prevents any displayed frame from being the result of only one type of PRF unless the operator has manually selected the PRF. In Figure 4-11, the first and third bars are HPRF and the second and fourth are Medium PRF in the first frame. This will be reversed in the next frame.

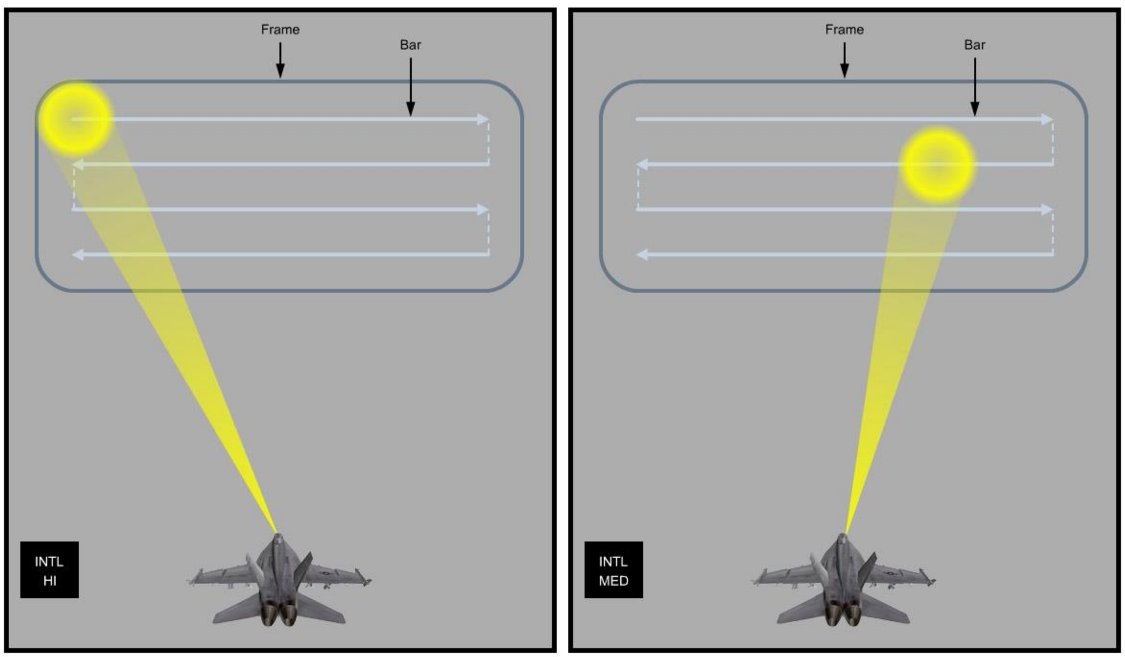

Figure 4-11 Interleaved PRF Scheme

8. Enhancing PD with FM Ramping

A closely related concept to PRF is frequency modulation ramping, or FM ramping also called "pulse color coding." At higher PRFs, the incoming and outgoing pulses overlap. To compensate for this, the radar minutely and automatically shifts the frequency of each pulse so that each pulse has a unique frequency. When that pulse is received, the radar can immediately identify the pulse by its frequency or "color" and the information contained. This technique is also used to reduce the number of false targets through modulation of the frequency as soon as a target is detected so that subsequent pulses reflected by that target can be evaluated as real or erroneous returns.

9. Search Volume

The combination of bar scan, azimuth selection, and range define the radar's search volume. The search volume can be defined as the volume of airspace that the radar may detect contacts and is based on its current operating settings. The aircrew are responsible for adjusting the scan volume's size and elevation to ensure that their area of responsibility (AOR) is sanitized, that is, clear of any unknown or hostile contacts. In Figure 4-12, the radar's search volume is a 3-D volume of space scanned each frame. The parameters that make up the frame determine the volume at any range.

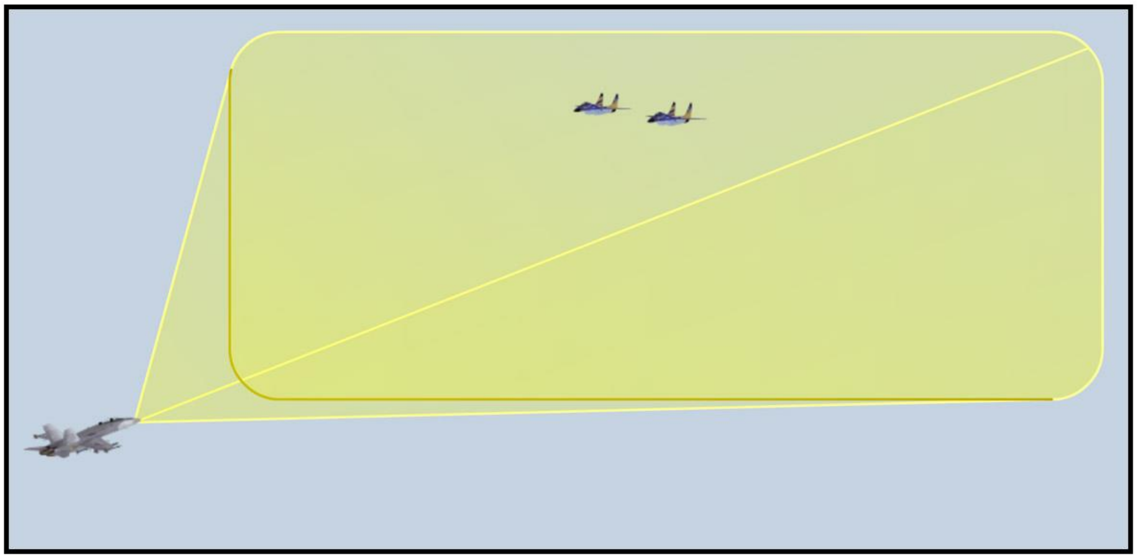

Figure 4-12 Radar's 3-D Search Volume

406. OFT AND VMTS A/A RADAR DISPLAYS

1. Radar Attack Display

The T-45C VMTS and OFT A/A radars simulate search and track modes similar to those found in the APG-73 of the F/A-18 C/D and early models of the E/F. Radar information is presented on the radar attack display. Although there are some differences between the OFT and VMTS radars, the presentation of the information is common to both.

The A/A format presented is called a "B-Scope" and is typical of modern fighter radars. The B-scope is an azimuth vs. range presentation. The scope presents a somewhat distorted view as the entire bottom of the scope represents the nose of the aircraft.

With the exception of velocity search, or VS mode, all displays in the VMTS and OFT systems are a B-scope, which displays azimuth versus range.

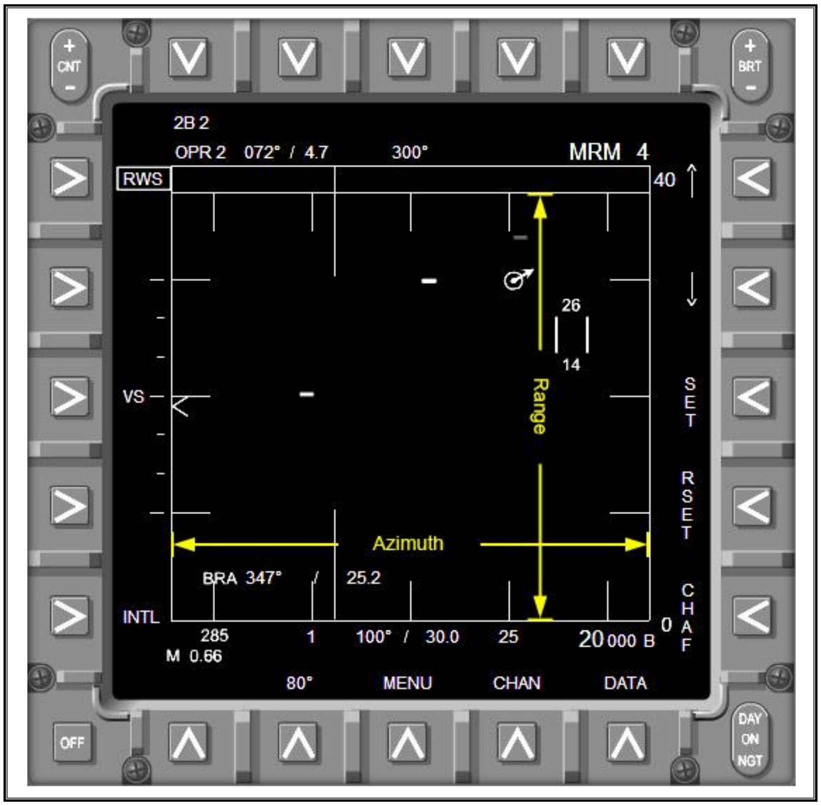

Figure 4-13 Azimuth Versus Range

2. Entering the Radar Attack Display

There are differences in how the information is entered into the OFT and VMTS displays.

3. OFT

In the OFT, the radar attack display is entered in the OFT by pushing the TMC switch on RHC forward while in NAV or A/A master mode.

4. VMTS

In the T-45C VMTS selecting the RDR pushbutton enters the radar attack page.

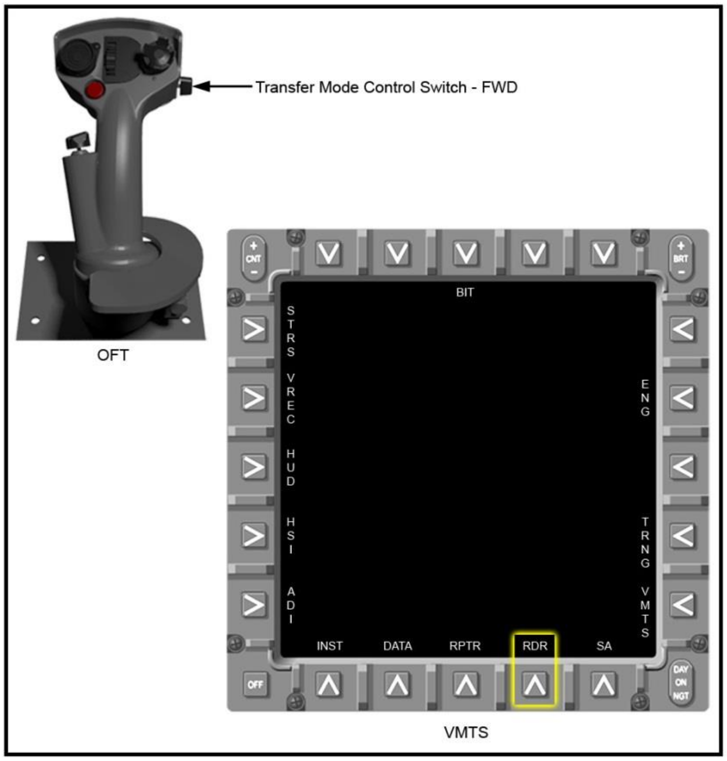

Figure 4-14 Entering the Radar Attack Display

5. Commonalities of VMTS and OFT Displays

There are a number of items on the display that are common to all radar modes. These are covered in the following screens.

6. Display Areas

The radar attack display is divided into non-tactical and tactical regions.

The non-tactical region:

a. Displays radar parameters and selection

b. Ownship information

c. Cursor position from bullseye

d. TDC selection of some parameters

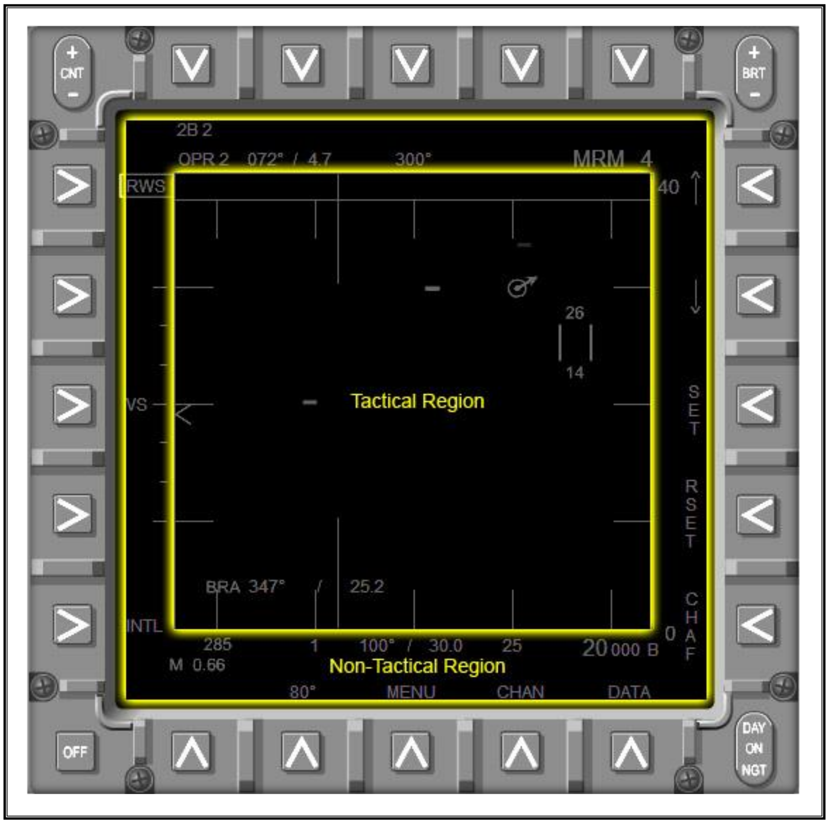

Figure 4-15 Tactical and Non-tactical Regions

Tactical region is inside the rectangle on the display. Information in the tactical region includes the display of detected targets, radar cursor, air-to-air waypoint and cursor BRA information as well as weapon launch zone and steering information when a contact is designated as a launch and steering (L&S) target.

7. Tactical Region Tick Marks

The radar's tactical region has horizontal and vertical tick marks.

Horizontal tick marks indicate subdivisions of the current range scale in Range While Search (RWS), Track While Scan (TWS) and Single Target Track (STT) modes. Range is represented as a fraction of the currently selected range. If 40 NM range is selected, the middle tick mark is 20 NM.

In Velocity Search, these horizontal marks represent velocity from 0 to a scale of 800 or 2,400 KTS.

The vertical tick marks denote azimuth angle off the nose in 30° increments. There are marks at 0-degrees, 30-degrees, and 60-degrees left and right which represent lines of bearing from the fighter's nose.

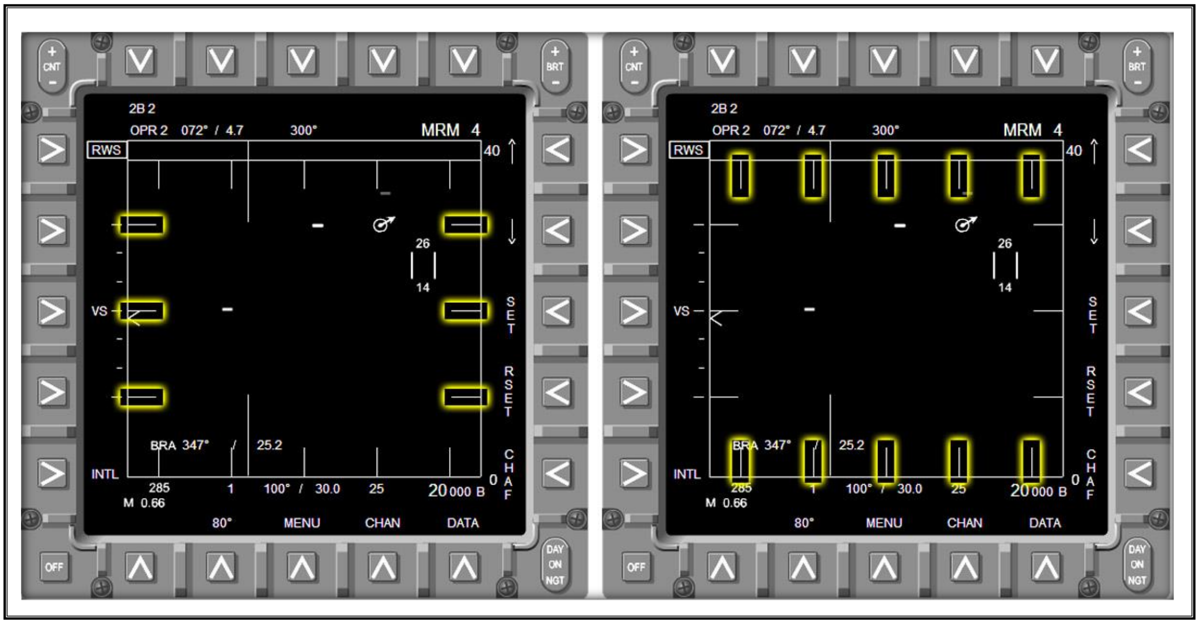

Figure 4-16 Horizontal andVertical Tick Marks

8. Antenna Elevation Scale

The scale on the outside left of the tactical display represents radar antenna elevation, just as it did in the A/G modes. In A/A modes, this scale represents -60 degrees to +60 degrees at the top and bottom of the tactical area and 0 degrees elevation in the center. The first 30 degrees of elevation in each direction are further subdivided into 10-degree tick marks on the outside of the tactical area. The caret indicating radar elevation in degrees is displayed inside the tactical region.

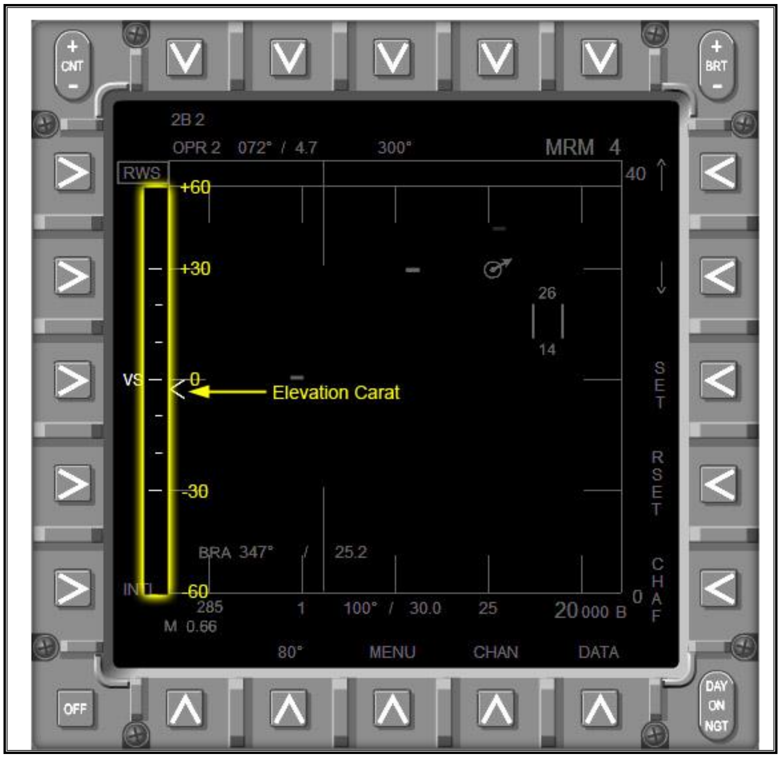

Figure 4-17 Elevation Scale and Caret

9. Displayed Ownship and Cursor Information

The attack display provides the following cues to aid in situational awareness:

a. Ownship Flight Information

b. Ownship Position

c. Cursor Position Information

Position information from the A/A reference waypoint, or bullseye, is based on the A/A waypoint selected on the waypoint data sublevel.

10. VMTS Ownship flight information

a. Altitude

b. Airspeed in KIAS and IMN

c. Heading

d. GINA GPS position figure of merit (PFOM); 1= BEST; VMTS Only

11. OFT Ownship flight information

Ownship flight information displayed includes:

a. Altitude

b. Airspeed in KIAS and IMN

c. Heading

d. No PFOM displayed

In both systems these values are directly repeated from the same source as those driving the HUD displayed values.

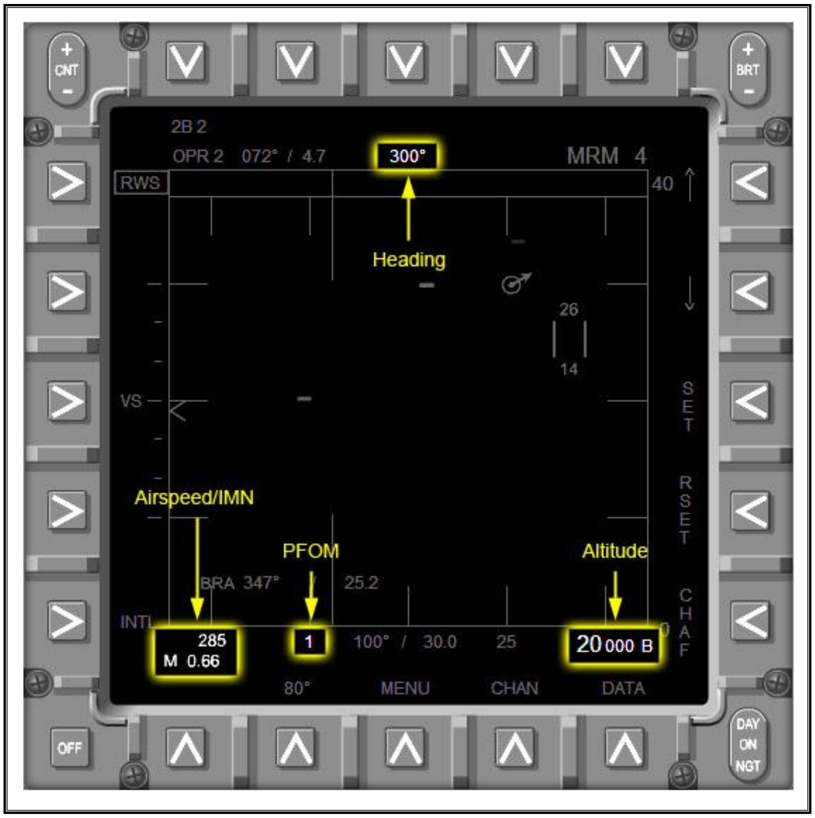

Figure 4-18 Ownship Information in VMTS

Ownship position from the A/A reference waypoint, also known as the bullseye, is provided at the center of azimuth display, just outside the tactical area in the VMTS. When within the range and azimuth limits of radar scan volume, the A/A waypoint is displayed as a circle with a north pointing arrow. Ownship position from bullseye is not displayed in the OFT radar.

12. Cursor Position Information

To aid in tactical situational awareness, the cursor position from bullseye is displayed in VMTS between the operating status and ownship heading left just outside the tactical area. This is not available in the OFT.

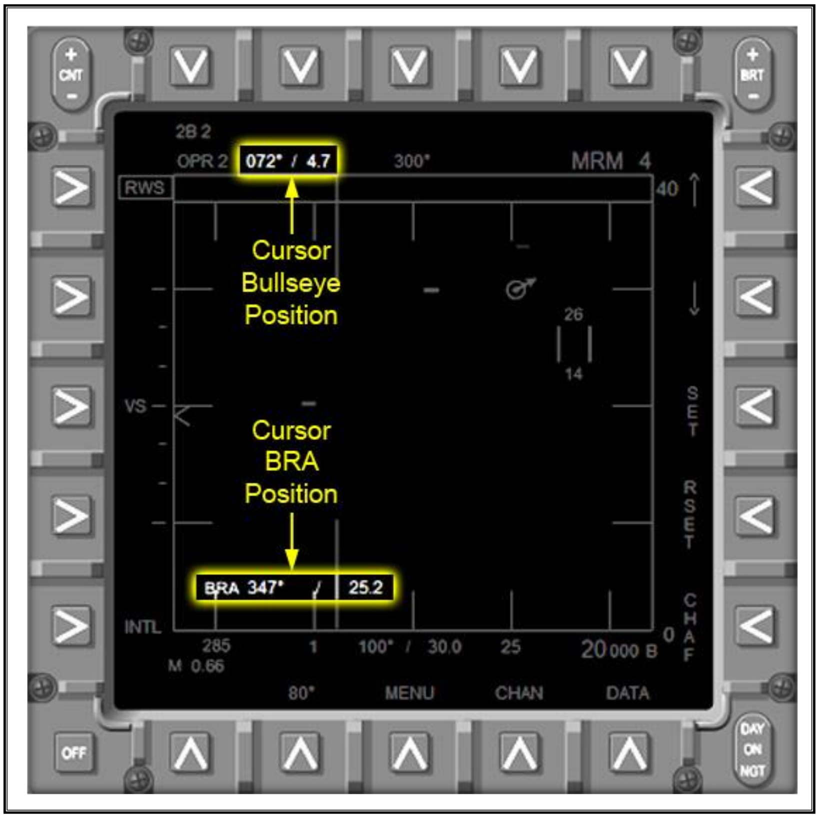

Figure 4-19 Cursor Information in VMTS

Cursor position from the ownship in bearing and range is displayed in both VMTS and the OFT at the bottom left of the tactical area preceded by BRA (Bearing, Range, Altitude). This information is based on the cursor position from the fighter and can be removed from the display via:

a. DCLTR (PB 12) option in DATA sublevel in the OFT

b. Unbox the BRA option (PB 14) on the DATA sublevel in the VMTS aircraft

13. Scan Volume Altitude Search Indications

The numbers displayed above and below the radar acquisition cursor correspond to the maximum and minimum altitudes of radar coverage, rounded to the nearest thousand feet MSL, at a given range. This volume is dynamic and is directly related to the bar scan selected. A scan volume with one bar will have a much smaller altitude coverage than one with multiple bars. In Velocity Search mode, these numbers represent scan volume at 80 NM range scale.

In order for the radar to detect a contact, the target must be at an altitude between the numbers displayed above and below the cursor at the target's range. Figure 4-20 shows the search volume for a 22,000 foot aircraft in a B scan.

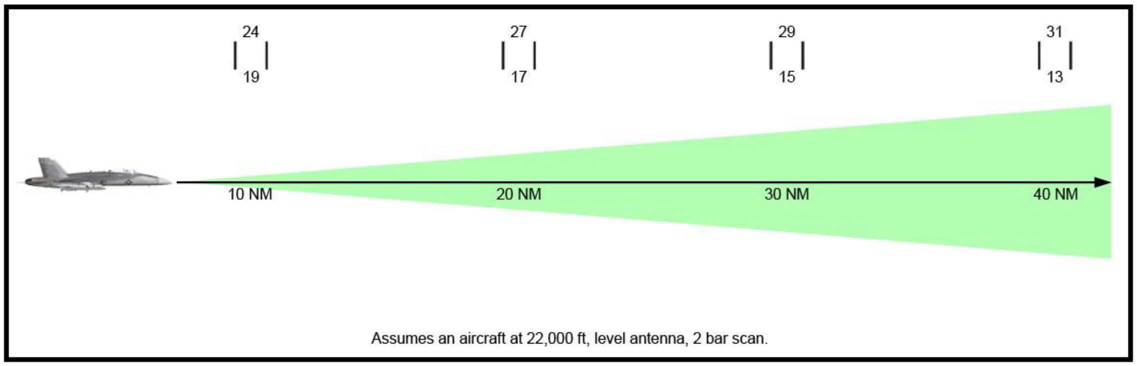

Figure 4-20 Search Volume Altitude

14. Changing Indications with a Moving Cursor

When the cursor is moved around the display, the cursor bullseye position, cursor BRA position, and altitude search volume indications will all change. The operator should expect and understand how these values change in order to predict where contacts will appear on the display and where the cursor should be placed to increase a more rapid detection of AIC identified contacts.

15. Azimuth Scan and Elevation Scan Volume Adjustment

The bar scan option at PB1 changes the number of bars the radar will scan in each frame. In both the OFT and VMTS, the options are 1, 2, 4, or 6 bars, depending on the radar mode. As these values are adjusted, the altitude search volume will change to show the altitude of radar coverage at the current range of the cursor. This volume is then adjusted up and down in altitude with the elevation control wheel.

Azimuth scan volume is adjusted at PB14 the same as in A/G mode. In addition to the azimuth indication above the pushbutton, the B-sweep, which is an indication of antenna position, will change as it travels across the display based on this selection, with 140 degrees providing full azimuth coverage. Anytime the azimuth selection is less than 140 degrees, the azimuth of the scan volume can be moved, as in the air-to-ground modes, by placing the cursor and the new desired center point and selecting first detent and release of the trigger in OFT and second detent trigger and release in VMTS.

16. Target Symbology

The radar displays A/A target symbology depending on the information known about the target.

Upon first detecting a target, the radar will display a hit, also called a "brick." Bricks represent a radar trackfile, not raw radar returns. Bricks will fade or "age" if there is not sufficient information in following frames and disappear based on the aging option on the data sublevel in VMTS. Target aging is automatically selected to be larger than frame time in the OFT.

In the OFT, once a trackfile has sufficient information for the radar to estimate its heading, airspeed, and altitude, a point acquisition cue (point acq cue) is displayed to alert aircrew that additional information is available. Point acq cue is not available in VMTS.

The designated target two (DT2) allows for a second trackfile to be always prioritized as the number two trackfile. LAR symbology is presented for the DT2 in addition to the L&S.

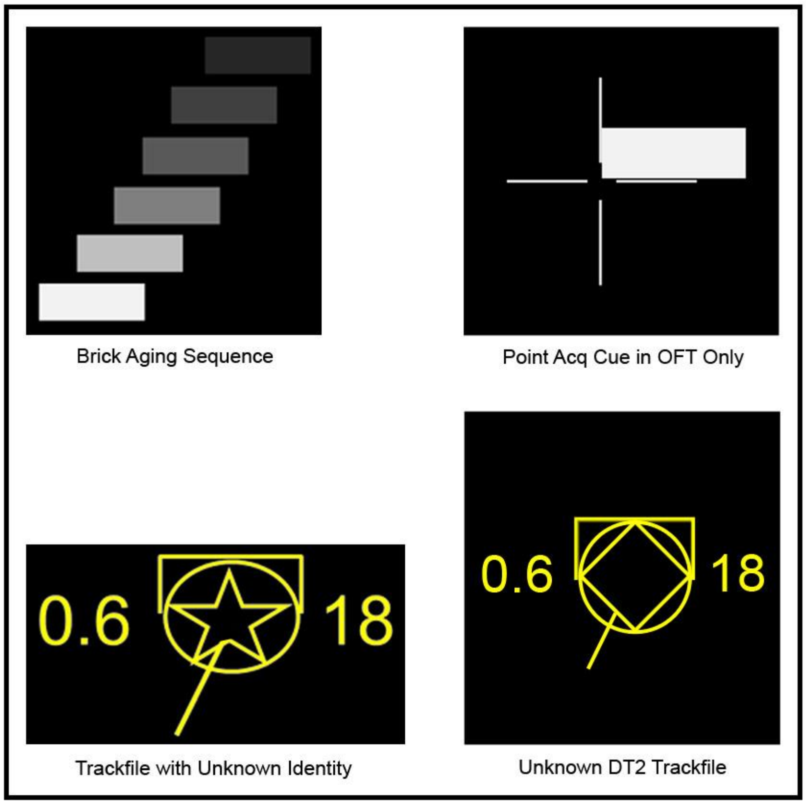

Figure 4-21 Trackfile Symbology

In VMTS the trackfiles are not in color. However, information about the L&S trackfile is displayed in the same place on both radar attack displays.

Common trackfile information includes:

a. L&S heading

b. V_C

c. Differential altitude

d. Computed altitude

e. Computed airspeed in IMN

f. Target aspect (TA) measured from the straight down position

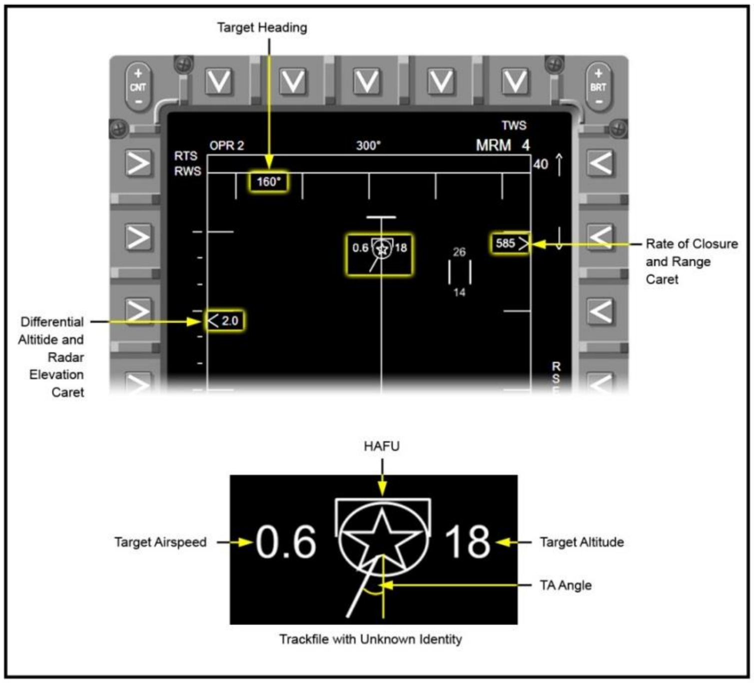

Figure 4-22 VMTS Information On Screen and Associated Trackfile

407. A/A RADAR CONTROLS

The controls and operation of the OFT and VMTS A/A radars, while similar, have several differences.

The A/A modes of both radars are controlled by manipulating:

a. The selected master mode

b. Radar Hand Controller

c. MFCD pushbuttons

d. Radar hand controller/hands on throttle and stick (HOTAS) functionality

1. Radar Hand Controller

In the A/A environment, the RHC is used as the primary interface with the radar.

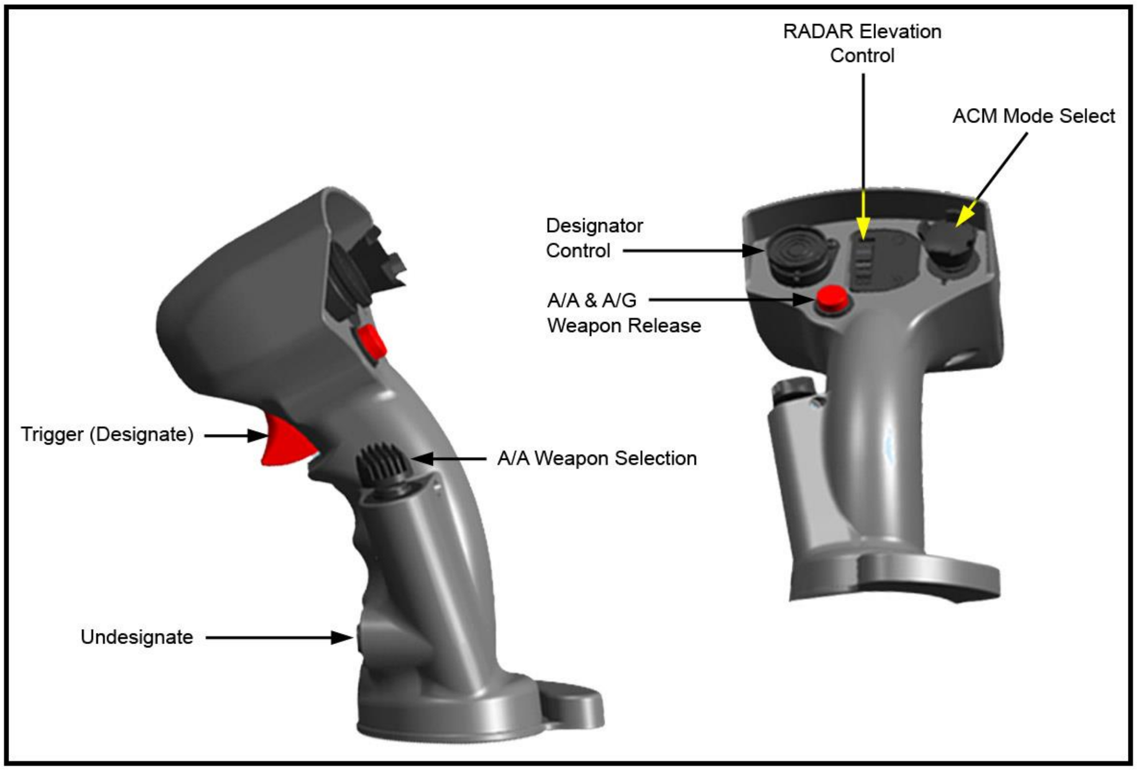

Figure 4-23 Radar Hand Controller Switches

2. Transfer Mode Control (TMC) Switch

The RHC in the OFT differs from that in the VMTS by the inclusion of the TMC switch. The TMC controls the mode in which the OFT displays are operating. Moving the TMC back changes the left display to the UMFO stores page, while moving the switch forward changes the right display to UMFO radar. The TMC was covered previously in this document.

3. Designator Control

The designator control (DC) is a two-axis isometric button with momentary center action detent. In A/A master mode, the DC moves the radar cursor to allow for designation of A/A targets and for the selection of range, azimuth, and bar scan options available through HOTAS functionality. The DC also has a momentary depression position. In A/A master mode, this has no functionality.

4. “Bump” Logic in OFT and VMTS

The radar scan volume can be changed via “display bumping,” defined as moving the cursor out of the tactical area and back in within 0.8 seconds. This action uses the following logic:

a. Bumping the upper border increments the radar range to the next scale

b. Bumping the lower border decrements the radar range to the next scale

c. Bumping left decreases the azimuth scale one increment

d. Bumping right increases the azimuth scale one increment

e. Bumping options wrap around from minimum to maximum and vice versa.

5. DC HOTAS Functionality

In the OFT, in addition to bumping, the following options are selectable by hovering the cursor over the option to show a list to select from:

a. Radar Mode

b. Bar Scan

c. Azimuth Scan

d. Range scale

Selection of options in this method is similar to a pull down menu. Once the list of selections appears, place the cursor over the desired selection and squeeze the trigger to the first or second detent. In addition, placing the cursor over the range arrows and depressing the DC will adjust the range according to the arrow selected.

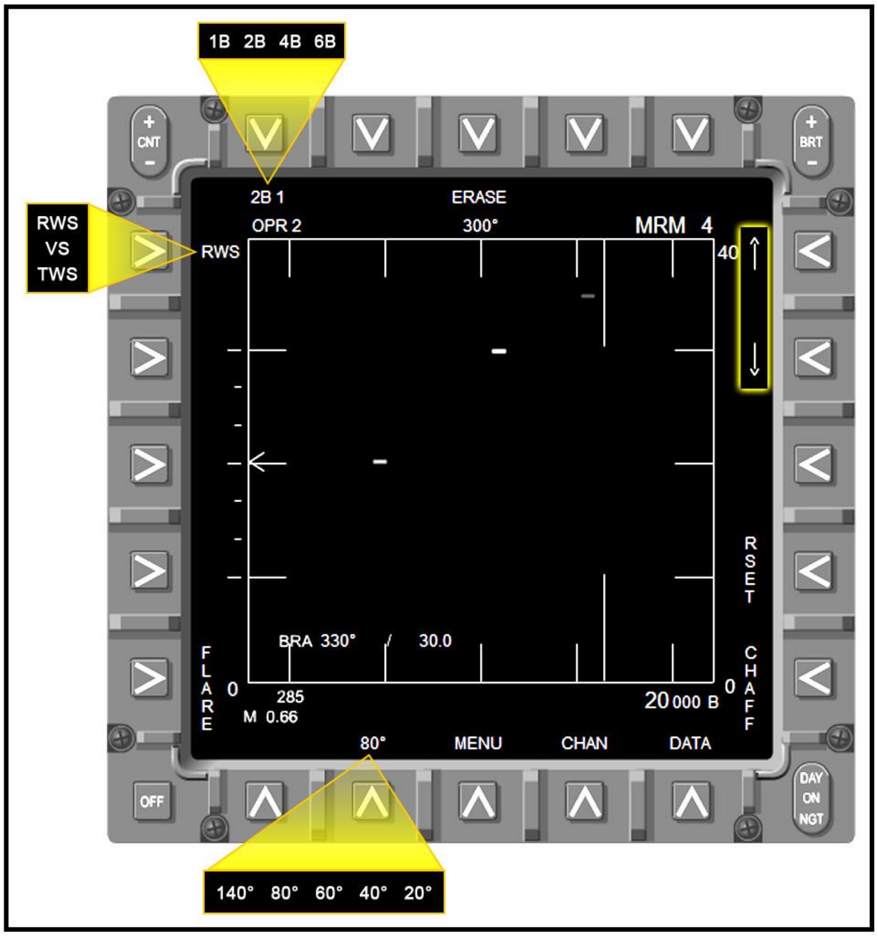

Figure 4-24 HOTAS Selections in OFT

6. Radar Elevation Control

The radar elevation control is a potentiometer that is spring-loaded to the center position. It adjusts the radar antenna elevation. In multiple bar scans, it adjusts the center of the scan volume as indicated by the elevation scale on the left side of the tactical area.

Inputs are ignored in ACM modes, STT and TWS with AUTO scan centering selected, due to the mechanization of these modes.

Holding the radar elevation control in either direction moves the antenna continuously in that direction. To enhance fidelity in adjusting the scan volume in elevation, momentary activation of the control in either direction adjusts the scan volume up or down by 1,000 foot increments.

7. Trigger (Track/Designate) Switch

The trigger is a two-stage pull trigger that provides for track designation. The trigger is recommended rather than DC depression for trackfile designation, because slewing of the cursor is possible while the DC is depressed.

The trigger is a two-stage trigger, which functions as follows:

a. In the OFT:

   i. The first detent and release designates the trackfile under the cursor as the L&S

   ii. The second detent and release commands STT on the L&S

   iii. The first detent also centers the scan volume when azimuth scan selection is less than 140 degrees

b. In VMTS, the first detent has no functionality, but the second detent:

   i. Centers scan azimuth when less than 140 is selected

   ii. First actuation makes the contact under the cursor the L&S

   iii. Second actuation commands STT

In VMTS, the first detent has no functionality, but the second detent:

a. Centers scan azimuth when less than 140 is selected

b. First actuation makes the contact under the cursor the L&S

c. Second actuation commands STT

8. Undesignate Switch

The undesignate switch is a momentary pushbutton located on the bottom front of the RHC. It is also called the “pinky” switch. In A/A master mode with an STT, depression of this switch commands the radar to return to search (RTS) in the mode from which STT was entered (RWS, TWS or VS).

In TWS or RWS, this switch steps the L&S to the next priority target or creates an L&S from the priority target if no L&S currently exists.

In the OFT only, the radar provides extrapolated track information based on the trackfile’s trends. This ability to track contacts and cycle between them is accomplished through the use of track while scan processing during the times the radar is between targets. This is called “latent” track while scan and provides much better information about the trackfiles than would otherwise be known from RWS alone. In the OFT, the point acq cue is a reminder that sufficient target information exists via TWS to designate a L&S trackfile. The point acq cue is a plus sign on the trackfile, or "brick."

9. ACM Mode Select Switch

The ACM mode select switch activates the ACM modes. These modes automatically command STT on the first target detected. Available modes include:

a. Vertical acquisition (VACQ)

b. Wide acquisition (WACQ)

c. Boresight acquisition (BST)

These are discussed in detail in a later section of this chapter.

10. A/A Weapon Select Switch

The A/A weapon select switch is a 4-position momentary switch spring-loaded to the center position, including a center position action detent. This switch selects the A/A weapons as follows:

a. Forward no action

b. Right MRM

c. Aft no action

d. Center press SRM

Selection of any A/A weapon automatically enters A/A master mode. In the OFT, this will not command the system to actuate the transfer mode control to change display functionality.

11. A/A Weapon Release Switch

The weapon release switch commands release of the selected missile or firing of the gun. Anytime this button is depressed, a HUD event marker appears in the HUD video until the switch is released.

Since all A/A weapons are simulated, depression of this switch will result in a fly out cue on the radar, with appropriate symbology, and a decrement of the selected weapon quantity from the displayed inventory.

12. Pushbutton Functionality

As in the air-to-ground mode, the MFCD pushbuttons control most of the functional options of the radar.

13. Pushbutton Functionality – Top of MFCD

Pushbutton (PB) functionality in the A/A radar is similar between the OFT and VMTS.

PB functionality is as follows:

a. PB 1: Bar Scan – displays currently selected bar scan and the bar which the radar is currently scanning. Bars are spaced 1.3 degrees apart. Options are 1B, 2B, 4B and 6B.

b. PB 3 (OFT Only): ERASE – erases raw hit bricks from display. Does NOT erase or reset trackfiles.

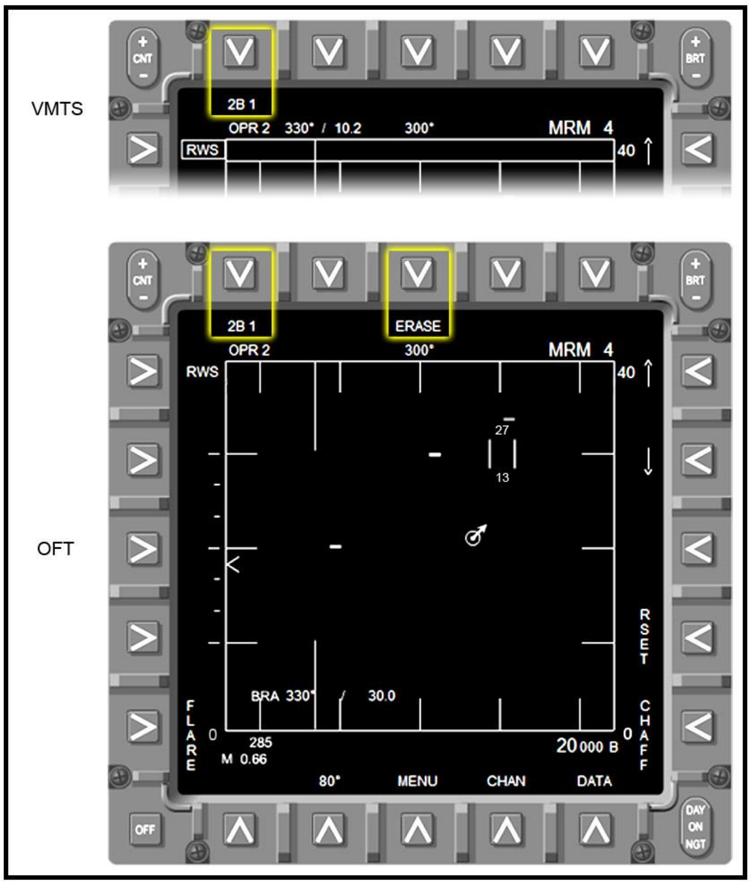

Figure 4-25 Top MFCD Pushbuttons

14. Pushbutton Functionality – Right side of MFCD.

a. PB 6: Increase range scale

b. PB 7: Decrease range scale

Range options are 5, 10, 20, 40, 80, or 160 and wrap around in both directions. HOTAS in OFT, HOTAS Bump in OFT and VMTS.

Continuing down the right side:

a. PB 9: RSET – Resets all trackfiles currently in radar memory. Cancels L&S designation. Radar will reprioritize trackfiles as they are detected.

b. PB 10: CHAF (VMTS) / CHAFF (OFT) – Provides for simulated release of chaff with HUD event marker.

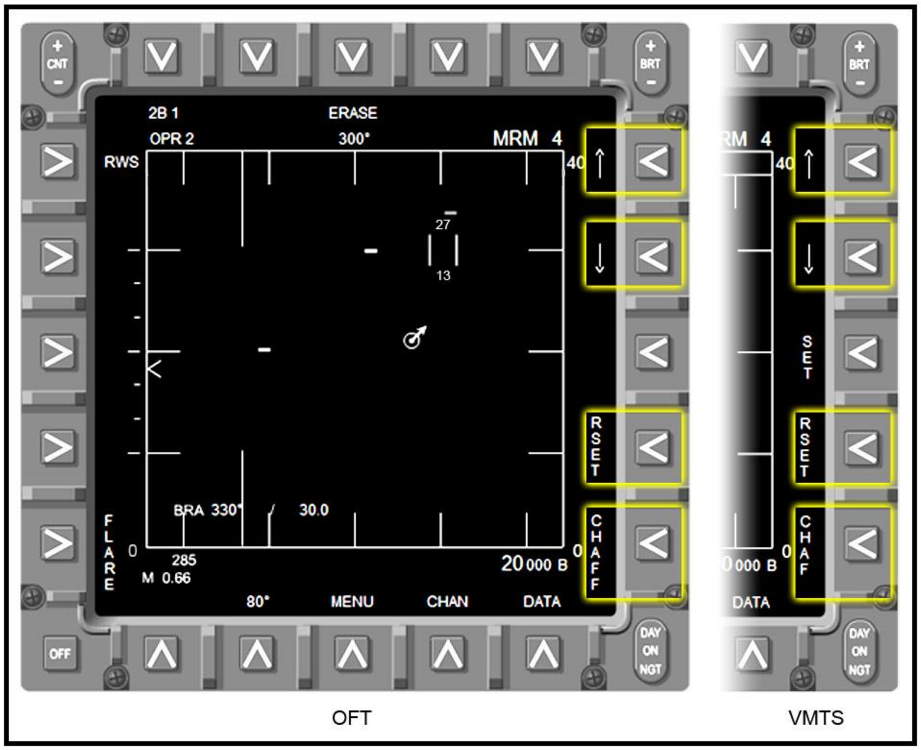

Figure 4-26 Right MFCD Pushbuttons

15. Pushbutton Functionality – Bottom

a. PB 11: DATA - Enter the DATA sublevel.

b. DATA Sublevel Functionality - Most DATA sublevel options are the same as A/G modes, including:

   i. PB 7, 8, and 9: Operating status

   ii. PB 14: BRA information

   iii. PB 16: STOP IBIT

   iv. PB 18: IBIT initiation

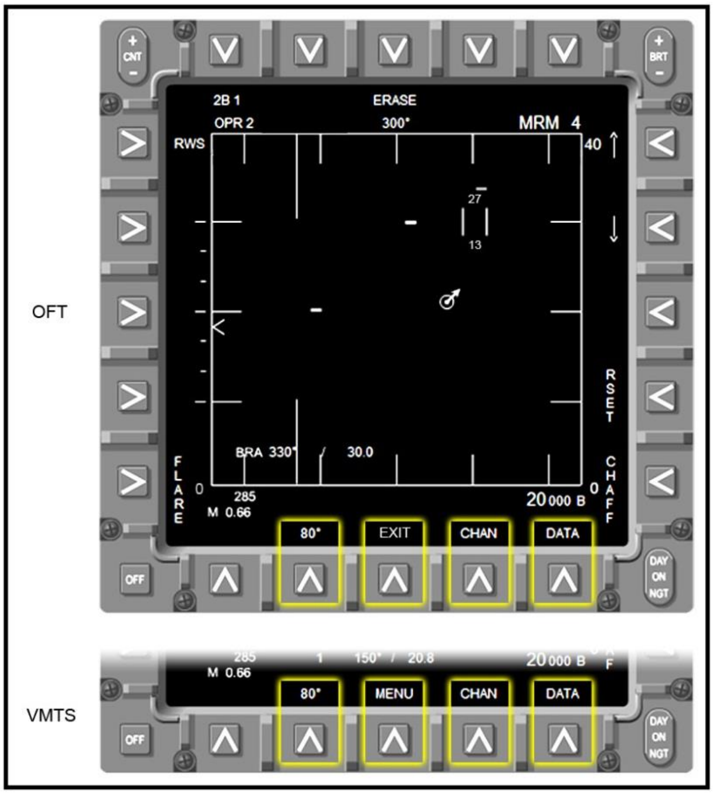

Figure 4-27 Bottom MFCD Pushbuttons

c. Target Aging (VMTS Only) – PB 5 allows for selection of target aging. This number represents the number of seconds it takes for the raw "brick" to fade out on the display with the following options:

   i. Options of 2, 4, 8, 16, or 32 seconds with wraparound

   ii. TWS is set to 2 seconds by default, but retains the new setting only if changed while in TWS

Target aging should always be just greater than frame time so that bricks do not completely age out each frame. This increases the aircrew SA as to which contacts are new. If target aging is always the maximum, the display can get cluttered with erroneous hits.

d. Declutter Options

i. Declutter Options: DCLTR (VMTS) & DCLTR1 (OFT)

ii. Declutter provides the option to remove some of the information from the display to aid in discerning targets

e. The default is unboxed in VMTS. In VMTS, the DCLTR boxed removes:

i. Target differential altitude

ii. Target heading

iii. Range rate (V_C)

iv. Range caret

f. The default is DCTLR1 selected in OFT. In OFT, DCTLR 1 removes:

i. Horizon bar

ii. Velocity vector

It is recommended that the default settings are used while at VT-86.

g. DATA Sublevel BRA Option

i. As in the A/G mode, unboxing BRA removes cursor BRA information from the attack display. Default is boxed, meaning the information is displayed.

ii. Recommended setting is BRA boxed.

iii. The RWR ATTAK option at PB 20, displays RWR information on the attack display. This information is displayed as an inverted triangle below the angle only track dugout on the display.

iv. Having RWR information on the attack display assists in correlating airborne threats with the recognized air picture. A spike from the same azimuth as a known threat correlates that threat's status, whereas a threat from an azimuth that does not match a known contact can be an indication of additional, unidentified threats.

v. VMTS only displays threats with an STT within the azimuth scan of the radar. The OFT display will stack threats at the edge of the display closest to azimuth of the detected threat.

h. Continuing across the bottom of the MFCD:

i. PB 12: CHAN – Increments the radar channel; In VMTS Channels 1-8 are available and wrap around. In OFT, channels 07-12 and 19-32 are available via HOTAS and pushbutton function.

ii. PB 13: EXIT (OFT) / MENU (VMTS) – Exits the attack display and returns to the MENU page. In OFT exits training mode to MENU.

iii. PB 14: Azimuth Scan Selection

(a). OFT options are 20 degrees, 40 degrees, 60 degrees, 80 degrees, and 140 degrees

(b). VMTS options are 20 degrees, 40 degrees, 60 degrees, 80 degrees, and 140 degrees

16. Pushbutton Functionality – Left

There is no indication of PRF in the OFT. In OFT, PRF is automatically selected and this PB simulates the dispensing of flares.

a. PB 16: PRF selection (VMTS) with MED, HI and INTL (default) options.

In OFT, the current radar mode is displayed. PB options are RWS and TWS. VS is only available through HOTAS selection after hovering the cursor at PB 20.

a. PB 20: Radar mode selection. In VMTS, the current mode is boxed and available options are RWS and TWS

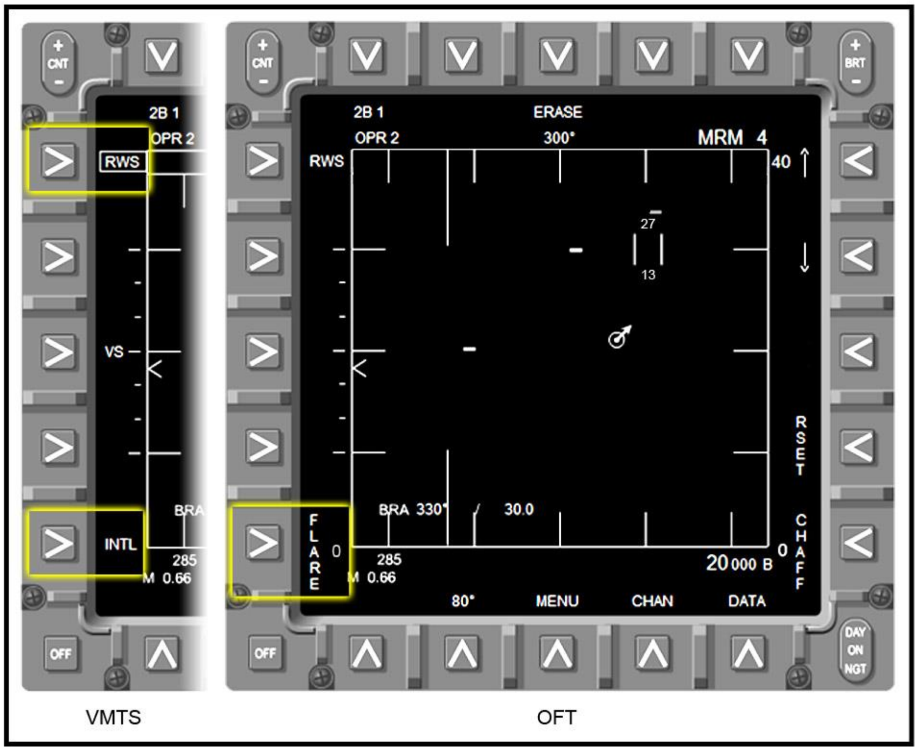

Figure 4-28 Left MFCD Pushbuttons

408. T-45C VMTS AND OFT RADAR SEARCH MODES

The T-45C VMTS and OFT A/A radars simulate search and track modes similar to those found in the APG-73 of the F/A-18 C/D/E/F. There are three A/A modes: Search, Track, and Auto Acquisition. Search modes are not weapon employment modes. They are designed to provide all aspect target detection, but are not mechanized to support radar missiles. The two search modes for the radar; Range While Search and Velocity Search.

1. Range While Search (RWS)

Range While Search (RWS) is the primary search mode of the radar. In this mode the display is in the B-scope format that is the width of the display represents degrees in azimuth while the height is range in NM. RWS provides all aspect target detection and maximum control over the search volume. It also allows for the largest search volume.

RWS is the default mode of the radar when the A/A master mode is entered. RWS can also be manually selected at pushbutton 20, or it can be selected via the RHC by hovering the radar cursor over the radar mode selection options and using a full action trigger.

RWS contacts are presented in the format of raw hits or "bricks." Detailed trackfile data is only displayed if the cursor is placed over the raw hit. RWS allows for detection of targets and the establishment of trackfiles. The radar will prioritize the top eight trackfiles and allow them to be cycled through as the L&S using the undesignate switch. To manually designate a trackfile as the L&S, place the cursor over that trackfile, squeeze the trigger to the first detent and release. Depressing and releasing the DC will also manually designate a trackfile; however, this technique is not recommended as it may inadvertently slew the cursor while attempting a designation.

2. RWS Selectable parameters

RWS allows for the following selections:

a. Range: 5, 10, 20, 40, 80, 120 NM

b. Bar Scan: 1B, 2B, 4B, 6B

c. Azimuth Scan

d. VMTS: 20 degrees, 40 degrees, 60 degrees, 80 degrees, 140 degrees

e. OFT: 20 degrees, 40 degrees, 60 degrees, 80 degrees, 140 degrees

In VMTS, PRF defaults to interleaved with interleaved (INTL), MPRF (MED), and HPRF (HI) selectable.

There are no limitations to the combinations of selections for these parameters in RWS.

f. INTL PRF in VMTS RWS

i. Because of the inherent differences in probability of detection between HPRF and MPRF, radar designers commonly interleave the PRFs in a single frame. This means that in a multi-bar frame, the first bar will be HPRF and the second MPRF. In the next frame, the first bar will be MPRF and the second HPRF and so forth.

ii. Using interleaving enhances PD by ensuring that each bar is scanned by different PRFs in successive frames. This provides the radar with all-aspect, look down, shoot down capability and means that targets are detected against surface clutter, in all weather conditions, and with any target aspect.

iii. The OFT assumes automatic selection of PRF to best maintain contact.

3. RWS Default Sets

In order to facilitate the rapid acquisition of targets with A/A weapons selected, there are default settings for azimuth, PRF, range, and bar scan for both the MRM and SRM when these modes are selected.

These default sets are entered any time the weapon is selected and radar is in RWS. If not in RWS, the operating parameters of the radar do not change.

The default radar sets are similar to those used by the F/A-18 community.

a. VMTS Default Sets – In VMTS, the MRM RWS default is:

   i. 80 NM range

   ii. 140 degrees azimuth scan

   iii. 6 bar elevation scan

   iv. INTL PRF

   v. 16 second target aging

      (a). This frame takes about 12 seconds to scan. Therefore, targets will not age out between frames.

b. The SRM default scan is:

   i. 40 NM range

   ii. 80 degrees azimuth scan

   iii. 4 bar elevation scan

   iv. INTL PRF

   v. 8 second aging

      (a). This scan volume allows for much faster update rates and target detection within 40 degrees of the fighter's nose.

c. OFT Default Sets – In the OFT, the MRM RWS default is:

   i. 80 NM range

   ii. 140 degrees azimuth scan

   iii. 6 bar elevation scan

      (a). Aging and PRF are set by the radar in the OFT. This frame takes 13 seconds to scan. Therefore, targets will not age out between frames.

d. In the OFT, the MRM RWS default is:

i. 80 NM range

ii. 140 degrees azimuth scan

iii. 6 bar elevation scan

(a). This frame takes 13 seconds to scan. Therefore, targets will not age out between frames.

e. The SRM default scan is:

i. 40 NM range

ii. 80 degrees azimuth scan

iii. 4 bar elevation scan

(a). This scan volume has faster update rates for target detection within 40 degrees of the fighter's nose.

4. Velocity Search

Velocity Search (VS) mode is unique in that the display shows azimuth vs. closing velocity in knots. The scale options of 800 and 2,400 indicate the maximum velocities displayed, with the higher the ROC, the higher the contact will be on the display. Altitude scan coverage is displayed for an 80 NM range scale at the current bar and elevation setting.

Although VS provides for the longest range detection of targets, the radar does not compute the distance to the target. VS is not a weapon employment mode. It is selectable only through TDC selection at PB 20 in the OFT and at PB 18 in VMTS. VS is useful in detecting small RCS, high velocity targets but due to its limitations it is not used at VT-86.

VS presents information in an azimuth versus closing velocity format. These selections do not wrap and are adjustable via up and down arrows at PB 6 and 7. VS is not available via HOTAS in the OFT. VS is only entered through HOTAS by hovering at the radar mode PB 20.

5. VS Display

VS presents information in an azimuth vs. closing velocity format. There are two selectable scales for closing velocity, 800 and 2,400 knots of closure. These selections do not wrap and are adjustable via up and down arrows at PB 6 and 7. In VS, contacts with higher closing appear closer to the top of the display, with low closure targets toward the bottom.

The cursor in VS displays altitude coverage based analogous to an 80 NM display range. Scan volume options for bar scan, azimuth and scan centering via DC action are similar to those in RWS. When the cursor is placed over a contact, the contact's closing rate is displayed.

STT can be entered from VS by placing the cursor over a contact and squeezing the trigger to the second detent. RTS RWS will then appear at PB 20 and TWS option will appear at PB5. There is no option to return to VS from STT.

ACM modes, covered in a later topic, take priority over VS. Deselecting the ACM mode entered from VS will return the radar to VS.

If SRM or MRM selected from VS, and an STT is then commanded, the radar will return to the selected weapons RWS set and not revert to VS when undesignate is selected.

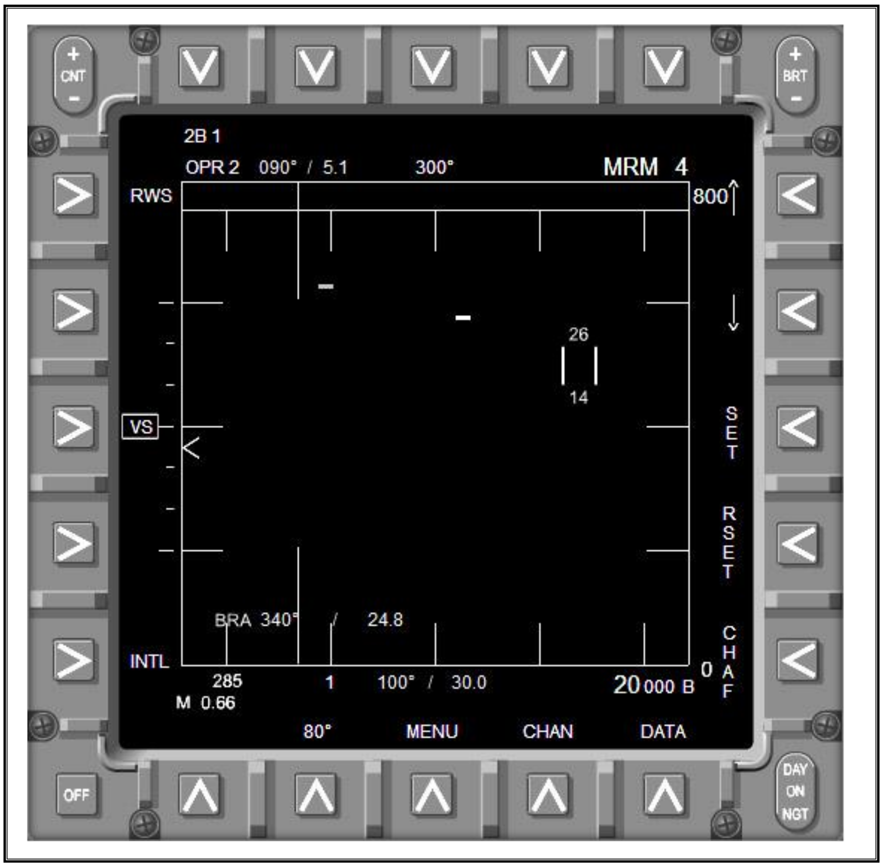

Figure 4-29 Velocity Search

409. T-45C VMTS AND OFT RADAR TRACKING MODES

The radar has two tracking modes, Track While Scan (TWS) and Single Target Track (STT). Both tracking modes are weapon employment modes.

1. Track While Scan (TWS)

TWS allows for simultaneous all-aspect detection and weapon quality tracking of up to 8 targets resolved in range, azimuth, and elevation. The multi-target tracking capability comes at the expense of scan volume size. TWS supports manual search volume combinations of azimuth and antenna elevation scan bars, to limit total radar antenna travel time to 3 seconds or less. This provides trackfile update rates for as many of the highest ranked target trackfiles as possible, allowing for weapon quality tracks to be maintained on 8 trackfiles simultaneously.

Scan centering is manually accomplished (MAN setting) if TWS is entered from RWS without an L&S. TWS scan volume is automatically positioned to center to support a missile in flight or on the priority trackfile if TWS is entered from STT. This functionality is used in the meld procedure taught in the A/A syllabus.

The top eight priority trackfiles will be displayed with a HAFU and their trackfile ranking number. The L&S trackfile can be stepped through displayed trackfiles via the undesignate switch. As in RWS, a DT2 can also be specified in TWS.

2. Entering TWS

Entering TWS is done manually by selecting TWS at PB 5. TWS is not the default mode for any weapon. Option sets cannot be set in VMTS the way they are in RWS.

In TWS, the scan volume is limited to specific combinations of azimuth and bar scans to reduce frame time and allow for tracking and weapon support to multiple targets.

Aircrew must ensure that the contacts they wish to track are inside the TWS scan volume. This is assisted by AUTO scan centering, which strives to keep the majority of trackfiles; however, trackfiles will continue to age out up to the 140 degree limit of the scope whether they are in the current TWS scan volume or not. The sensor operator must keep this in mind when using TWS.

3. Scan Volume Options

Because of the frame time restrictions in TWS, the following combinations of bar scans and azimuth are available:

a. 2B/20 degrees, 2B/40 degrees, 2B/60 degrees, 2B/80 degrees

b. 4B/20 degrees, 4B/40 degrees

c. 6B/20 degrees

Selecting a bar scan will force an azimuth selection compatible with that bar scan. A two bar scan provides the widest available azimuth; 80 degrees. If the bar scan is increased to 4 bars, the azimuth will automatically decrease to 40 degrees.

HOTAS bumps in range and azimuth the same as in RWS within azimuth selections of 20 degrees, 40 degrees, 60 degrees, and 80 degrees. Bumping azimuth out will decrease the bar scan to a compatible scan.

4. Scan Centering

Because of the reduced scan volume in TWS, the option for manual or automatic scan centering is available at PB 13 in both VMTS and OFT.

The AUTO selection centers azimuth and elevation to include as many trackfiles as possible. This is automatically selected if TWS is entered from STT or if a break track occurs.

Manual scan volume positioning is default when TWS is entered from RWS or VS. Positioning of the scan volume is done by depressing and releasing the DC in an open space in the tactical area (not on a trackfile).

5. TWS Trackfile Ranking

Target ranking in TWS is done via the following logic:

a. Designated target (L&S) is always the number one priority trackfile

b. Trackfiles with an MRM in flight (up to 4) are the next priority

c. Trackfiles with closing are ranked by range rate of closure, then by range

d. Trackfiles that show opening or are co-speed are ranked by range, with closest being highest priority

e. Trackfiles with unknown range or closure are ranked by their azimuth and distance from the nose

6. L&S and Trackfile Data

With no L&S selected upon entering TWS, pressing and releasing the undesignate switch will make the highest ranked trackfile the L&S. Subsequent presses of the undesignate switch will step the L&S through displayed trackfiles wrapping back to the first.

In VMTS, trackfiles outside the currently selected range scale are displayed at the correct azimuth at the bottom of the dugout.

To manually assign the L&S, place the cursor over a trackfile and use half action trigger or depress the DC to assign that trackfile as the L&S. L&S symbology is as previously stated, with LAR symbology for MRM or SRM displayed for the L&S and the DT2, if designated.

7. Launch Acceptability Region (LAR)

The MRM or SRM missile launch zones, or launch acceptability region (LAR), is shown for the L&S (and DT2 if one exists).

This LAR symbology consists of a maximum (R_{MAX}) and minimum (R_{MIN}) range tick marks connected by a line and an "IN LAR" cue at the bottom of the tactical area. In the OFT, a no escape range (R_{NE}) is also displayed, indicating the range at which the target's execution of a 180 degrees turn will be insufficient to defeat the missile.

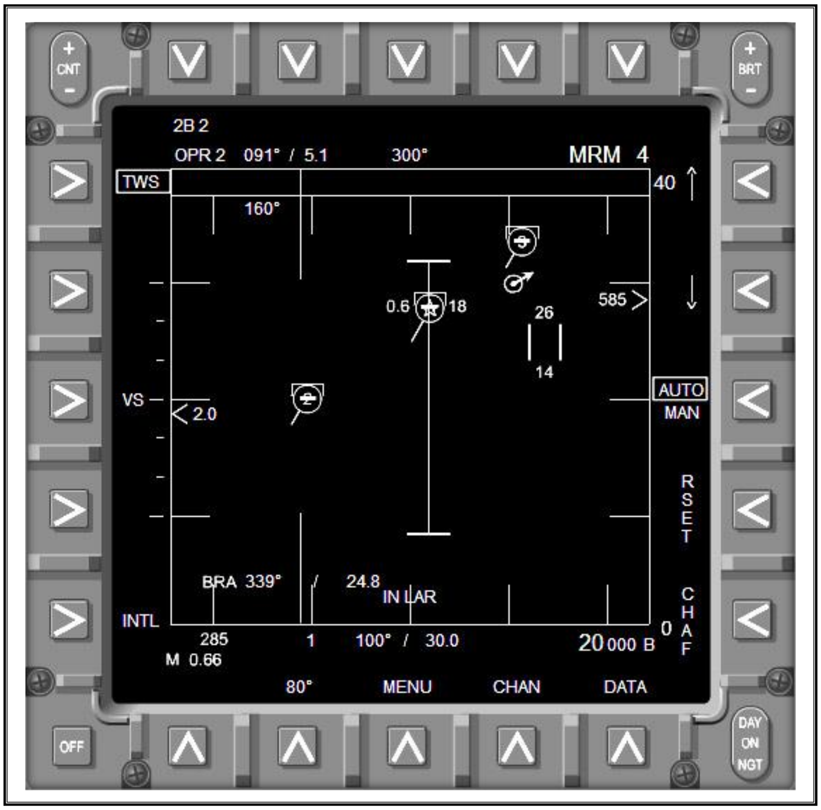

Figure 4-30 VMTS TWS Display

IN LAR indication indicates that the missile can reach the target if launched in the current intercept conditions. IN LAR will be displayed for the L&S when:

a. R_{MIN} < Target Range < R_{MAX}

b. MRM or SRM selected

c. Not in RWS

d. L&S is not in MEM condition

In the OFT, IN LAR will flash at 2 Hz when inside R_{NE}.

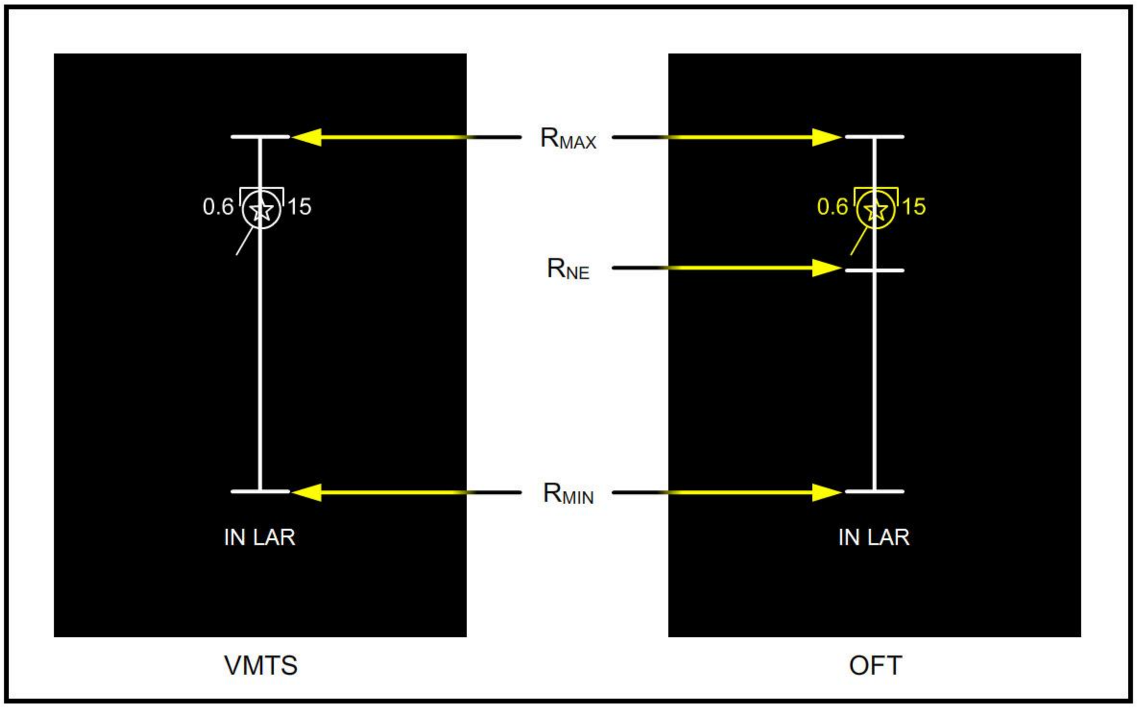

Figure 4-31 LAR Symbology in VMTS and OFT

Anytime a missile is selected and an L&S designated, a pre-launch missile time to go (TTG) is displayed. In VMTS, this represents the time to reach the target for the currently selected missile. In OFT, this is a time to active state of the selected missile or time to reach the target.

8. OFT TWS EXP Sub-Mode

In the OFT, TWS offers an expand mode, similar to the A/G expand modes, to aid in target discrimination in TWS. The purpose of this mode is to concentrate the TWS logic on the L&S in an attempt to break out additional targets flying in close proximity to the L&S.

When selected, the scope becomes a 10 NM, 20 degrees azimuth scan centered at the L&S. The maximum and minimum ranges for the scan are shown on the right just outside the tactical area.

Additional targets detected are given their own trackfiles and are then displayed as separate trackfiles even on return to normal TWS scan volumes.

Expand mode is entered from the EXP option at PB and exited by PB 15, selecting gun or selecting reset, which removes the L&S from memory.

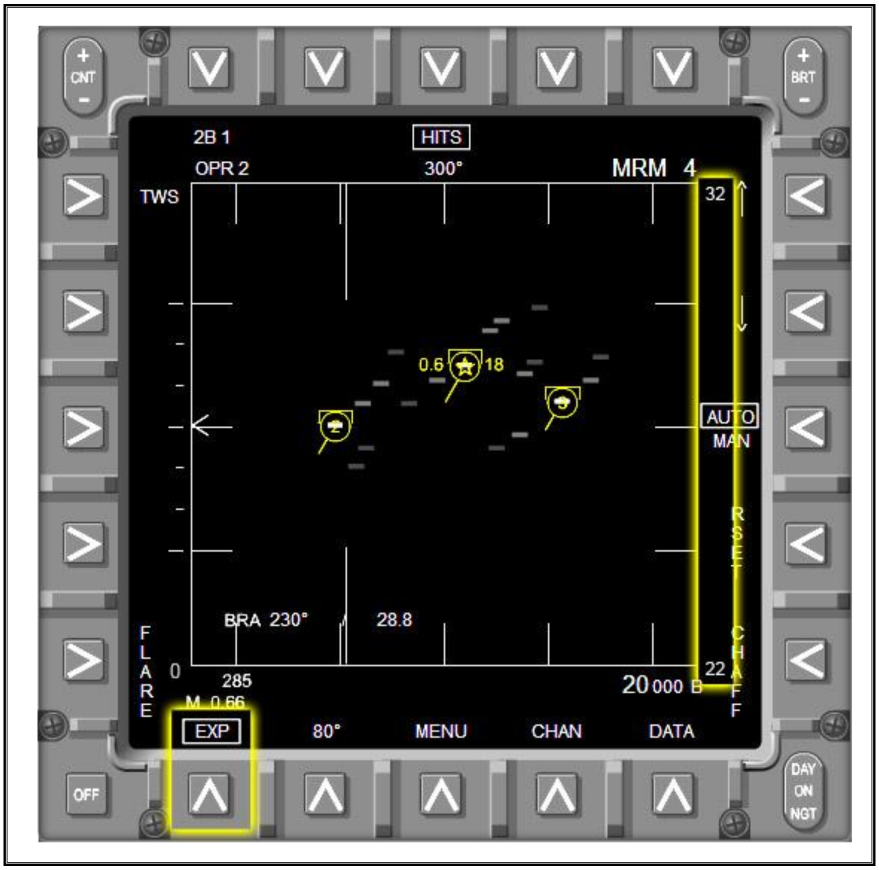

Figure 4-32 OFT TWS EXP Mode

9. OFT ASE Circle and Steering Dot

In the OFT, an allowable steering error, or ASE, circle and steering dot represent deviation from optimal heading for collision course and deviation from optimal heading and elevation to have the missile on collision course at launch. The steering dot, used in conjunction with the ASE circle, is a “fly to” cue, meaning fighter should turn toward the dot to center it in the ASE circle. Outside 1.2R_{MAX} the ASE and dot represent collision course for the aircraft. Inside 1.2 R_{MAX} centering the dot represents collision course for the missile.

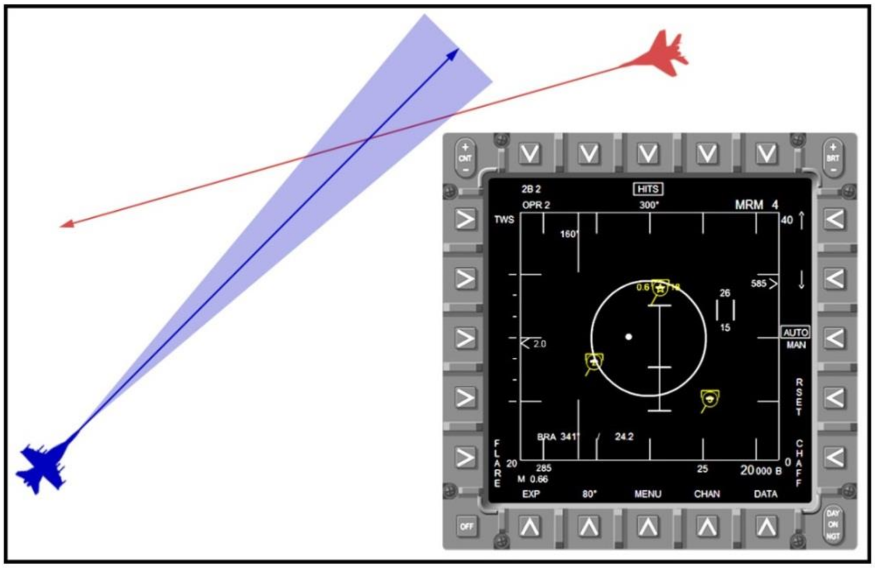

Figure 4-33 SE Circle and Steering Dot on the OFT TWS Display

10. OFT and VMTS RWS Differences

The OFT and VMTS have minor differences in the presentation of TWS display. Specifically, in the OFT:

a. The FLARE option replaces PRF at PB 16

b. TWS mode does not box in the OFT

c. OFT has EXP option at PB 15

d. OFT TWS Expand (Raid) mode

e. Allowable steering error (ASE) circle and steering dot with L&S and weapon selected

Otherwise, the functionality of the radars in TWS is the same.

11. Single Target Track

STT mode provides the highest update rate available to a single target resolved in range, azimuth and elevation. STT "locks" the radar on a single target and does not allow for any additional search or track information. STT mode is also called a radar "lock." In STT, the radar tracks a single target in azimuth, elevation, and velocity at the expense of detection or tracking of any other targets. STT provides the highest update rate to the target being tracked and instantaneous detection of target maneuvers. STT is always the preferred weapon employment mode for both MRM and SRM (through radar pointing of the IR sensor). STT is the mode entered from auto acquisition modes including ACM modes, which will be discussed in another topic of this lesson.

STT is a B-scope formatted display that will provide target tracking of the priority trackfile until a coherent trackfile cannot be maintained. Loss of a coherent trackfile could be induced by the required target data becoming invalid, losing the target, or the radar being commanded to return to a search mode.

From STT, options exist that allow the user to return to either TWS or RWS from STT, with the undesignated button on the RHC returning to the mode from which STT was entered.

12. Entering STT and the STT Display

STT can be entered from RWS, VS, or TWS by placing the cursor over the target, squeezing the trigger on the RHC to the second detent and releasing. STT will also be entered upon target detection in any of the scan volumes of the auto-acquisition ACM modes. Due to its function, bar scan, azimuth scan and PRF (VMTS) options are removed from the display.

a. Cursor Placement When Commanding STT – Placement of the radar cursor when STT is commanded is critical to ensuring that the radar acquires the target.

i. Ideally, the cursor is placed slightly in front of the target (one to two miles or so on a 40 NM scope), which allows the radar to begin STT acquisition processing as the contact enters the acquisition window.

ii. If the cursor is on or beyond the contact, the STT attempt may fail due to the contact flying out of the acquisition scan volume.

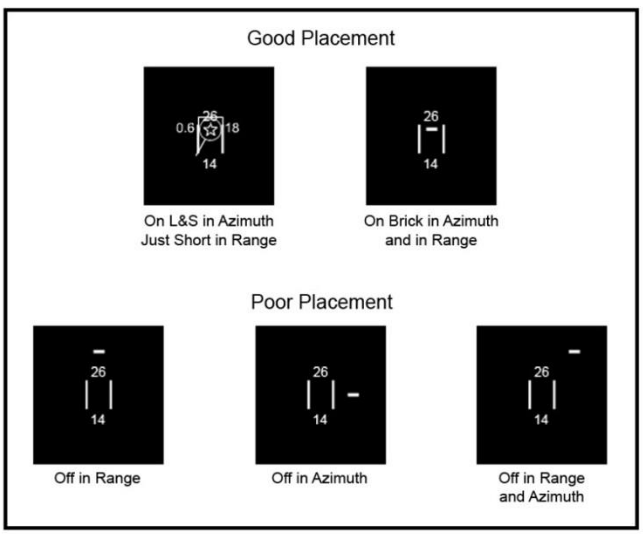

Figure 4-34 Cursor Placement in Relation to the L&S or Brick

13. STT Without an L&S

In the OFT, the first detent on the trigger will designate contact as the L&S or DT2. Press and release to the second detent will command STT on any trackfile, whether or not it is the L&S.

In the VMTS aircraft, the first detent is inoperative. Therefore the first actuation and release of the second detent will make the contact an L&S and the second actuation will command STT if attempting to command STT on a non-L&S return.

With the cursor NOT on a trackfile, action of the trigger to the second detent (OFT) or two actuations of the trigger (VMTS) will command STT on the L&S, regardless of cursor position. If no L&S exists, then the trackfile with the most confidence (in RWS) or the highest priority (TWS) will be locked. If neither of those conditions is met, then the hit with the shortest range (in RWS and TWS) or highest velocity (VS) will be locked.

14. ARSA and Scan Volume Options

STT provides for Automatic Range Scale Adjustment (ARSA) logic, which will adjust the range scale to keep the STT target between 40 percent and 90 percent of the displayed range. This keeps the STT target from reaching the bottom of the display in order to enhance aircrew SA. ARSA will automatically reduce the range of the display when the STT L&S reaches 40 percent of the selected range scale. If the range scale is manually changed while in STT, ARSA is disabled but can be re-enabled by selecting RSET.

In STT, PRF, bar scan and azimuth adjustment options are removed from the attack page. Range scale options remain.

15. STT LAR Information

With an STT, the following L&S and LAR information is displayed:

a. Star Symbol

b. Circle around star indicating the trackfile is from the radar

c. Target range caret with closing velocity

d. Target elevation caret with differential altitude

e. Launch zone cues R_{MAX}, R_{MIN}, and R_{NE} (OFT only)

f. Missile prelaunch TTG

g. IN LAR or cue when appropriate, flashing inside R_{NE} (OFT only)

h. If entered from RWS, RWS trackfiles will age out.

16. Exiting STT

STT can be exited in three ways:

a. Pressing the undesignate switch. This returns the radar to the mode from which STT was entered.

b. PB 5 RTS TWS or RTS RWS – This PB is shorthand for "return to search" in the mode from which STT was entered. If STT was obtained from an ACM mode or RWS the option will be RTS RWS. If entered from TWS, the option will be RTS TWS. The L&S is retained.

c. PB 10 TWS – This provides the option to enter TWS from STT and retain the L&S.

i. Undesignate Return to TWS Settings

(a). If the undesignate switch is used to return to search, the radar returns to the search mode from which STT was entered. If this mode was TWS then the following will occur:

(1). L&S will be retained

(2). Previous trackfiles will be restored as TWS is resumed

(3). Scan centering will be AUTO

(4). Trackfile ranking analysis will resume

The L&S will step through trackfiles with subsequent presses of the undesignate switch.

410. AUTO ACQUISITION MODES

The ACM modes are used during maneuvering to acquire a radar lock. All modes provide scan volumes optimized for different situations. ACM modes automatically lock the first target detected in their scan volume and enter STT on that target. The three ACM modes available are Boresight Acquisition (BST), Wide Acquisition (WACQ), and Vertical Acquisition (VACQ).

The T-45C ACM modes are intended for use in a maneuvering environment. All ACM modes use a Medium PRF and have a limited range to which they will detect targets.

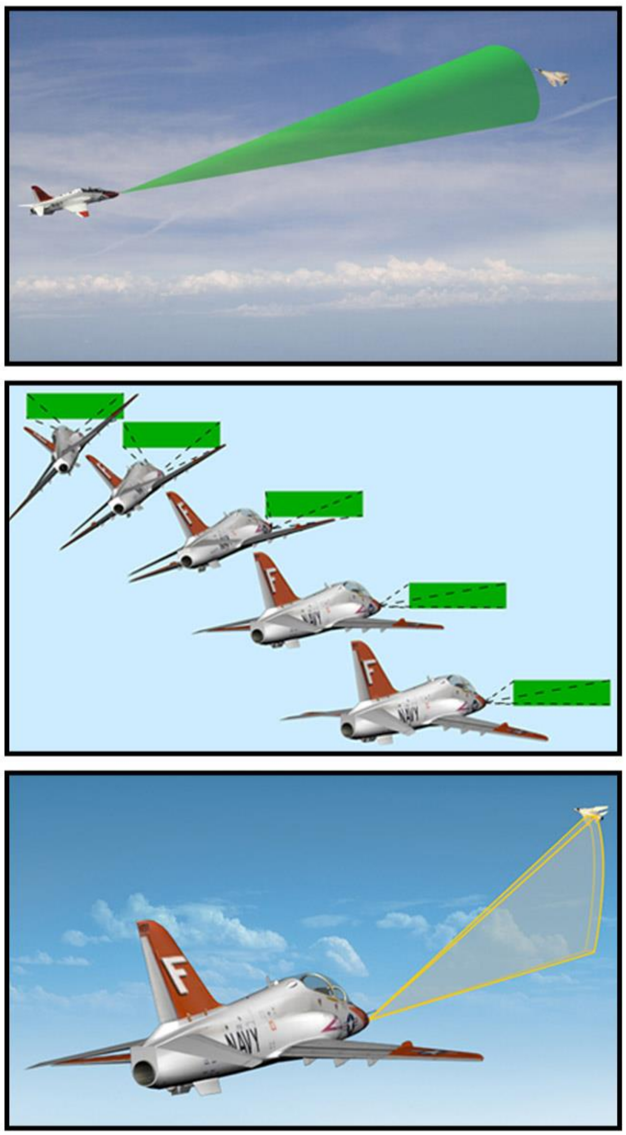

Figure 4-35 Boresight Acq (BST), Wide Acq (WACQ), and Vertical Acq (VACQ)

1. Entering and Exiting ACM Modes

ACM modes are only entered via the ACM mode "castle switch" on the RHC. You must select BST before you can enter WACQ or VACQ. To exit any ACM mode and return to the previous search mode, pull the castle switch back. ACM mode can also be exited by unboxing "ACM" at PB7 on the MFCD in VMTS.

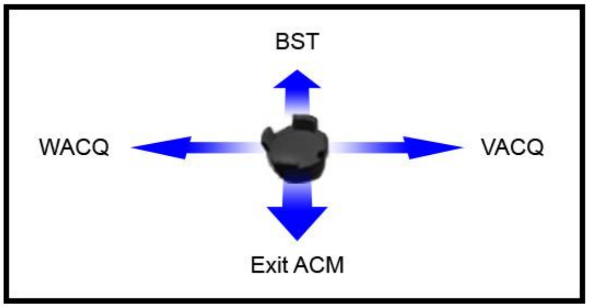

Figure 4-36 ACM Mode Select Switch, or Castle Switch

2. ACM Boresight (BST)

ACM BST stabilizes the antenna at 0 degrees azimuth and elevation. The antenna maintains this orientation regardless of aircraft pitch, roll or heading. Scan volume is a 3.3 degrees circle, in MPRF with a 10 NM detection limitation. STT is automatically commanded on the closest contact detected in the beam of the radar. With no STT, BST is exited by:

a. Selection of another ACM mode

b. Exit of ACM modes via the RHC

c. Exit of A/A master mode

BST indicated on the radar and provides a circle in the HUD for the pilot to place over a visually acquired target to achieve an STT from a visual acquisition.

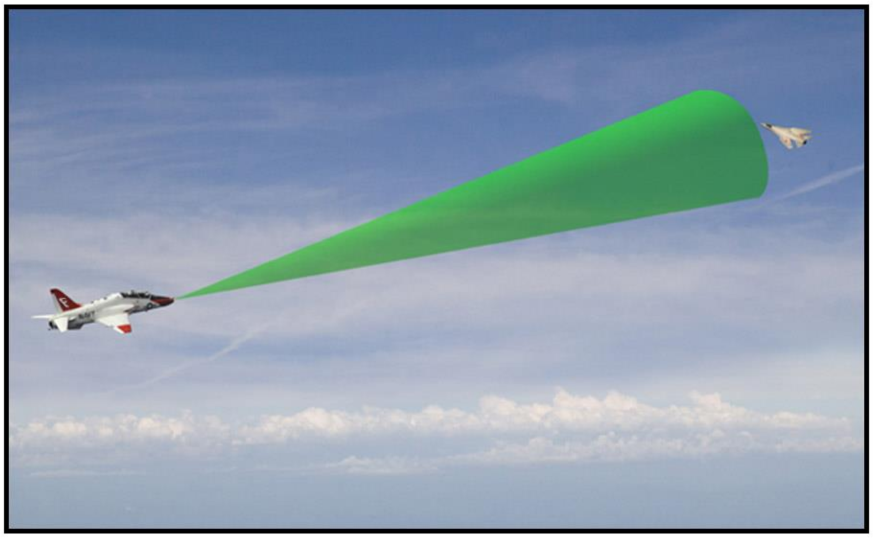

Figure 4-37 ACM Boresight

3. ACM Wide Acquisition WACQ

WACQ provides for a horizontally stabilized automatic acquisition frame regardless of aircraft roll or pitch angle.

WACQ scan volume is defined by the following parameters:

a. 6 Bar

b. 60 degrees azimuth

c. 10 NM range

d. MPRF

e. 1.3 degrees bar spacing

f. Centered 1.5 degrees below waterline

STT is commanded on the first or closest contact detected in the scan volume.

WACQ is often used to clear merges and as the first step in rebuilding radar SA. Without an STT, WACQ is exited when another ACM mode is selected, ACM mode is exited or A/A master mode is exited.

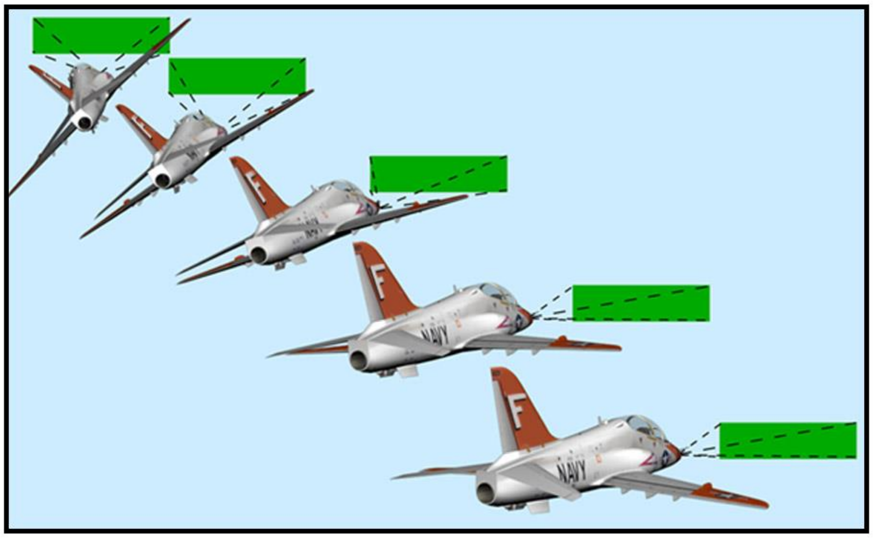

Figure 4-38 Wide Acquisition WACQ

4. ACM Vertical Acquisition

VACQ is designed to be used in a turning fight to get the radar into lead ahead of the fighter's turn. It will command STT on the first target detected within 5 NM in its scan volume. Without an STT, VACQ exits when another ACM mode is selected, ACM mode is exited or A/A master mode is exited.

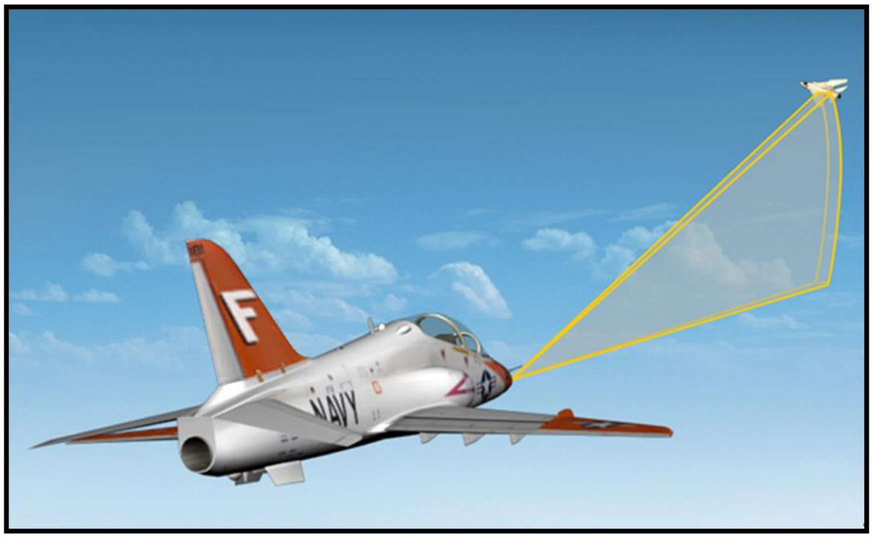

Figure 4-39 Vertical Acquisition VACQ

411. SUMMARY OF VMTS AND OFT A/A RADAR DIFFERENCES

This section provides a quick reference of recognized differences between the VMTS and OFT A/A radar presentations. At the time of this writing, some of these differences are being examined for rectification. For full VMTS functionality, the SNFO should refer to the applicable NATOPS change that discusses the VMTS system, its components, and operation. The SNFO is expected to recognize and understand these differences in order to focus on training procedures. The SNFO cannot use the differences between the OFT and the VMTS aircraft as an excuse for poor procedural execution. The radars operate in fundamentally the same way, with similar enough presentations not to adversely affect training objectives. The differences are subtle.

1. Recognized Differences

The following symbology differences exist between the OFT and VMTS.

2. Radar Contribution Circle

OFT displays a radar contribution circle for all radar contacts. VMTS does not at the time of this writing. This issue is being addressed to bring the VMTS system in line with OFT and F/A-18 D/F software symbology.

3. $R_{NE.}$

OFT displays a No-Escape Range, R_{NE} with a missile selected and L&S (and DT2) designated; VMTS does not display $R_{NE.}$

4. Missile Flyout Symbology

OFT missile fly out cue timing counts down to a simulated active state, then displays “A” with a countdown to impact for approximately the last 5 seconds.

VMTS displays a pre-launch TTG which represents a time to impact. This symbology flashes for the last 5 seconds time of flight to simulate active state.

5. Cursor Bullseye, Ownship Bullseye Position, and Cursor BRA

VMTS displays the bullseye position of both the ownship, at bottom center, and the cursor, at top left, of the display to assist in target acquisition and picture recognition.

OFT does not display a bullseye position for ownship or cursor.

Both VMTS and OFT display BRA to the cursor.

6. Precision Figure of Merit (PFOM)

VMTS radar displays a PFOM value underneath the 30 L AO tick mark on the radar. This is reported directly from GINA PFOM and represents the relative accuracy of VMTS in correlating and cueing air targets and local terrain in cockpit displays. The lower the number (1-9), the better it is.

WARNING

> Because there may be positional error related to PFOM, strict adherence to training rules is critical.

A PFOM of 1 indicates no greater than 200 feet of spherical error for the aircraft's position in the VMTS system. With two linked aircraft, this equates to potentially observed variations of 5 degrees in heading, 100 feet in altitude and 10 kts in airspeed against a non-maneuvering target.

Assuming two linked aircraft with a PFOM of 1, the target's position on a 10 NM scale attack display will be accurate to within 3,000 feet (0.5 NM) in range and 2 degrees in azimuth with a non-maneuvering target. In Figure 4-40, based on PFOM information, the aircraft represented by the trackfile in VMTS may be anywhere in the green region on a 5 NM scale.

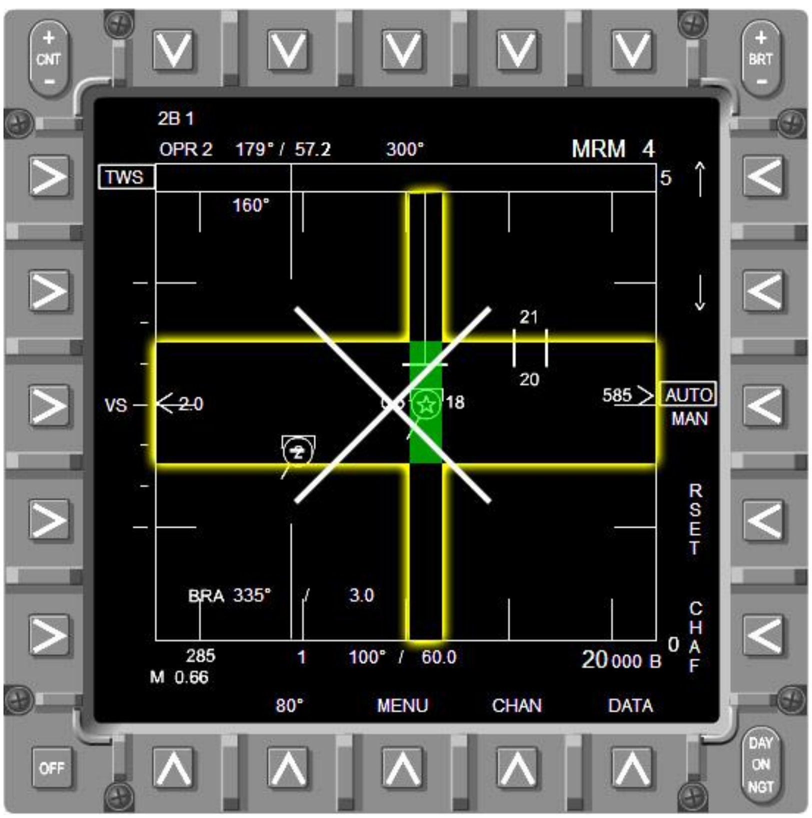

Figure 4-40 PFOM Information in VMTS

The OFT system separates the radar from the T-45C flight software; therefore, PFOM is not communicated to the radar. Rather, the OFT position is used to determine what is displayed on the radar without any degree of error.

7. VS Mode Selection

VS is entered in OFT only through HOTAS hover at PB20. In VMTS, VS has its own pushbutton at PB18.

8. TWS EXP Mode

TWS EXP sub-mode is available only in the OFT.

9. PRF Selection (VMTS)/FLARE Dispense (OFT).

VMTS allows for selection of PRF at PB 16.

OFT automatically selects PRF and replaces this option with the capability to dispense flares against IR threats. This is accomplished at PB16.

10. DATA Sublevel Target Aging

VMTS allows for selection of brick timeout aging. OFT automatically selects brick timeout length to be longer than frame time.

11. Modification of Default Sets

VMTS allows for saving changes to default radar sets. This allows the SNFO to set the radar range, azimuth, PRF, aging and bar scan to something other than the default set for MRM and SRM. The new set is remembered for each new selection of the weapon and replaces the default set for the remainder of the flight. This mirrors current F/A-18 D/F APG-73 functionality of the "SET" option.

The OFT does not allow for saving of custom sets. VT-86 SOP search sets must be manually entered for each selection of MRM or SRM. This is easily accomplished through the use of bump logic and HOTAS controls.

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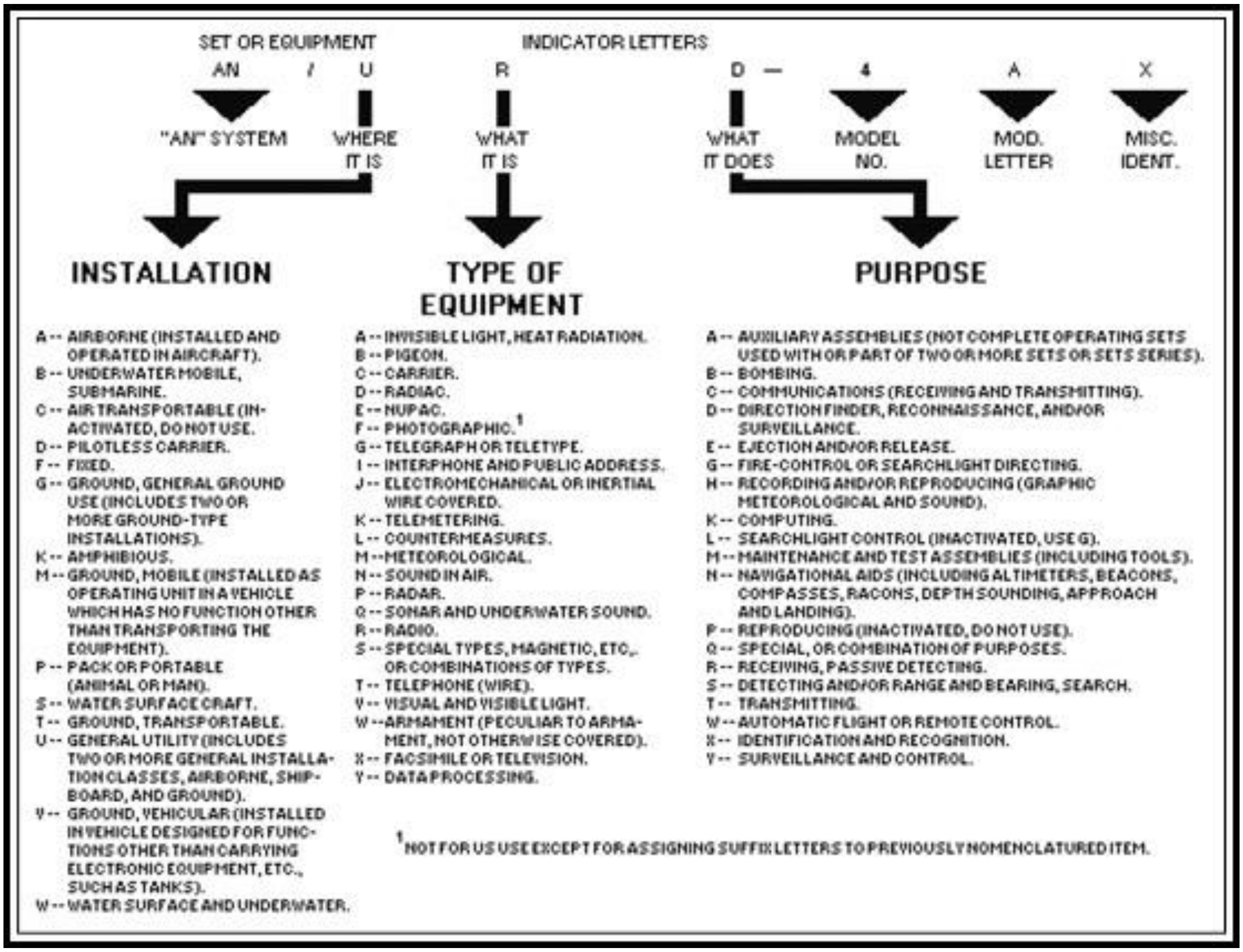
APPENDIX A
JOINT ELECTRONIC TYPE DESIGNATION SYSTEM



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