COMMAND AND STAFF TRAINING INSTITUTE

BANGLADESH AIR FORCE

Individual Staff Studies Programme (ISSP)

PROFESSIONAL SUBJECT-2: AIR DEFENCE WEAPON CONTROL
PHASE-16 : PART-II

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PHASE-16 : PART-II

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INTRODUCTION TO THE PHASE

Scope of the Phase

1. This phase deals with professional study materials on the subject of Air Defence Weapon Control, which has been divided into two parts Part-I and Part-II. The materials contained in this volume constitute Part-I of the phase. The individual topic has been so presented as to help you to gain theoretical background leading to its practical utilization.

Guidance on Methods of Study

2. In addition to this phase note you should study different manuals and Publications pertaining to this subject to improve your knowledge.

TOPIC-1
AIR POWER

DEFINITION AND TENETS OF AIR POWER

Air power is the most difficult of military force to measure or even to express in precise terms. The problem is compounded by the fact that aviation tends to attract adventurous souls, physically adept, mentally alert and pragmatically rather than philosophically inclined.

- Winston Churchill

1. The aim of this Chapter is to define air power and identify the key characteristics that need to be considered if air power is to be properly exploited in the conduct of joint and multinational operations. This Chapter covers the British definition of air power, offers a brief overview of air power history and highlights the factors that apply for the exploitation of air power. The Chapter includes a section on air power and the Principles of War and an introduction to the British core capabilities of air power.

Definition of Air Power

2. Air power has always been a difficult concept to define. From the birth of aviation to the development of independent air forces, many have seen air power as an all embracing concept. For example, Marshal of the Royal Air Force Sir John Slessor argued that *"air power is a compound of Air Forces and all those things on which Air Forces directly or indirectly depend, such as a flourishing aircraft industry and civilian aviation, a good meteorological service, secure fuel supplies and so on."* Today, the British definition of air power, which is reflected in Joint Doctrine publications, is:

> "Air Power is the ability to project military force in air or space by or from a platform or missile operating above the surface of the earth. Air platforms are defined as any aircraft, helicopter or unmanned air vehicle." This definition does not exclude civilian elements such as contractor support, particularly to sustain air operations, as Chapter 10 makes clear.

Tenets of Air and Space Power

3. The application of air and space power is refined by several fundamental guiding truths. These truths are known as tenets. They reflect not only the unique historical and doctrinal evolution of airpower, but also the specific current understanding of the nature of air and space power. The tenets of air and space power, listed below, complement the principles of war.

a. Centralized Control & Decentralized Execution

b. Flexibility & Versatility

c. Synergistic Effects

d. Persistence

e. Concentration

f. Priority

g. Balance

4. While the principles of war provide general guidance on the application of military forces, the tenets provide more specific considerations for air and space forces. They reflect the specific lessons of air and space operations over history. The tenets state that air and space power:

a. Should be centrally controlled and de-centrally executed

b. Is flexible and versatile

c. Produces synergistic effects

d. Offers a unique form of persistence

e. Must achieve concentration of purpose

f. Must be prioritized

g. Must be balanced

5. As with the principles of war, these tenets require informed judgment in application. They require a skillful blending to tailor them to the ever-changing operational environment. The competing demands of the principles and tenets, for example mass versus economy of force, concentration versus balance, and priority versus objective; require an airman's expert understanding in order to strike the required balance. In the last analysis, commanders must accept the fact that war is incredibly complicated and no two operations are identical. Commanders must apply their professional judgment and experience to the principles and tenets as they employ air and space power in a given situation.

Centralized Control and Decentralized Execution

6. Centralized control and decentralized execution of air and space power are critical to effective employment of air and space power. Indeed, they are the fundamental organizing principles for air and space power, having been proven over decades of experience as the most effective and efficient means of employing air and space power. Because of air and space power's unique potential to directly affect the strategic and operational levels of war, it must be controlled by a single airman who maintains the broad, strategic perspective necessary to balance and prioritize the use of a powerful, highly desired yet limited force. A single air commander, focused on the broader aspects of an operation, can best mediate the competing demands for tactical support against the strategic and operational requirements of the conflict.

7. Centralized control of air and space power is the planning, direction, prioritization, synchronization, integration, and de-confliction of air and space capabilities to achieve the objectives of the joint force commander. Centralized control of air and space power should be accomplished by an airman at the air component commander level who maintains a broad theatre perspective in prioritizing the use of limited air and space assets to attain established objectives in any contingency across the range of operations. Centralized control maximizes the flexibility and effectiveness of air and space power; however, it must not become a recipe for micromanagement, stifling the initiative subordinates need to deal with combat's inevitable uncertainties.

8. Decentralized execution of air and space power is the delegation of execution authority to responsible and capable lower level commanders to achieve effective span of control and to foster disciplined initiative, situational responsiveness, and tactical flexibility. It allows subordinates to exploit opportunities in rapidly changing, fluid situations. The benefits inherent in decentralized execution, however, are maximized only when a commander clearly communicates his intent.

9. Centralized control and decentralized execution of air and space power provide theatre-wide focus while allowing operational flexibility to meet theatre objectives. They assure concentration of effort while maintaining economy of force. They exploit air and space power's versatility and flexibility to ensure that air and space forces remain responsive, survivable, and sustainable.

10. Modern communications technology provides a temptation towards increasingly centralized execution of air and space power. Although several recent operations have employed some degrees of centralized execution, such command arrangements will not stand up in a fully stressed, dynamic combat environment, and as such should not become the norm for all air operations. Despite impressive gains in data exploitation and automated decision aids, a single person cannot achieve and maintain detailed situational awareness when fighting a conflict involving many simultaneous engagements taking place throughout a large area. A high level of centralized execution results in a rigid campaign unresponsive to local conditions and lacking in tactical flexibility. For this reason, execution should be decentralized within a command and control architecture that exploits the ability of strike package leaders, air battle managers, forward air controllers, and other front-line commanders to make on-scene decisions during complex, rapidly unfolding operations. Nevertheless, in some situations, there may be valid reasons for execution of specific operations at higher levels, most notably when the JFC (or perhaps even higher authorities) may wish to control strategic effects, even at the sacrifice of tactical efficiency.

Flexibility and Versatility

11. Air and space power is flexible and versatile. Although often used interchangeably, flexibility and versatility are different. Flexibility allows air and space forces to exploit mass and manoeuvre simultaneously. Flexibility allows air and space operations to shift from one campaign objective to another, quickly and decisively; to "go downtown" on one sortie, then hit fielded enemy forces the next; to re-role assets quickly from a pre-planned mission to support an unanticipated need for close air support of friendly troops in contact with enemy forces. Versatility is the ability to employ air and space power effectively at the strategic, operational, and tactical levels of warfare. Air and space forces, unlike other military forces, have the potential to achieve this unmatched synergy through asymmetric and parallel operations.

12. Parallel operations are operations coordinated to occur simultaneously and continuously against a broad spectrum of targets. Used appropriately, parallel operations can generate sufficient force to overwhelm the enemy, resulting in paralysis that provides the leverage to dominate operations in all mediums. Properly planned and executed in parallel attacks, air and space power can attain effects which present the enemy with multiple crises occurring so quickly that there is no way to respond to all or, in some cases, any of them. Such a strategy places maximum stress on both enemy defences and the enemy as a whole.

Synergistic Effects

13. Air and space power produces synergistic effects. The proper application of a coordinated force can produce effects that exceed the contributions of forces employed individually. The destruction of a large number of targets through attrition warfare is rarely the key objective in modern war. Instead, the objective is the precise, coordinated application of the various elements of air, space, and surface power to bring disproportionate pressure on enemy leaders to comply with our national will. Air and space power's overwhelming ability to observe adversaries allows us to counter their movements with unprecedented speed and agility. Air and space power is unique in its ability to dictate the tempo and direction of an entire war fighting effort from Mil Op Other Than War (MOOTW) through major conflict.

Persistence

14. Air and space power offers a unique form of persistence. Air, space, and information operations may be conducted continuously against a broad spectrum of targets. Air and space power's exceptional speed and range allow its forces to visit and revisit wide ranges of targets nearly at will. Air and space power does not have to occupy terrain or remain constantly in proximity to areas of operation to bring force upon targets. Space forces in particular hold the ultimate high ground, and as space systems advance and proliferate, they offer the potential for "permanent presence" over any part of the globe; unmanned aerial vehicles (UAVs) are offering similar possibilities from the atmosphere. Examples of persistent operations might be maintaining a continuous flow of materiel to peacetime distressed areas; constantly monitoring adversaries to ensure they cannot conduct actions counter to those agreed upon; assuring that targets are kept continually out of commission; or ensuring that resources and facilities are denied an enemy or provided to an ally during a specified time. The end result would be to deny the opponent an opportunity to seize the initiative and to directly accomplish assigned tasks.

15. Factors such as enemy resilience, effective defences, or environmental concerns may prevent commanders from quickly attaining their objectives. However, for many situations, air and space operations provide the most efficient and effective means to attain national objectives. Commanders must persist in air and space operations and resist pressures to divert resources to other efforts unless such diversions are vital to attaining theatre goals or to survival of an element of the joint force. Given sufficient time, even the most devastating strategic effects can be circumvented by resourceful enemies; the goal is to keep pressure on and not allow the enemy that time.

Concentration

16. Air and space power must achieve concentration of purpose. The versatility of air and space power makes it an attractive option for almost every combat task. Airmen must guard against the inadvertent dilution of air and space power effects resulting from high demand. One of the most constant and important trends throughout military history has been the effort to concentrate overwhelming power at the decisive time and place. The principles of mass and economy of force deal directly with concentrating overwhelming power at the right time and the right place (or places). With forces as flexible and versatile as air and space forces, the demand for them will often exceed the available forces and may result in the fragmentation of the integrated air and space effort in attempts to fulfil the many demands of the operation. Depending on the operational situation, such a course of action may court the triple risk of failing to achieve operational-level objectives, delaying or diminishing the attainment of decisive effects, and increasing the attrition rate of air forces-and consequently risking defeat.

Priority

17. Air and space power must be prioritized. Demands for air and space forces (because of their flexibility and versatility) will likely overwhelm air commanders in future conflicts unless appropriate priorities are established. Only theatre-level commanders of land and naval components can effectively prioritize their individual air and space support requirements to the JFC, and only then can effective priorities for the use of air and space forces flow from an informed dialogue between the JFC and the air component commander. The air commander should assess the possible uses of his forces and their strengths and capabilities to support the overall joint campaign, air operations, and the battle at hand. Limited resources require that air and space forces be applied where they can make the greatest contribution to the most critical current JFC requirements. The application of air and space forces must be balanced among their abilities to conduct operations at all levels of war, often simultaneously. The principles of mass, offensive, and economy of force, the tenet of concentration, and the airman's strategic perspective all apply to prioritizing air and space forces.

Balance

18. Air and space operations must be balanced. Balance is an essential guideline for air commanders. Much of the skill of an air commander is reflected in the dynamic and correct balancing of the principles of war and the tenets of air and space power to bring air and space power together to produce a synergistic effect. An air commander should balance combat opportunity, necessity, effectiveness, efficiency, and the impact on accomplishing assigned objectives against the associated risk to friendly air and space forces. An air commander is uniquely and best-suited to determine the proper theatre wide balance between offensive and defensive operations, and among strategic, operational, and tactical applications. Commensurate with this capability is the air commander's responsibility to adequately communicate the intended effects of air and space power to the JFC and other component commanders, especially those schooled in surface operations. Technologically sophisticated air and space assets will be available only in finite numbers; thus, balance is a crucial determinant for an air commander.

Reference:

1. AP 3000 3rd Edition

2. AFM 1-1

COMPONENTS OF AIR POWER ALONG WITH TAXONOMY

Combat Air Power

1. British Defence Doctrine describes military capability in terms of a conceptual component, a moral component and a physical component. This provides a suitable model by which the concept of combat air power can be expressed. This concept is illustrated in the following diagram**:**

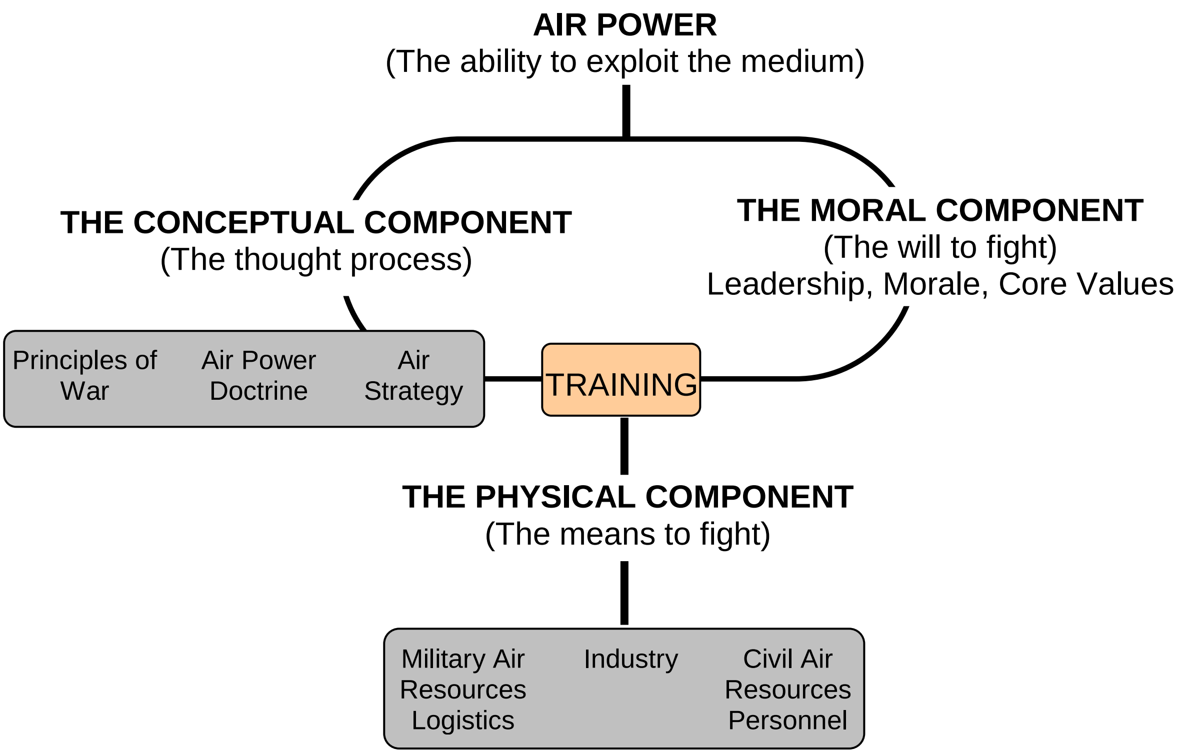


Fig 1.1 : Air Power

The Conceptual Component

2. The conceptual component is the thought process and teaching that underpin air power. The conceptual sources of air power are the history of air campaigns and operations and the lessons learned or identified from them, the Principles of War, air power doctrine, air strategy and campaign planning techniques which are all derived from experience and doctrine. This knowledge acts as a guide in the process of training and educating airmen, staff officers and current and future commanders at all levels. This volume is part of that process.

The Moral Component

3. The ability to get people to fight penetrates to the very core of air power. Armed Forces reflect the society they serve, but require a much greater degree of sacrifice and commitment than comparable professions. Volunteer air forces of mature democracies must rely on the support and contribution of regular, full and part time reserve forces, civilians and contractors to achieve mission success. There are three elements that merit consideration within the moral component:

a. **Leadership**. The nature of leadership has been a source of debate throughout history, but there has never been any doubt about its importance as a war-winning factor. Inspirational leadership is one of the foremost elements in raising and sustaining morale, which has often proved to be a decisive ingredient in determining the outcome of military operations, even against the most overwhelming odds. Born leaders tend to be few, but a good proportion of the art of leadership can be learned, particularly from the example of others. Successful leadership can take many forms and styles both in the air and on the ground, but invariably includes professional mastery and moral courage. Study of history is seldom wasted if one wants to understand what makes a good leader. Historically, air forces have tended to foster an ethos which is different from those at sea or on land. Although all personnel on an airfield, aircraft carrier or forward operating strip may share the same dangers if attacked, only a small minority of aircrew directly and regularly engage in direct combat. Leadership in the air similarly takes many forms. At more senior levels of command, air leaders are isolated from the immediate air action by the centralization of control that the efficient use of air power demands, fostering what can be perceived as a remote style of leadership. At all levels, air commanders must recognize that the largest proportion of their personnel provide support on the ground and that this generates additional but equally important demands on them as commanders. A fighting force in peacetime must provide the encouragement and the conditions in which leaders of different styles can thrive and develop.

b. **Core-Values**. Core values are the permanent foundations on which the identity and purpose of the British Armed Forces are built and are a small number of ethically based principles which serve, in all circumstances, to guide the behaviour of members of the Service in a way which both furthers its purpose and is ethically sound. Just as the nature of warfare does not change, so the core values necessary for its successful and ethical prosecution has remained constant. Core values can be expressed in many ways, but will always include such recognizably military virtues as physical courage, total commitment and service before self. In addition, virtues such as integrity and moral courage are no less important to the armed forces of a nation which is pledged to uphold international laws and conventions relating to the use of military force. Core values capture the very essence of what is important to the Service and those who serve within it, thereby engendering justifiable pride. Although important at all times, they are most valuable at times of extreme personal commitment, when together with leadership and training, they sustain and inspire personnel in circumstances which might otherwise overwhelm them.

c. **Education**. Military education and personal development remain key requirements for the development of successful commanders. The study of military history is a fundamental element of professional education and should continue throughout an individual's service. Education can be guided by doctrine and training, but must be underpinned by personal commitment to professional development to develop an understanding of the considerations which apply to the exploitation of air power. Training and education do not stop with appointment to senior rank. This volume is Part of the education process.

The Physical Component

4. The physical component represents the means to fight and is bounded by the resources available to defence. The successful exploitation of British air power depends upon superior and timely information exploitation, a quicker decision/action cycle than that of the opponent and flexible and capable forces that can offer the rapid and precise application of air power across the spectrum of conflict. Combat air power must be supported by robust and sustainable logistics. It is the combination of civil, military and industrial resources to procure combat effective platforms and weapons systems in sufficient numbers which underpins the national means to exploit air power. If the potential of air power is not to be wasted, command and control considerations are extremely important.

Ref: AP 3000 (2nd and 3rd Edition)

TAXONOMY OF AIR POWER

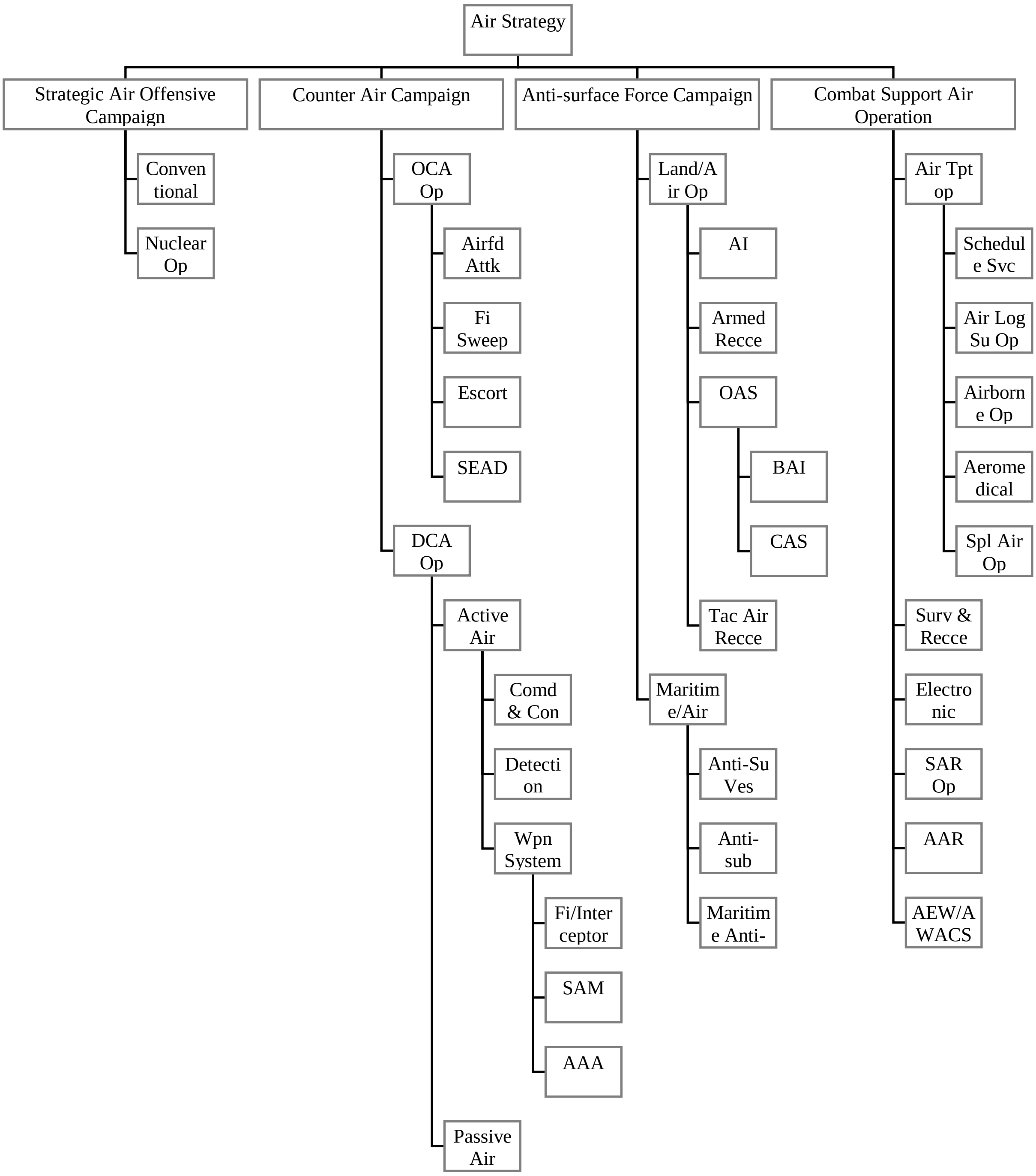


Fig 1.2 : Taxonomy of Air Power

AIR POWER ROLES

Training Objective. At the end of this chapter students should know about air and space power's capabilities in terms of its four fundamental roles: control of the air, air mobility, intelligence and situational awareness, and attack.

Role 1: Control of The Air

1. **Freedom of Air and Surface Manoeuvre**. Control of the air is the primus inter pares of the four air power roles. It has doctrinal primacy because it enables freedom of manoeuvre in all of the Service environments: air, land and maritime. Control of the air provides commanders with the ability to retain the initiative while denying it to the enemy, and although military operations may be attempted without it, success may be fatally compromised beneath contested airspace. Control of the air above Iraq in 2003, for example, paved the way for major combat operations at a much reduced risk of casualties to Coalition surface forces, which enjoyed almost complete freedom of manoeuvre while facing Iraqi ground threats that had been fixed and severely degraded by air attack. Few activities can be conducted without air and space control; successful deployment to an operational theatre, for instance, depends on a benign environment created by control of the air to allow vulnerable transport vehicles, vessels and aircraft to operate safely, while space control provides the bearers that support, inter alia, asset tracking for materiel and accurate navigation.

2. **Defining Control of the Air**. Consequently, traditional conceptions of air superiority have limited utility in contemporary operations. Instead, control of the air may be considered in terms of freedom and denial, so that control of the air is defined as:

"The freedom, bound by time, to use a volume of airspace for one's own purposes while, if necessary, denying its use to an opponent."

Against this relative standard of freedom of action, the required degree of control is achieved when a commander assesses that a planned surface or air operation will not be compromised by enemy action and that the risk to his own forces posed by enemy air is acceptable.

3. **Achieving Control of the Air: Counter-Air Operations**. Counter-air operations achieve control of the air through the destruction, degradation or disruption of an enemy's air capability. Counter-air operations may include the actions of any component and involve the use of land or ship-based assets to counter threats including manned or unmanned aircraft, surface-to-air systems, ballistic and cruise missiles and maritime or land forces. Counter-air operations are subdivided into following:

a. **Offensive Counter-Air (OCA) Missions**. OCA missions are offensive operations aiming to destroy, disrupt or degrade enemy air and missile threats, either by destroying them on the ground, or as close to their source as possible. Such operations may be pre-planned or immediate, and are conducted across enemy territory at the initiative of friendly forces. Pre-planned operations depend on continuous and accurate intelligence, while immediate operations are conducted against unexpected mobile and time sensitive targets, where there may be only a small window available for attack. OCA includes surface attack operations, air-to-air missions the Suppression of Enemy Air Defences (SEAD) and Electronic Warfare (EW).

b. **Defensive Counter-Air (DCA) Operations**. DCA operations are synonymous with Air Defence (AD). They consist of active and passive operations to detect, identify, intercept and destroy or negate enemy air and missile forces attempting to penetrate friendly battle space, or the reduction of the effectiveness of such attacks, should they escape destruction.

Role 2: Air Mobility

4. **Deployment, Sustainability and Manoeuvre**. Air mobility and lift (including precision air delivery) enable the global, regional and local deployment of military and civilian personnel and materiel. Although air lift is limited in payload in comparison with surface lift, in many crisis situations it represents the only way of providing immediate influence by rapidly deploying and sustaining forces. Like air and space control, air mobility acts as a fundamental enabler for surface manoeuvre; it is particularly useful for moving light and Special Forces where the threat to surface movement is high. Air mobility is vital for swift casualty evacuations from austere locations, underpinning the moral component of fighting power; it is often the only way to get wounded personnel to specialist medical care quickly enough to preserve life.

5. **The Provision of Air Mobility**. Air mobility enables forces to be moved and sustained worldwide, across the entire spectrum of operations. It provides rapid and flexible options to military planners and national and international government agencies, allowing rapid responses to crisis situations globally. It consists of the following six sub-sets:

a. **Air Lift**. Air lift provides the capability to enable rapid global deployment and redeployment of military personnel and associated equipment. In times of crisis and when speed of response is essential, air lift provides an ability to extract non-combatants. Integral to the defence Logistics Support Chain, it provides a highly agile and responsive means to sustain deployed forces worldwide. Inter-theatre air lift is the air bridge that links theatres to home bases and to other theatres, whilst intra-theatre air lift provides air lift within a specific theatre or JOA. Whilst it cannot match the capacity of sea lift, air lift allows rapid and focused responses anywhere in the world.

b. **Air to Air Refuelling**. Air to Air Refuelling is a significant force multiplier. It increases the range, endurance, payload and flexibility of all receiver-capable aircraft and is especially important when forward basing is limited or unavailable, or where access, basing and over-flight limitations would otherwise impose constraints on air operations.

c. **Airborne Operations**. At one end of the scale, airborne operations project combat power through the air delivery of land forces onto an objective. They may be operational or strategic in nature; however, they are invariably high-risk, high-gain undertakings. At the other end of the scale, the discrete insertion of small patrols has much utility in low-density battle space, such as recent operations in Afghanistan.

d. **Special Air Operations**. Special Forces (SF) are usually small units of carefully selected personnel employing modified equipment and unconventional tactics against strategic and operational objectives. They are heavily dependent on air support, and special air operations elements are an integral part of SF.

e. **Aerial Delivery**. Aerial delivery enables the rapid precision delivery of logistics stores to remote or isolated locations that are not served by either a secure landing strip or a secure surface line of communication.

f. **Aero medical Evacuation (AE)**. AE is a specialized form of air lift for transporting ill or injured personnel under medical supervision to appropriate medical treatment facilities.

Role 3: Intelligence and Situational Awareness

6. **Surveillance and Reconnaissance**. Surveillance and reconnaissance are the means by which air and space power provides intelligence and situational awareness, whether for operational level commanders taking a theatre-wide perspective using space-based assets, or individual soldiers exploiting live video feeds from manned or unmanned aircraft. The high vantage point afforded by air and space allows an almost unhindered view 'over the hill' and across the electromagnetic spectrum, providing intelligence at all levels of command, although a robust capability is required to direct, collect, process and disseminate information. Air and space systems now have sufficient sensor resolution to find and identify very small targets, down to individual people. They can also map terrain and infrastructure and even monitor patterns of change and behaviour, routinely penetrating poor weather and overcoming concealment techniques. Sensors can also intercept communications and other signals, helping to build a comprehensive and coherent intelligence picture; the 10,000 surveillance and reconnaissance sorties flown in the Middle East and South Asia during 2007 demonstrate the critical nature of air power in building a comprehensive intelligence picture.

7. **Achieving Air Intelligence and Situational Awareness**. The intelligence provided by space-based sensors and air platforms, manned and (increasingly) unmanned, significantly contributes to reducing uncertainty in the decision-making process and improving the ability to gain and maintain information superiority, which in turn increases flexibility, enhances effectiveness, increases responsiveness, aids force protection and – above all else – contributes to situational awareness.

8. **Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR)**. ISTAR links several battle space functions to allow a combat force to employ its sensors and manage the information gathered to best effect. ISTAR has four components:

a. **Intelligence**. Intelligence is the product resulting from the collection, processing, integration, analysis, evaluation and interpretation of available information. Good intelligence provides accurate, relevant, timely and predictive analysis to support operations.

b. **Surveillance**. Surveillance is the continuing and systematic observation of air, space, surface or subsurface areas, places, persons or things, by visual, aural, electronic, photographic or other means. Airborne (and space) surveillance assets exploit elevation to detect opponents' activities at range and behind obstacles.

c. **Targeting**. Targeting consists of six steps: detection, location, identification, decision, execution and assessment. ISTAR operations play a prominent role in four of these steps: detection (ISTAR assets detect potential new targets or significant changes to existing targets), location (allows a target to be positioned accurately within a designated reference system), identification (the recognition and classification of targets in sufficient detail to allow decision-making), and assessment (allowing commanders to analyse progress against the campaign plan).

d. **Reconnaissance**. Reconnaissance complements surveillance by using visual observation, or other detection methods, to obtain specific information about the activities and resources of an enemy or potential enemy. It may also secure data concerning the meteorological, hydrographical or geographic characteristics of a particular area.

Role 4: Attack

9. **Strategic, Operational and Tactical Flexibility**. The concept of coercion, underpinned by air power's demonstrable capability to attack, can be used at the strategic, operational or tactical levels. However, it is no longer particularly useful to define air power roles only in association with specific levels of warfare. Air power is inherently flexible, and the levels of warfare are now so blurred in contemporary operations that the imposition of artificial labels can confuse an understanding of the totality of air power's coercive capability. For example, large fixed-wing bombers, originally designed for strategic attack, are quite capable of tactical close air support if properly armed and integrated with surface forces. Similarly, short-range tactical aircraft are capable of achieving strategic effect; it is how they are used and in what context that matters, not the range or reach of particular aircraft types. Air power has enormous potential to exert influence through coercion. Because of its almost unlimited flexibility, it may be used to attack a wide range of mobile and static targets across multiple theatres of operations. Like other forms of military power, air power can also generate inadvertent strategic consequences; collateral damage may create adverse effects out of all proportion to the damage actually inflicted. Nevertheless, the successful use of air power as a coercive instrument operating seamlessly across the strategic-operational-tactical continuum has permitted a lower ground footprint to be adopted in conflicts such as Afghanistan since 2003, reducing friendly casualties and imposing a relentless pressure on adversaries.

10. **The Delivery of Air Attack**. Attack from the air can no longer be simply divided into tactical or strategic categories, as air power spans the spectrum of conflict in range, reach and effect. Additionally, attack is not solely kinetic, because air power can also provide a very effective lever against an opponent's cognitive domain. Attack from the air may be broken down into deep attack, counter-land and counter-sea operations, and information operations.

a. **Deep Attack**. Deep Attack describes attacks conducted against targets often (but not always) deep in enemy territory and of significant, often strategic, importance. Deep attack is used to disrupt or destroy centres of gravity or other vital target sets such as leadership, command elements, war production resources, fielded forces or key supporting infrastructure. It seeks to disrupt an enemy's strategy, ability or will to wage war, or to carry out aggressive activity. It is the outcome required that defines deep attack, not the specific weapon system, delivery platform or type of target attacked.

b. **Counter-Land Operations**. Counter-land operations aim to gain and maintain a desired degree of control of the land battle space by targeting fielded enemy ground forces and the infrastructure directly supporting them, or by using the psychological effects of air power to attack the enemy's will. The overall campaign strategy and the specific circumstances of the conflict will determine how counter-land operations are conducted. The synergy of air forces and surface forces, operating as an integrated joint force, can often be overwhelming in cases where the activities of a single component alone would not be decisive – this is the preferred method of employment. Counter-land operations fall into three mission types:

(1) **Air Interdiction (AI)**. AI is action to destroy, disrupt, divert or delay the enemy's surface potential before it can be used effectively against friendly forces, or otherwise achieve its objectives. It is carried out at such distance from friendly forces that detailed integration of each air mission with the fire and movement of friendly forces is not required.

(2) **Close Air Support (CAS)**. CAS is action by fixed and rotary wing aircraft against hostile targets requiring detailed integration with the fire and movement of friendly forces for targeting guidance and to avoid fratricide. CAS provides ground or amphibious forces with firepower in offensive and defensive operations, by day and night, to destroy, suppress, neutralise, disrupt, fix or delay enemy forces in close proximity to friendly ground forces.

(3) **Counter-Air Operations for Psychological Effect**. Air power is not employed solely for kinetic purposes. The psychological impact of air power, from the presence of a UAV to the noise generated by an approaching attack helicopter, has often proved to be extremely effective in exerting influence, especially when linked to information operations.

c. **Counter-Sea**. Counter-sea operations extend the application of air power into the high seas or the littoral and its adjacent waters, and extend the attack range and capability of surface and sub-surface elements.

(1) **Anti-Surface Warfare (ASUW)**. ASUW operations are conducted to destroy or neutralise enemy naval surface forces.

(2) **Anti-Submarine Warfare (ASW)**. ASW operations are conducted with the intention of denying the enemy the effective use of submarines.

(3) **Aerial Mining**. Aerial Mining Operations are conducted to support the control of vital sea areas, by inflicting damage on an enemy's vessels or submarines to hinder operations and impede the flow of traffic through a given area.

d. **Information Operations**. Information Operations are primarily non-kinetic actions taken to influence, affect or defend information, systems and decision-making. They must be integrated into air (and space) operations in the same manner as more traditional capabilities to create effects across the entire battle space. Information Operations include:

(1) **Electronic Warfare (EW)**. EW seeks control of the electromagnetic (EM) spectrum, both to enable friendly-force operations, and to deny an enemy the same degree of freedom.

(2) **Influence Operations**. Influence operations affect behaviours, protect operations, communicate intent and project accurate information across the cognitive domain. The desired outcome is a change in behaviour or in an enemy's decision-making process.

(3) **Computer Network Operations (CNO)**. CNO integrate the planning and employment of military capabilities to achieve desired effects across the digital battle space. They are conducted in the information domain, consisting of hardware, software, data and human components.

Reference:

1. AP 3000 4th edition.

TOPIC-2
AIR CAMPAIGN

TYPES OF AIR CAMPAIGN

The Air Campaigns

1. To prosecute each of the military-Strategic applications of air power, specific types of operational-level and tactical-level capabilities are required. These capabilities can only be fully effective if they arc brought together in cohesive, dedicated air campaigns.

2. **Definition**. The term air campaign is defined as a coordinated series of air operations designed to achieve a specific air strategic objective

3. **Air Campaign Structure**. The three air campaigns are complementary, rather than alternative, strategic instruments. In most major conflicts they have been prosecuted concurrently. However, the proportion of total air effort that different nations have devoted to each air campaign has varied considerably, ref1ecting their differing strategic priorities. This has been true not only for different conflicts, but also for different phases of the same conflict. The following two examples help to illustrate this:

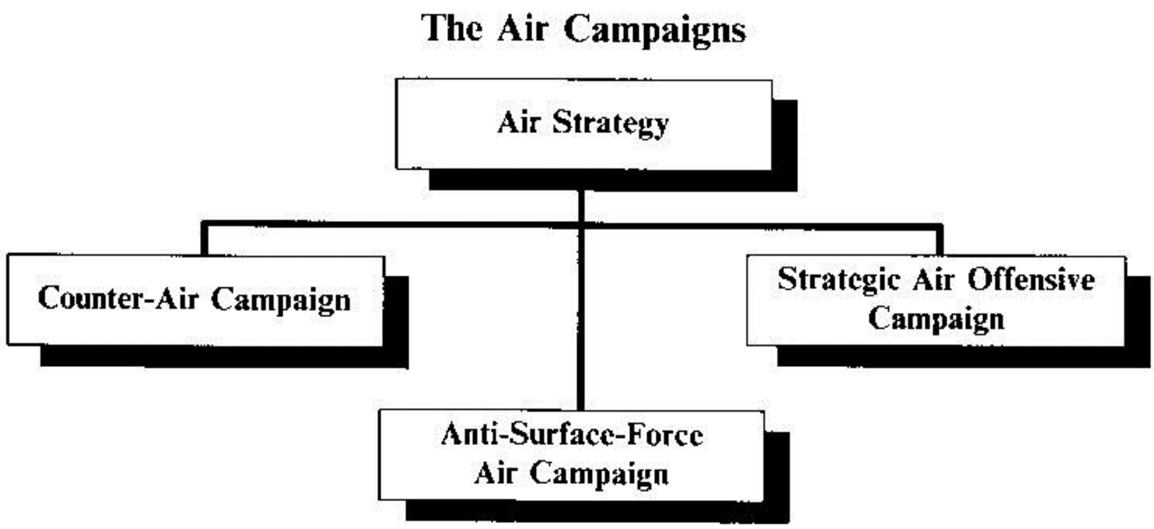


Figure 2.1: The Air Campaigns

a. During the first two days of the 1967 Six-Day Arab-Israeli War. Israel devoted virtually all of her air forces to the counter-air campaign. In the remaining four days the Israelis switched the bulk of their air effort into the anti-surface force campaign.

b. The Gulf War of 1991 provides a more complex example of strategic air planning, the forces involved being far larger, the defences far more formidable, the planned duration of the operation far longer and the scope of operations far greater. The air strategy employed by the international coalition against Iraq was divided into four - rather than two - distinct phases. Phase I - planned to last for seven to ten days - was designed primarily to achieve control of the air and - in parallel to damage Iraqi strategic capabilities. Phase-2 effectively a sub-element of the counter-air operations was designed to suppress the Iraqi surface-to-air defences within the Kuwait theatre of operations. In Phase 3, the Allies intended to concentrate their attacks against the Iraqi Army in the Kuwait theatre of operations. The prime aim of the fourth and final phase was to cooperate directly with the Allied land offensive to achieve the physical liberation of Kuwait, However, typical frictions of war caused the planned timescales to slip, and, as a result, the different phases tended to merge and at times overlap as operations progressed.

UNDERSTANDING COUNTER-AIR CAMPAIGN

The only security upon which sound military principles will rely
is that you should be master of your own air'
Winston Spencer Churchill

The Aim of the Counter-Air Campaign

1. The strategic aim of the counter-air campaign is to achieve and maintain the required degree of control of the air, Achieving friendly control of the air is both an end in itself and a means to an end. It prevents the enemy from using his air power effectively against friendly forces, rear areas and homelands, while allowing allied use of air power against him. Control of the air is achieved by deterring, containing or defeating the enemy air forces,

Degrees of Control of the Air

2. There are three basic degrees of control of the air:

a. **Favourable Air Situation**. A favourable air situation is one in which the extent of air effort applied by the enemy air forces is insufficient to prejudice the success of friendly land, sea or air operations.

b. **Air Superiority**. Air superiority is defined as that degree of dominance in the air battle of one force over another which permits the conduct of operations by the former and its related land, sea and air forces at a given time and place without prohibitive interference by the opposing force.

c. **Air Supremacy**. Air supremacy is defined as that degree of air superiority wherein the opposing air force is incapable of effective interference.

Degree	Condition
Favourable Air Situation	Enemy air effort is insufficient to prejudice friendly success
Air Superiority	Allows conduct of friendly operations to proceed at a given time and place without prohibitive enemy interference
Air Supremacy	Enemy air force incapable of effective interference

Table 2.1: Degrees of Control of the Air

The History of Counter-Air Warfare

3. **World War- I**. The origins of counter-6ir warfare date back to World War I. As the effectiveness of air power in the scouting role became apparent, so the need to contain enemy air power increased. In September 1914 the first direct attacks were made against airfields and other air power facilities, and the following month the first air-to-air combats took place between opposing scout aircraft. By early 1915 the first aircraft designed specifically to fight other aircraft (the Fokker Eindecker) appeared. Such aircraft were soon used in offensive sweeps not only to seek out enemy aircraft, but also to provide close protection for scout and bombing aircraft. By the end of World War I most of the counter-air roles had emerged, and the need to achieve control of the air was recognized as an important aim in its own right.

4. **Inter-War**. The importance of control of the air continued to be recognized throughout the inter-war period. However, major differences emerged about how this aim should be achieved. The predominant view within the RAF in the l920s and early 1930s was that control of the air would be achieved through offensive action, and in particular by means of strategic air offensive action against the enemy's aircraft industry. However, German experience in the Spanish Civil War appeared to confirm the World War I lesson that it was necessary at least to contain the enemy air forces if strategic air offensive action was to be sustained.

5. **World War II**. In World War lithe importance of control of the air and the need for a dedicated counter-air campaign soon became apparent. The air forces of Poland, Belgium, Holland, Yugoslavia and Greece were rapidly destroyed by German offensive counter-air action, while those of France and Russia were crippled. However, defensive counter-air action also proved effective, first by the Luftwaffe in the air battles over Heligoland Bight, then by the RAF in the Battle of Britain and subsequently — for a period — by the Luftwaffe during the Allied Strategic Bombing Offensive against Germany. In the Western Desert, the Atlantic and Western Europe, control of the air was again shown to be crucial to the success not only of air operations, but also of virtually all types of surface and sub-surface operations. Similarly, in the Far East, from the outset, it became clear that the first objective of all commanders, whether ground, sea or air, whether Allied or Japanese, was to ensure control of the air. Speaking in 1947, Lord Tedder remarked that "the outstanding lesson of the last war was that air superiority is the prerequisite for all war-winning operations, whether at sea, on land or in the air".

6. **Post-World War- II**. The advent of nuclear weapons in 1945 and the apparent impossibility of providing an adequate defence against nuclear bombers seemed to show that the established concepts of control of the air were no longer valid. However, the limited military utility of nuclear weapons soon became apparent, and the over-riding importance of establishing control of the air reasserted itself. During a series of post-war conflicts — particularly in Korea, Indo-China, the Arab-Israeli wars, Vietnam, and the Falklands — control of the air proved to be the key to the effective use of air power.

7. **The Gulf War 1991**. At the outset of the Gulf War the Iraqis possessed a very strong, integrated surface-to-air defence system, a large force of fighter aircraft and over fifty airfields, nearly half of which were very large and heavily fortified. Yet they were soon overwhelmed by the power of the Coalition counter-air offensive which destroyed the cohesion of their air defence system. In the first few hours of the conflict a relatively small number of "stealth" aircraft destroyed Iraqi command and control structure and other aircraft inflicted heavy dam-to their airfields. By the ninth day of the War, the enemy dispersed his surviving aircraft either to Iran or to the woods and villages around its bases, where they remained until the fighting ceased. Some three hundred Iraqi aircraft were destroyed (mostly on the ground) and most of Iraq's airfields sustained very serious damage. The Gulf War was a graphic illustration of the potential power of offensive counter-air action.

8. **Summary**. The major doctrinal points which emerge from the history of counter-air operations are as follows:

a. Control of the air is of crucial importance not only to air operations, but also to virtually all types of surface and sub- surface operations.

b. To achieve the required degree of control of the air, a dedicated campaign to suppress the enemy air power is required. However, experience in the Gulf War suggests that, in certain operational situations, stealth technology can produce a sufficiently favourable air situation.

c. Even in a generally hostile air situation, it is usually possible to achieve temporary and/or local air superiority for specific operations.

d. The relationship between offensive and defensive counter-air action is dynamic. They are complementary and not alternative elements; and the balance between them will depend upon a range of factors.

Counter-Air-The Primary Campaign

9. In most major conflicts all three of the air campaigns (Counter- Air, Anti-Surface Force and Strategic Air) have had to be prosecuted simultaneously. Rut experience has shown that — when facing an enemy with powerful air power — priority has to be given to achieving control of the air. The more formidable the Opposing air power, the more important this task becomes. Thus, invariably, the Counter-air campaign will be the primary air campaign, and the other air campaigns will be of subordinate importance. Emergency situations may occur when Easels needed to achieve or maintain control of the air have to be diverted to other tasks. But such diversions must only be temporary, and they should never he Used as the basis for planning.

10. The counter-air campaign — like the other campaigns -- requires a wide Spectrum of air and ground combat support operations to be fully effective. There are also significant interactions between the counter-air campaign, the other air campaigns and surface campaigns. Surface campaigns depend on control of the air, but they can also affect the outcome of counter-air battles. Thus, the relationship between counter-air operations and other types of air and surface operations is interactive and can be portrayed graphically as shown below in Figure 5.1.

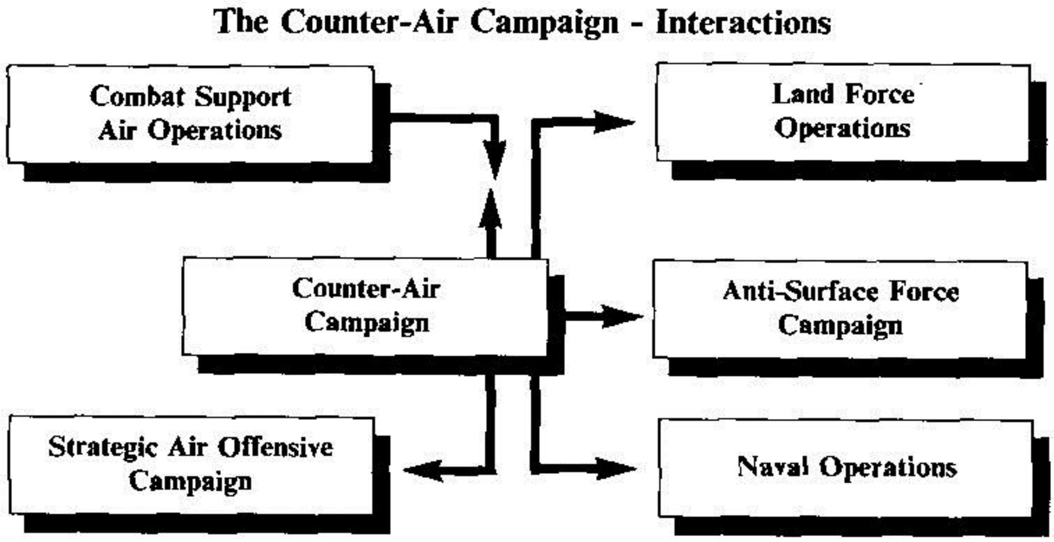


Figure 2.2: The Counter-Air Campaign — Interactions

The Offence/Defence Balance

11. **Offensive Air Action**. Carrying the fight to the enemy in the counter-air campaign confers the following inherent advantages:

a. Offensive action allows the attacker to seize the initiative, exploit to the full the capabilities of air power and concentrate strength against weakness.

b. It reduces the number of offensive sorties that he can mount and compels him to devote a proportion of his total air power assets to purely defensive duties.

c. It can better exploit the three-dimensional space of the skies, the vagaries of light and weather and the masking effect of terrain.

d. It denies the enemy a sanctuary.

12. **Defensive Air Action**. Some defensive counter-air action will usually be necessary to protect friendly air and surface forces. Moreover, defensive action may be unavoidable for the following reasons:

a. There may be over-riding political constraints on offensive action.

b. An enemy's technological superiority in defensive operations may make offensive operations too costly.

c. The enemy's bases and supporting facilities may be out of range, in which case defensive operations may be the only option.

d. Defensive operations may have to be undertaken in order to weaken the enemy s air forces as a prelude to offensive operations.

e. They may also be needed to secure a base from which offensive air action can be conducted.

13. Defensive air action also possesses certain inherent advantages:

a. A defensive battle is normally fought over the defender's territory. This allows the defender to draw upon his supporting infrastructure and bring a greater number and diversity of weapon systems into the battle.

b. Defending aircrew who abandon their aircraft over friendly territory can frequently be fed back into the battle, whereas aircrew who survive an abandonment over hostile territory are generally taken prisoner.

c. The defender's airfields are normally far closer to the battle area than those of the attacker. Thus, the defender is able to achieve a higher sortie rate and hence make more intensive use of the assets at his disposal.

d. Historically, defensive operations have proved less difficult to sustain than offensive operations.

14. **Variable Factors**. Assessing correctly where the balance lies between offence and defence is crucial to operational success. The advantages offered by offensive air action have traditionally been seen as decisive. However, a number of variables affect the extent to which offensive action is practicable:

a. **Depth**. In general, depth favours defensive air action. The greater the effective defensive depth, the earlier that attacking air systems can be detected and the better the prospects for a successful engagement. Earl3$ detection enables the defender to concentrate his forces against incoming raids, and it allows more time to prepare potential targets to withstand or survive an attack. Defensive depth enables the defender to construct a layered air defence system employing different weapon systems. This presents the attacker with successive hurdles which he must overcome to reach his target. Experience has shown that no air defence system can provide complete protection against air attack, but, historically, a layered system capable of inflicting progressive attrition on the attackers has always produced the best results.

b. **Force-to-space Ratio**. In general, the lower the overall force-to-space ratio within a theatre of operations, the more favourable the conditions for offensive air action. For the defender, a low force-to-space ratio means thinner defences supported by fewer local reserves which place a greater reliance on accurate and timely attack warning to enable forces to be concentrated against the attacker. But they do not impede the attacker's ability to concentrate. Indeed, by simplifying the problems involved in concentrating sufficient forces in space and time, they make it easier for him to saturate the defences. This is true in all forms of warfare, but in air warfare —with its very high levels of speed and reach — it is particularly important.

e. **Technology**. Technological changes can have a major impact on the offence/defence balance, For example, improved air defence sensor technology and longer-range air defence weapons tend to increase the effective defensive depth and theatre force-to-space ratios; thus, they enhance defensive power. In contrast, improved electronic countermeasures, longer-range stand-off weapons and "stealth' techniques can have the opposite effect. The expected rate and direction of technological change should thus have a major impact on future force-structuring and resource allocation. However, two points need to be borne in mind in this context:

(1) Technology has tended to deliver less than it has promised, later and at a greater cost. Therefore, over-reliance on purely technological solutions to operational problems should be avoided.

(2) Technology should not be allowed to set its own agenda. There will always be an interaction between technology and doctrine, but in essence doctrine should drive — rather than be driven by -- technology.

Counter-Air Operations

15. The counter-air campaign — like the anti-surface force and strategic air offensive campaigns — depends on the full range of combat-support air operations and ground combat-support activities, discussed in Chapters 8 and 9 respectively. This chapter will consider only those combat air operations and roles which are unique to the counter-air campaign. The counter-air campaign consists of two distinct but complementary types or operation: offensive counter-air operations and defensive counter-air operations. The various components of the counter-air campaign can be displayed graphically as at Figure 5.2 below.

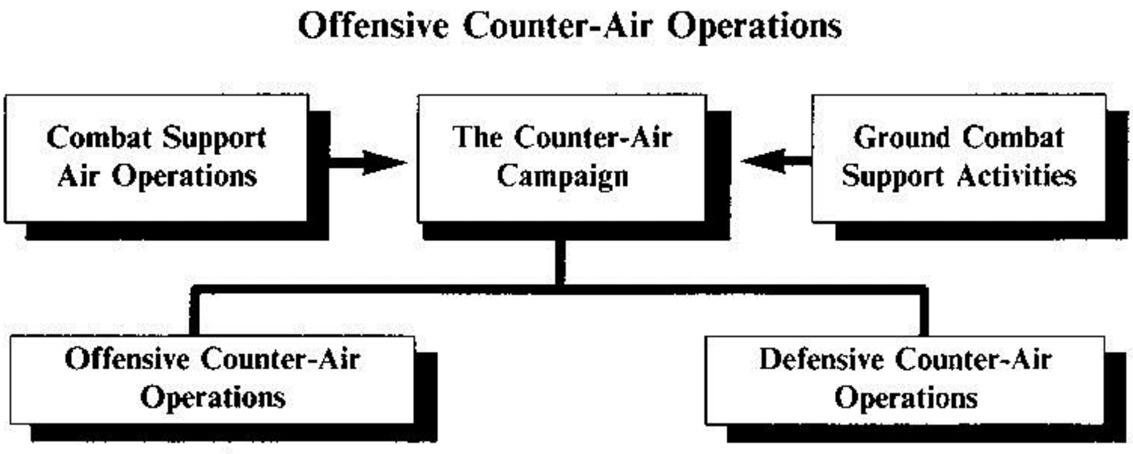


Figure 2.3 : Counter-Air Campaign Components

TOPIC-3
AIR FORCE AND AIR DEFENCE

ROLES & MISSIONS OF AIR FORCE

Training Objective. At the end of this chapter the student should know about the roles and missions of a balanced air force.

Introduction

1. Defence of the country is primarily vested on the armed forces, which has three main components: army, navy and air force. The army is responsible for the conduct of land battle. The navy fights to keep the sea-lanes open and destroy enemy's force in the sea, while air force is responsible to fight the battle in the air. Although the Services have defined areas of operation, for successful conduct of any military operation close co-operation and co-ordination between the Services are essential. A modern war is, therefore, mostly termed as "Joint Warfare" instead of being purely a land war, sea war or air war.

Roles and Missions of an Air Force

2. Roles define the broad purposes or functions of air force; on the other hand, missions define specific tasks that the forces can perform. Most air forces can perform multiple roles and missions, and some can perform in unique ways. Large air forces, such as the USAF or RAF can, obviously, perform more roles and missions then could small air forces such as in Bangladesh or Sri Lanka. Doctrine of the USAF (AFM 1-1) describes four basic roles for air force: Aerospace Control, Force Application, Force Enhancement and Force Support.

a. **Aerospace Control**. Aerospace control assures the friendly use of the aerospace environment while denying its use to an enemy. Aerospace control includes all missions whose objectives are designed to gain and maintain control of the aerospace environment. Please note the use of the term 'aerospace' instead of 'air', because the USAF capability extends into the space too. Aerospace control roles include two types of mission and these are: counter space mission and counter air mission. The aim of counter space missions is the control of space. Counter air missions are those whose objective is the control of air. Counter air missions are further divided into offensive and defensive. Offensive counter-air (OCA) missions seek out and neutralise or destroy enemy air force and ground-based air defences at a time and place of our choosing. Defensive counter-air (DCA) missions detect, identify, intercept and destroy enemy air forces attempting to attack friendly forces or to penetrate the air environment above friendly surface forces.

b. **Force Application**. Force application role includes all those missions that apply combat power against surface targets except those missions whose objective is aerospace control. Force application role includes missions such as; strategic attack, interdiction and close air support. The objective of the strategic attack mission is to destroy or neutralise an enemy's war-sustaining capabilities or will to fight. Interdiction delays, disrupts, diverts or destroys an enemy's military potential before it can be brought to bear against friendly forces. Close air support directly supports the surface commander by destroying or neutralising enemy forces that are in proximity to friendly forces.

c. **Force Enhancement**. Force enhancement increases the ability of air force and surface forces to perform their missions. Missions included are: air lift and space lift, air refuelling, electronic combat, surveillance and reconnaissance. Airlift projects air power by transporting people and material rapidly without regard to surface obstacles. Air refuelling increases the ability of aircraft by extending their range, payload and endurance. Space lift projects power by transporting people and material to and through space. Electronic combat controls the electromagnetic capabilities. It aims to enhance friendly electromagnetic capabilities while degrading those of the enemy's. Surveillance and reconnaissance provide data needed for effective combat operations.

d. **Force Support**. Force support includes all those missions that enable air force to sustain operations for a prolonged period. Forces performing the base operability and defence mission defend air force installations from attack, help air forces survive such attacks and return installations to full capability after attacks. Combat support provides essential services to keep personnel and material in operational conditions, while logistic support ensures availability of ordnance and store in right quantity, in right time and in right places.

Roles	Typical Missions
Aerospace Control (Control the Combat Environment)	Counter space Counter air
Force Application (Apply Combat Power)	Strategic Attack Interdiction Close Air Support
Force Enhancement (Multiply Combat Effectiveness)	Airlift, Air Refuelling Electronic Combat Surveillance and Reconnaissance Special Operations
Force Support (Sustain Forces)	Base Operability and Defence Combat Support Logistics

Table- 3.1 Roles And Typical Missions of Aerospace Power

3. **Short Notes on Various Types of Mission**

a. **Counter Air Operation**. Counter air operations are designed to gain and maintain a favourable air situation. Although an unfavourable air situation does not necessarily prevent the conduct of air, land and naval operations, it greatly reduces the chances of success. Although counter air operations are intended to counter an enemy threat, they provide indirect support for all other operations; and success in the counter air battle is as important to the land or naval commander as it is to the air commander. So counter air operations may be defined as the use of air power to deter, contain and defeat the enemy air forces. Examples of OCA are: air attack on enemy airfield, aircraft on the ground or in the air, HAS (Harden Aircraft Shelter), radars, SAMs, AAA batteries etc. Examples of DCA are: interception of enemy aircraft/missile/UAV(unmanned aerial vehicle) by friendly fighter interceptor/SAM/AAAs, PAD (passive air defence) measures etc. Fighters and fighter-bombers such as F-16, F-15, Mig-29, Mirage-2000 etc are used in counter air missions.

b. **Strategic Attack**. Strategic air attack encompasses the use of air power in offensive operations to destroy or damage enemy's war making capacity. The aim of strategic air attack is to undermine the enemy's ability and will to continue with the war. Examples are: attack on enemy's command and control structure, key industries, transportation lines, telecommunication centre, ordnance factory etc. For Bangladesh, Zia International Airport in Dhaka, Eastern Refinery in Chittagong, power plant at Ghorashal etc could be the target for strategic attack. Various bombers such as B-1, B-2, B-52 etc are used for this mission, but fighter-bomber such as F-15C or FA-18 could also be used.

c. **Air Interdiction (AI)**. Interdiction operations are those operations conducted to destroy, neutralise or delay the enemy military potential before it can be brought to bear effectively against friendly forces. The air interdiction battle is directed at preventing the enemy moving into, within and out of the area of engaged forces. Thus, interdiction target may include troops and vehicle concentrations, supply trains and convoy, communication centres and headquarters, bridges, railways, roads and waterways. Various fighter-bomber aircraft are used in these missions.

d. **Close Air Support (CAS)**. Close air support is air action against hostile targets, which are in close proximity to friendly forces and which require detailed integration of each air mission with the fire and movement of friendly forces. Typical targets would include enemy armoured formations, artillery and infantry in the battlefield. Forward Air Controller (FAC) suitably equipped with ground/air communication can be of considerable assistance in directing ground attack aircraft on to CAS targets. FACs are specially trained army or air force personnel. Fighter-bombers are used in CAS. Aircraft such as A-10 or Su-22 are specially designed for CAS operations.

e. **Air-to-air Refuelling (AAR)**. Air-to-air refuelling operations are those, which involve the transfer of fuel from one aircraft to another in flight. Air-to-air refuelling can contribute to combat air and combat support air operations by extending the range, payload, time-on-task and flexibility of aircraft. It can be used to support all three air campaigns as well as all types of combat air support operations. Air-to-air refuelling can be used to enhance the capabilities of virtually all types of aircraft in air power roles. Normally tankers are used in AAR role, however fighters/transports are also used for refuelling. Examples of tanker aircraft are: KC-135, KC-10, KC-130 etc.

f. **Surveillance and Reconnaissance**. Surveillance and reconnaissance involves obtaining of information about the activities and resources of the enemy by visual, photographic, electronics or other detection methods. Reconnaissance shows data of immediate nature, whereas surveillance is the systematic analysis of the data over a long period. Most aircraft are modified for surveillance or reconnaissance role, while some are designed purely to perform these roles. Examples of surveillance aircraft are: SR-71, U-2, etc and examples of reconnaissance aircraft are: MIG 25R, Mirrage III R, RC-135S etc.

g. **Special Operation**. Special operation is one conducted, at any level of conflict, in support of unconventional warfare, clandestine, covert and psychological operation. Examples of special operation are dropping leaflets to demoralise the enemy in fighting war, para-dropping, para-trooping etc.

h. **Air Lift**. Airlift falls basically under air transport operation. It can be divided into two broad categories as strategic airlift and tactical airlift.

(1) **Strategic Airlift**. Strategic airlift is the carriage of passengers and cargo between theatres of operation. It can be referred as inter-theatre airlift. Aircraft used in this role are: IL-76, C-5, C-17, An-124 etc.

(2) **Tactical Airlift**. Tactical airlift is the carriage of passengers and cargo within a theatre. It can be referred as intra-theatre airlift. Aircraft used in this role are: An-32, C-130, Dornier-228, G-222 etc.

j. **Electronic Combat**. Electronic combat falls basically under combat support operation. In wider sense it is the electronic warfare (EW) operation; which involves the military use of electronics to determine, exploit, reduce or prevent hostile use of the electromagnetic spectrum and actions taken to ensure its effective use by friendly forces. Electronic warfare is divided into three main roles:

(1) **Electronic Support Measure (ESM)**. ESM is that division of EW, which involve action taken to search for intercept, identify and locate radiated EM energy for the purpose of immediate threat recognition.

(2) **Electronic Counter Measure (ECM)**. ECM is that division of EW, which involves actions taken to prevent or reduce an enemy's effective use of the EM spectrum.

(3) **Electronic Counter Counter Measure (ECCM)**. ECCM is that part of EW, which ensures friendly effective use of the electromagnetic spectrum despite the enemy's employment of EW.

Examples of aircraft used for electronic combat are: EA-6, EC-130H, EF-4, EF-111 etc.

BRIEF OVER VIEW ON DEFENSIVE COUNTER AIR OPERATION

Defensive Counter-Air Operations

1. **Definition**. Defensive counter-air (or Air Defence) operations comprise all measures designed to nullify or reduce the effectiveness of hostile air action.

2. **Defensive Counter-Air Aim**. Establishing the correct aim is fundamental to the success of defensive counter-air operations. Essentially, there are two choices:

a. To minimize the damage sustained by friendly forces and facilities.

b. To inflict the maximum attrition on the enemy.

3. To a certain extent these aims are interdependent; the more enemy aircraft that are shot down, the fewer that are available to inflict damage in future raids, The less damage that the Allies sustain, the more capable they are or defending themselves if the enemy continues with his attacks. Deciding where the priority lies between these two aims has major implications for operational art and force structuring, and thus for resource allocation.

a. **Operational Art**. If the over-riding priority is to inflict maximum attrition, then enemy aircraft can be intercepted wherever they can be found, before or after they have attacked their targets. In contrast, if minimum damage is the aim, then all the resources need to be devoted to deterring or containing the incoming raids, even if that means leaving vulnerable home-bound enemy aircraft.

b. **Force Structuring.** If the prime aim is to minimize damage, then significant resources will need to be allocated to passive defence and resilience measures However if the aim is to inflict maximum attrition on the attackers, then passive defence measures will play a less important part, and the need to provide the strongest possible active defence forces will dominate resource allocation

4. **Priorities**. Deciding where the priority lies between the ‘minimum damage’ aim and the ‘maximum attrition’ aim will depend partly on friendly vulnerability and partly on the nature of the threat. For example, if the friendly infrastructure is seen to be particularly fragile or if the enemy is able to attack only intermittently, then a ‘minimum damage’ approach may well be best. On the other hand if friendly infrastructure is robust or if one is faced with the threat of a sustained attack, then ‘maximum attrition could well be the better option.

5. **Active Air Defence System — Requirements**. Although the aim will shape the relative allocation of the resources between active and passive defence systems, this will be a question of emphasis rather than of alternative In all cases, an

active air defence system will be needed, even though its scale might vary. And to be effective, such a system must be capable of carrying out the following sequence or functions:

a. Detecting and identifying potential target(s);

b. Assessing the potential threat posed by such targets and whether or not they need to be intercepted or engaged;

c. Passing the tactical information needed by agencies and units involved in the interception or engagement;

d. Assigning weapons and/or aircraft and placing them under appropriate tactical control.

e. Intercepting or engaging the target(s).

f. Recovering to their bases of any aircraft involved in the operation.

6. **Active Air Defence System — Structure**. Any active air defence system consists of three basic and closely integrated components:

a. A detection system to track the enemy and direct friendly weapon system.

b. A command, control, communications and information system to link the weapon and detection systems and thus make best use of the available assets.

c. A weapon system to destroy attacking enemy air vehicles.

7. **Detection System**. Detection and tracking information on hostile aircraft can be obtained from a variety of sources: for example, visual sightings, infra-red or acoustic monitoring, conventional line-of-sight radars (fixed, transportable maritime and airborne), over-the-horizon-radars and space-based detection systems. The information from these systems must then be merged into a recognized 1k picture, which can then be disseminated to all agencies and forces involved in defensive counter-air operations.

8. **The Weapon System**. An air defence weapon system will normally consist of two complementary components: surface-to-air defences and fighter aircraft:

a. **Surface-to-Air Defences**. Surface-to-air defences consist of surface-to-air missiles and anti-aircraft artillery. Surface-to-air defences allow high-readiness states to be maintained over long periods, they give quick response and in certain cases — they can be used to counter ballistic missiles. But, in comparison with fighter aircraft, they have limited range and low mobility, and therefore relatively large numbers of surface-to-air defence systems may be deeded to defend anything but point targets. Moreover, anti-aircraft artillery has very limited range and surface-to-air missiles have very limited flexibility;

the latter are single-role systems and, except in the case of some point-defence SHORAD systems which can be optically sighted, are unable Positively to identify their targets prior to engagement — a point which is of major importance particularly for peacetime air policing and during times of tension.

b. **Fighter Aircraft**. Fighter aircraft have limited endurance, and they cannot be rearmed re-crewed or serviced in the air. But they are flexible and reusable and can therefore be switched to tasks other than air defence should the operational situation demand it. Fighter aircraft are also mobile and hence can be used to protect very large areas or be concentrated rapidly to counter enemy saturation raids. Moreover they are far better able to identify targets positively before engaging them. Fighters can be used for the following types of task:

(1) **Interception**. An intercept mission may involve the scramble of fighters from a high state of readiness or the direction of aircraft from combat air patrols. Interceptions can be carried out autonomously or with the assistance of air defence radars.

(2) **Combat Air Patrols**. Combat air patrols are mounted over an objective area, over the force protected, over the critical combat zone, or over an air defence area, for the purpose of intercept-mg and destroying hostile aircraft before they reach their targets. They enable rapid reaction to enemy intrusion and may be positioned well forward of the areas to be defended. Combat air patrols may be conducted to support both defensive and offensive counter-air operations. They are essentially defensive in nature, and sustaining them particularly at long range and over long periods can absorb a great deal of effort.

(3) **Escort**. Escort missions (defined above) by fighter aircraft may be needed to support other aircraft carrying out offensive, defensive or combat support tasks.

c. **Fighter/surface-to-air Force Mix**. The preferred force mix between fighters and surface-to-air defences within an air defence system — and the nature of their operational deployment — will depend on a variety of factors, of which perhaps the most important are warning time and geography:

(1) **Warning Time**. When warning time is short and hence interception opportunities limited, effective defence is best provided by a screen of high-readiness surface-to-air systems backed up by a mobile reserve of air defence fighters. As warning time increases, so the opportunities grow for exploiting the air defence fighter’s far greater mobility and ability to concentrate firepower in space and time.

(2) **Geography**. The larger the area, the more difficult and expensive it is to provide an effective level of surface-to-air defence cover. When large areas have to be defended, the mobility offered by air defence fighters makes them particularly cost-effective. Surface-to-air defences can offer a useful option for providing, for example, a permanent, forward, air defence presence along a continental border or within a limited geographic area. In general, surface-to-air defences are

best suited to local and point defence, whereas air defence fighters are best suited to area defence,

Layered air Defence System

I. Early Warning — long range detection by AEW/AWACS and land based radars.

2. Long range interception — by Combat Air Patrols with AAR support.

3. Interception — by land based QRA aircraft.

4. Area SAM

S.SHORAD — and point defence, including IDF aircraft.

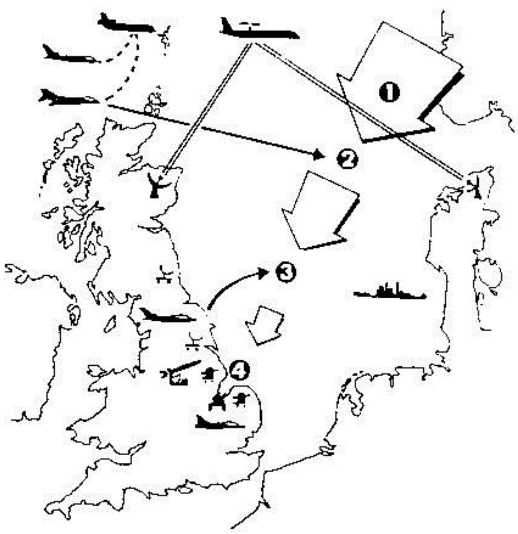


Figure 3.1 : An integrated and layered air defence system.

9. **Command and Control System**. The purpose of the defensive counter-air and control system is to integrate all of the various elements of then and detection systems into a coordinated entity, thus ensuring the optimum use of available resources against the threat. The overall command and control of defensive counter-air operations must be vested in one person: the air defence commander. If the area to be defended is large and the intensity of operations is likely to be high, a number of defensive sectors can be established, each the control of a sector commander who reports to the air defence commander.

10. **Participation of the Surface Forces**. In defensive counter-air operations, naval and land force organic surface-to-air and detection capabilities can add to effective defensive depth and increase the level of attrition on attacking enemy aircraft. Thus, the air defence command and control system must be integrated with the command and control systems of the surface forces within a theatre to ensure that joint defensive counter-air assets are employed in a fully coordinated fashion.

11. **Passive Air Defences**. Passive air defences are defined as all measures, other am active air defence, taken to minimize the effect of hostile air action. These assure include deception, dispersion, concealment and camouflage, the use of protective construction and the increased redundancy of operating strips. Some of these aspects are examined in the ground defence section of Chapter 9. The 9&all structure of defensive counter-air operations is shown graphically in Figure 3.2 below:

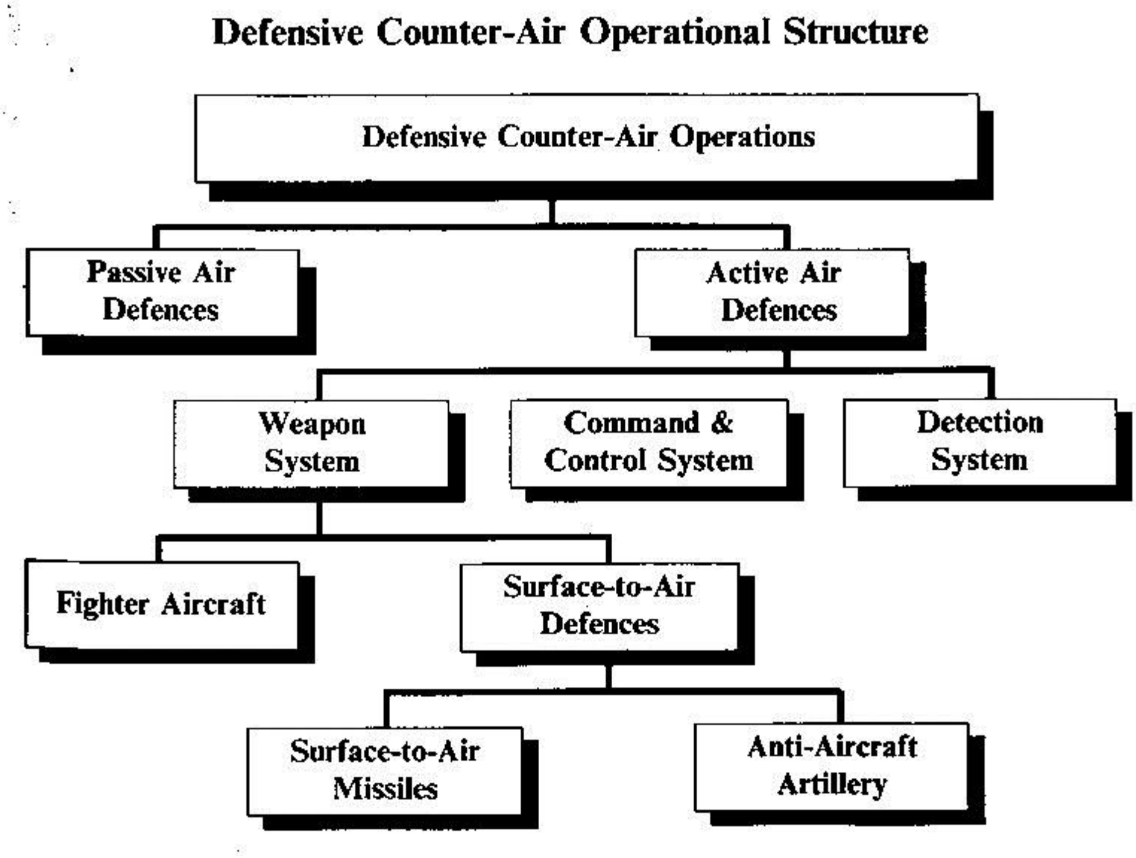


Figure 3.2: Defensive Counter-Air Operation Structure

TOPIC- 4
ORGANISATION OF AIR DEFENCE

COMMAND AND CONTROL OF AIR DEFENCE ORGANIZATION

"Nothing is so important in war as undivided command"
- Napoleon Bonaparte

Training Objective. At the end of this lesson the student should know:

a. What are the key principles of AD Command and Control?

b. What is Command, Ops Command, Ops Control and Tactical Control?

c. The Layout of air defence command of Bangladesh.

d. How the Command and Control is exercised over the various echelons of Air Defence.

Introduction

1. Successful command and control is paramount to the efficient employment of air power. Command and control should not be confused with command, control, communications, computer and information (C^4I), which describes the equipment, facilities and procedures used in the exercise of command and control.

2. AD system includes a number of active and passive elements, belonging to different services and civil organisations. A unified command and control system is necessary to bring together various elements of AD into an organised fighting force. The command and control system should be such that everybody clearly knows his duties and responsibilities, and all elements of the AD system function as a team. One must be sure to whom and for what he is responsible.

Principles of Command & Control

3. Experience has shown that unified action is essential for the effective use of air power. The natural characteristics of, speed, reach and flexibility of air power, enables it to be employed in diverse and varying task. If not employed competently, this could lead to division of forces and dissipation of effort. The high cost of air assets generally means that fleet sizes are limited; hence tasking priorities has to be set and there will always be insufficient air resources to meet all demands. Optimisation of air resources requires sound understanding of certain key principles to be followed in order to ensure that air power capabilities are used efficiently as the operational situation demands.

4. The key principle of command and control in AD is **centralised control and decentralised execution**. It means that the AD resources must be controlled centrally. However, it does not restrict the commanders and operators at lower levels from taking their own initiatives and decisions to meet fast changing situations. Centralized command and control promotes an integrated effort and enables forces to be employed to the priorities of the designated commander. It also allows air action to be refocused quickly to exploit fleeting opportunities, be responsive to the

changing demands of the operational situation and be concentrated at the critical place and time to achieve decisive results. AD resources will always be limited compared to the demands. We are not likely to have enough fighters, guns, missiles, AD ships or radars to meet our requirement. Commanders at higher level, who has the total picture of the battle, can assess the situation and allocate resources according to the priorities. Without centralised control, resources are likely to be wasted on less important threats, leaving us vulnerable when the main attack comes. In modern warfare the AD assets are centrally controlled by a single joint force air defence commander (ADC). The ADC is generally an air force officer or from the service that provides the bulk of the AD forces.

5. No single commander can direct personally all of the detailed actions of a large number of air units or individuals nor is it desirable for higher commanders to go into the details of tactical actions at the lower levels. Therefore, decentralized execution is essential, and it is accomplished by delegating appropriate authority to execute missions and tasks. Decentralized execution allows subordinate commanders to use their judgement and initiative within the overall pattern of employment laid down by their superiors. It becomes especially important when command and control systems are lost through enemy action. Decentralized execution can lead to subordinate commanders taking divergent initiatives, which would weaken the cohesion of a campaign. But this effect can be avoided if doctrine and the overall operational objectives are properly understood at all levels of command.

Definition of Command and Control

6. Command and Control (C2) is defined as the exercise of authority and direction by a designated commander over assigned and attached forces in the accomplishment of the mission. C2 functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission. Essentially 'command' represents the authority to direct, coordinate and control military forces and 'control' characterises the responsibility to implement orders or directives. Legally, it allows delegation of command to a subordinate, and ensures compliance with higher orders. Operationally, it provides the means for implementing the commander's decision and monitoring the results. However, the commander still remains responsible to higher authority for the conduct of operations by his subordinates, and may delegate his duties but still bears the ultimate responsibility.

7. In current military usage, command and control have specific meanings. A working understanding of command terminology is essential to understand the relationships among components and the responsibilities inherent in organisation. This tenet suggests that command and control should be the responsibility of a single authority and should not be devolved to a level lower than that where a commander is able to communicate his guidance, intent and mission directives to lower formations. Thus, the authority of command and control can be divided into several levels or degrees of authority. A working understanding of command terminology is essential to understand the relationships among components and the responsibilities inherent in organisation. This tenet suggests that command and control should be the responsibility of a single authority and should not be devolved to a le vel lower than that where a commander is able to communicate his guidance,

intent and mission directives to lower formations. Thus, the authority of command and control can be divided into several levels or degrees of authority.

a. **Command**. Command is defined as the authority that a commander in the Armed Forces lawfully exercises over subordinates, by virtue of rank or assignment. Command includes the authority and responsibility for effectively using available resources and for planning the employment of, organizing, directing, coordinating, and controlling military forces for the accomplishment of assigned missions. It also includes responsibility for health, welfare, morale, and discipline of assigned personnel. The various levels of authorities used by commanders include three command relationships i.e. Full Command, Operational Command (OPCOM) and Tactical Command (TACOM).

(1) **Full Command**. Full command covers every aspect of military operations and administration and exists only within national services. The term command as used internationally implies a degree of authority than when it is used in purely national sense. Such as no NATO commander has full command over his personnel as nations, assigning forces to NATO, assign only operational command and operational control. Full control over personnel can not be delegated to a commander from other service. Full command equates to ownership.

Example: The COAS exercises Full command over all BAF Personnel, Bases and units.

(2) **Operational Command (OPCOM)**. Operational command is the authority granted to a commander to assign missions or tasks to subordinate commanders, to deploy units, to reassign forces, and to retain or delegate operational and/or tactical control as may be deemed necessary. It does not of include responsibility for administration or logistics. OPCOM has been linked to long term leasing.

Example: A Joint Force Commander, when delegated, exercises OPCOM over the forces palced under him.

(3) **Tactical Command**. Tactical Command is the authority delegated to a commander to assign tasks to forces under his command for the accomplishment of the mission assigned by higher authority. It does not include authority to alter the structure of the force by assigning separate employment to various components of the force and may not be delegated to another commander.

b. **Control**. Control has two meanings. In one sense, it is ofetn regarded as the process through which command operates. Such as staff and communication facilities to regulate forces and function to execute commander's intent. The other application of control relates to specific authority exercised by a commander over forces not normally under his command. NATO simply defines control as the responsibility to implement order and directives. The various levels of control used by commanders include two control relationships i.e. Operational Control (OPCON) and Tactical Control (TACON).

(1) **Operational Control**. Operational control is the authority delegated to a commander to direct forces assigned so that the commander may accomplish specific missions or tasks which are usually limited by function, time or location, to deploy units concerned, and to retain or assign tactical control of those units. It does not include authority to assign separate employment of components of the units concerned, nor does it include administrative or logistics.

Example: ADOC exercises OPCON over Air Defence Ground Environment.

(2) **Tactical Control**. Tactical control is concerned with the detailed and, usually, local direction and control of movements or manoeuvres necessary to accomplish missions or tasks assigned. Tactical control can be considered as short term process.

Example: A GCI Controller exercises TACON over the fighters while carrying out a GCI.

AD Command & Control in Bangladesh

8. **Higher Echelon of Command & Control**. Higher Echelon of AD Command is described below:

a. **President**. The President is the Supreme Commander of the Defence Forces of Bangladesh. He acts on the advice of the Prime Minister except during the period of the Interim Govemment when he assumes the executive power of the Commander in Chief.

b. **Prime Minister(PM)**. The PM, who currently holds defence portfolio, is responsible for all defence matters, including AD. Thc PM runs day to day activities of the armed forces through the Armed Forccs Division (AFD). The PM is also the head of the National Committee for Security Affairs (NCSA) and JCC, when formed.

c. **Chief of Air Staff (COAS)**.The COAS, BAF is the ADC. He is responsible to the Defence Minister for planning, organising and functioning of the AD forces. ADC with the help of his staff prepares the plan for AD, and formulates the policies to organise and activate the AD system.

d. **Air Officer Commanding, Air Defence {AOC (AD)}**. AOC (AD) is responsible to the ADC for conducting AD battle during war, exercising the air and ground based AD systems, conducting AD exercises, co-ordinating training and ensuring desired level of operational standard of different AD components. At present, Assistant Chief of Air Staff (Ops & Trg) is concurrently designated as AOC (AD).

e. **Commander ADA Brigade (Comd, ADA Bde)**. Bangladesh Army AD elements are organised into an Independent ADA Bde. The role of the

ADA Bde is to provide AD protection from the ground to designated VAs and VPs in the rear and the army deployed in the field. Comd, ADA Bde acts as the advisor to ADC on all matters of ground-based AD weapons. He exercises OPCON over the ADA Bde.

f. **Air Defence Operations Centre (ADOC)**. The AOC (AD) exercises various degrees of command and control of AD resources through the Chief Controller (CC) of ADOC. ADOC functions round the clock in peace and in war. It exercises OPCON of AD ground environment (ADGE) and TACON of allotted AD weapons of army, navy and airforce. The Representatives from the ADA Bde, the MHQ (if established), BN and the Civil Defence HQ are available in the ADOC for maintaining liaison with the respective HQs. Lower echelons of AD elements are described below.

9. **Lower Echelon of Command & Control**.

a. **Sector Operations Centre (SOC)**. During war or hostilities, the ADC may divide Bangladesh into a number of defensive sectors. A sector is placed under the operational control of an air force offcer known as the Sector Commander. The ADC issues policy directives to Sector Commanders. The Sector Commander exercises controlling authority through a Sector Operations Centre (SOC). SOC is connected to the ADOC, adjacent SOCs and subordinate control organisations within the sector. Like ADOC, SOC exercises OPCON over ADGE and TACON over all allotted AD weapons within the sector. SOC will have army and naval gun control officers. When SOC is established in Chittagong, the SOC and the AMHQ Chittagong will exchange Liaison Officers to ensure proper coordination and smooth conduct of the AD. Similar arrangement will be made regarding coordination with AMHQ Khulua in case SOC is established at Khulua.

b. **Early Warning/Ground Control Interception Station**. Early Warning (EW) stations carryout surveillance and provide early warning of airborne objects. The roles of Ground Control Interception (GCI) stations include surveillance, early warning and control of interceptors. ADOC/SOC exercises OPCON of these units.

c. **Fighter-Interceptor Aircraft**. The task of fighter-interceptors is to intercept, identify, and if necessary, shoot down enemy aircraft or airborne objects before they deliver their weapons or achieve their objectives. In case, destruction of the intruders is not possible, the fighters will dissuade the attackers from reaching their objective or deliver their weapons on the target. The fighters, when deployed on AD role, come under the TACON of ADOC/SOC for the purpose of the state of readiness, scrambling and fire control orders. The OPCON is exercised by their respective Base/Unit Commanders.

d. **Army AD Weapons**. Their mission is to destroy the enemy aircraft and other airborne objects or to nullify their effectiveness by forcing the attackers to abandon their mission. Army HQ exercises command of these forces, while Comd, ADA bde exercises OPCON over them. AOC AD exercises TACON through ADOC over all the deployed AD units including those deployed with the Fd army through the Control and Reporting Liaison

Officer (CRLO) deployed with the ALO/TACP. An ADA Liaison Officer, known as ADA Executive (ADE) sits in ADOC/SOC and is connected to AD Arty Command Post (CP) at various locations. ADE is responsible to pass gun control orders and readiness states promptly and accurately from the ADOC to AD Arty CP.

e. **Area Maritime Headquarters (AMHQ)/Commander Task Force (CTF)**. The AMHQ is a part of the Bangladesh Navy. Two AMHQs are in Chittagong and Khulna while the MHQ is co-located at NHQ. The Naval Liaison Officer (NLO) who sits in ADOC, is the link between NHQ/AMHQ and the national AD system. Information regarding air raids on naval establishments, port area and forwarded bases/hideouts may be passed to the concerned AMHQ. The gun control orders and warning of air raids over naval shore installations is passed through NLO to the AMHQ. At present, BN does not possess its own shore-based AD weapon systems. ADA of Bangladesh Army provides ground based AD support to BN shore establishment, Ports and Harbours. In future, when BN acquires own AD assets and those are deployed, ADOC will exercise TACON over those forces,depl ashore in the same way it does over the AD forces of ADA Bde during exercise/operation. AD responsibility of the Flotilla/TF is primarily vested on the CTF. BAF LOs on board designated ships of BN Flotilla/TF/TG will maintain link with ADOC/SOC and AMHQ for raid warning, gun control orders, coordination, CAP etc. CAP depl on AD msn will be under TACON of CTF/CTG/OTC for the pd of depl.

f. **Civil Defence Ops Room**. Civil Defence Ops Room is connected with the ADOC and the district level civil defence organisation. The civil defence representative in ADOC receives and relays air-raid warning to Civil Defence Ops Room. Civil Defence Ops Room is responsible for passing and dissemination of air raid information to the concerned district civil defence organisations.

10. **Air Defence Committee**. The AD committee is a high-level joint services committee under the chairmanship of AOC (AD). The committee has members from all the three services. The committee meets at least once in six months to decide upon the various aspects of AD and to form uniform national policy conceming AD of Bangladesh. The composition of the AD Committee and its role and task are given in next chapter.

Air Defence Organisation

11. The Command and Control Structure of the Air Defence organisation of Bangladesh is shown below:

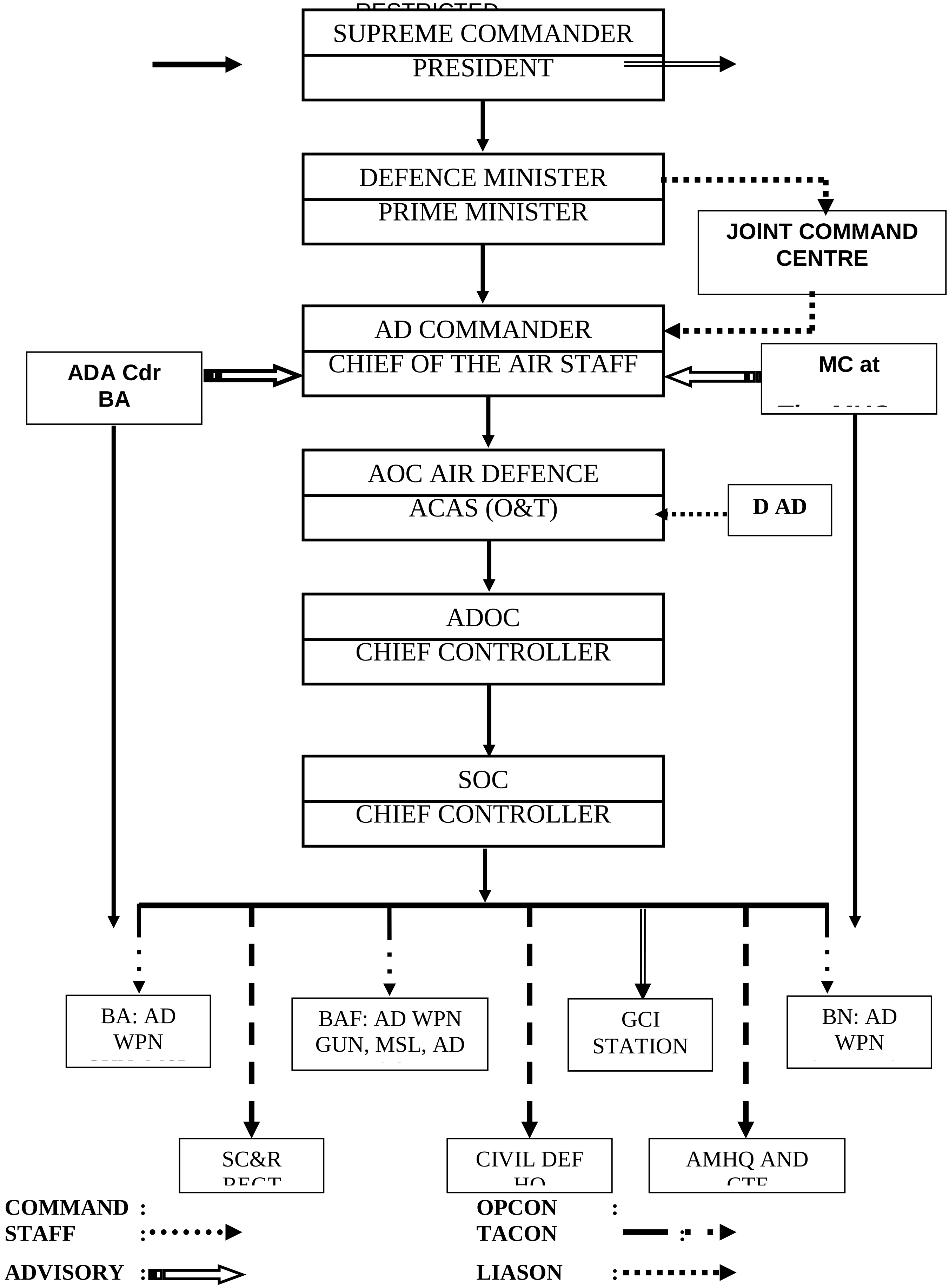


Figure 4.1: AD Command and Control Structure of Bangladesh

PRINCIPLES OF AIR DEFENCE

Training Objective. At the end of this chapter the student should know the different principles of an effective air defence system.

Introduction

1. An effective air defence system will have to detect an impending air attack in time and destroy it before it reaches the target. The air defence system, therefore, works on the following principles:

a. Detection.

b. Identification.

c. Threat Evaluation.

d. Weapons Assignment/Tactical Action.

e. Engagement Assessment.

Detection

2. It is with the detection that all actions aimed at destruction of the enemy are initiated. Unless detection is achieved well in time the air defence system may fail to achieve destruction of the enemy before it reaches the Weapon Release Line. Hence it is obvious, that earlier the detection, more time will be available for planning and execution and destruction will take place further from the target protected. With the modern technological developments in aviation the enemy is capable of flying very low and attacks the desired target giving very less or no early warning at all. On the other hand, bombers may attack at very high altitude using Electronic Counter Measures (ECM) and other decoys. Therefore, to counter the threat of both high and low flying air attacks on VPs, a combination of high power and low looking radars are deployed. If tactical situation demands then Mobile Observer Unit (MOUs) have to be deployed to augment the surveillance by low looking radars.

3. Because of the introduction of stand-off weapons such as air to ground missiles, TV/Laser guided bombs etc the attacking aircraft can release its weapon staying many miles away from the target. In order to intercept these targets, our detection has to be many miles further than it was in the past.

4. Since the surveillance equipment are looking all around the Bangladesh airspace, any airborne object entering their area of responsibility of the surveillance system, is detected and plotted on the plotting board and data display board of the Operation Room. Its strength, direction of movement, height and speed is also determined and awaits identification.

Identification

5. Having detected an airborne object it is essential to establish its identity, because all further actions/decisions on the object detected is determined by its identity. The air defence system has various means such as electronic interrogation, flight plan information etc to identify an airborne object. Using these means the identification is done. If the airborne object has the prior permission to fly over Bangladesh airspace then it is declared friendly. If it has not obtained prior permission for such flight, then the object is declared unfriendly and further action is taken by the air defence system and that is “threat evaluation”.

Threat Evaluation

6. Once an airborne object has been declared unfriendly, based on available data in the Air Defence Operation Centre, it is assessed as to what sort of threat it poses to the country. This evaluation is done considering points like:

a. Did the airborne object originate over hostile territory?

b. Has the aircraft emitted unauthorised ECM?

c. Has the aircraft violated prohibited zone?

d. Is the aircraft flying in an open area?

e. Is it not a friendly aircraft returning home with its IFF system non-operational due to battle damage?

f. Which is the probable VP towards which this threat is heading?

g. What is the strength, height and probable type of aircraft?

Weapon Assignment

7. Based on the points mentioned above, the threat evaluation is done. Once the threat has been evaluated, air defence system proceeds to intercept the enemy. The interception should be accomplished as far away from the target and to allow as much time as possible, so that the interceptor forces have sufficient time to achieve complete destruction. Weapons assignment is the optimum allocation of available weapon resources by the air defence system to engage target effectively that are selected for engagement. Depending on the type and nature of threat, different types of weapons are used by the air defence system. Weapon systems may comprise of:

a. Interceptor Aircraft.

b. Surface to Air Guided Missile (SAM).

c. Anti-Aircraft Artillery (AAA).

Engagement Assessment

8. Last principle of air defence is engagement assessment. Once an airborne object has been identified as unfriendly and threat assessment has been done, weapon is assigned. The air defence must now evaluate how far they have succeeded in dealing with the threat. Engagement assessment is the continuous real time analysis of engagement data to determine the success of “Air Defence System”. The analysis can be broken into four distinct time periods during the engagement:

a. Launch.

b. Guidance and Flight.

c. Intercept.

d. Kill.

9. The four phases of engagement are explained below:

a. **Launch**. In case of the interceptors, 'Launch' means the taking-off of ADA aircraft. In case of SAM and AAA, it is the actual launch of missiles or firing of guns.

b. **Guidance and Flight**. An interceptor will have to be guided by GCI station to a position from where the pilot can intercept the enemy. In case of guided missile, command has to be given to the missile in-flight to continuously correct its flight path.

c. **Intercept**. An on-time launch and accurate guidance will generally lead to a successful interception. In case of an interceptor, a visual identification may be necessary, especially in peace time before engaging the targets. In case of SAM, interception will be proceeded by electronic identification of the target.

d. **Kill**. Engagement and destruction of a target will depend on engagement policy. Kill rate is highly variable; depends on the air defence system proficiency, enemy's tactics and techniques, armament, weather etc.

COMPONENTS AND FUNCTIONS OF A BALANCED AIR DEFENCE SYSTEM

Training Objective. At the end of this chapter the student should be able to know the major components and functions of a balanced Air Defence System.

Main Components

1. The main components of a highly organised air defence system are as follows:

a. A control and reporting (C&R) system.

b. Interceptor fighter aircraft.

c. Surface to Air Missile.

d. Anti-Aircraft Artillery.

e. Concealment and Deception.

f. Civil Defence.

2. The Offensive counters Air Operation which is directed against enemy airfield and associated installation, although not a purely defensive element is considered as an essential part of the air defence battle.

Control and Reporting System

3. The task of the control and reporting system is to provide warning of the approach, and therefore, to continue the tracking of enemy aircraft and to co-ordinate and direct defensive measures.

4. The entire C&R system must be maintained at the peak of efficiency, for all time, is a vital factor. The greatly increased speed and height at which modern aircraft can operate, allow little time for the defence to meet and defeat the attack before the target is reached. It is essential, therefore, that the time between the initial detection of approaching hostile aircraft and the interception by fighters or guided weapons should be reduced to the minimum. In addition to improving the performance characteristics of the fighters employed, efforts to minimise system delay should be the aim of C&R system. Automatic presentation of the air situation to all users, and the delegation of authority to lower formations to order fighters into the air are two means by which these time delays can be reduced. Additional early warning time is also advantageous and can be achieved by deploying the detection system as far forward as possible within the area of continuous coverage, and by linking the system with adjacent defence areas. The main weaknesses in radar cover in a C&R system are at low level, since the radar horizon is essentially limited to line of sight. It is in this area that Airborne Early Warning (AEW) has a major part to play in extending or supplementing the low level cover from land based radars.

5. The sections of a C&R system detailed below are essential elements of a highly organised air defence system. The methods of operation within each depend on the type of equipment available both on the ground and in the air. The major components of the C&R system are as follows:

a. **Raid Reporting Organisation**. Information of the approach of aircraft is obtained from a carefully planned system of radar stations of various types fixed, mobile, or airborne and from a ground observers organisation located so as to provide continuous coverage of all approaches to the defended area. Under certain circumstances naval vessels in coastal waters can supplement the information from land stations and ships may be positioned especially for this purpose. Identification of tracks is done by receiving identification signal responses from allied aircraft, and by cross-reference with the known movements of friendly aircraft. In tactical areas, where many offensive missions may be flown, an essential task for the offensive support is to pass movements of such sorties to the relevant authority.

b. **Control Organisation**. The collection and display of information obtained by the reporting organisation is used mainly for the control and direction of the battle, though all other active, passive, and civil defence cells work from the same display. The Duty Controller at ADOC, as the representative of the AOC Air Defence, is responsible for assessing the air situation and for ordering counter action in sufficient time to achieve a kill before the weapon release point. This is done by ordering the firing of AAAs, launching of SAM and or ordering off fighters, and then delegating the fighters to the most conveniently placed radar control station within Bangladesh. When SOC's are created, the authority of scrambling fighter is delegated to the Duty Controller at SOC. A GCI controller then directs the fighters to a position sufficiently close to the enemy to complete the process of making contact by airborne radar or visual means. Fighters may be handed over to adjoining sectors if this is necessary in the interests of a successful and early interception. The ADOC/SOC is also responsible for ordering states of ground preparedness for fighters, AAAs and SAMs, for liaison with other services, and for maintaining the entire air defence organisation at the maximum state of efficiency.

c. **Fighter Recovery Service**. To increase control capacity, and to assist in the recovery of fighters after combat when aircraft navigational aids are inadequate, a fighter recovery service is included in the C&R organisation. This service controls a number of DF or fixer stations and is assisted by its own radar display. With these aids it is responsible for the safe passage of all fighters which are in RT contact and for guiding them back into their home airfields, or, if necessary, to a diversionary airfield. The responsibility of the fighter recovery service ends when the fighters transfer to the control of the selected airfield.

d. **Defensive Radio Warfare**. The task of the DRW organisation is to deceive, divert and hinder enemy offensive air operations by denying the enemy use of his radio, radar navigational and bombing aids, and to aid the defence by exploiting the enemy's radio and radar transmission. This task can be achieved by emitting ECM to enemy radar and navigation aids, jamming their radio and communication network, confusing their missile and interceptors by using decoys, chaffs and by generating false target with the help of electronic signals. By monitoring the enemy's radar and radio aids we can also come to know about enemy's intention, tactics, technique and their development.

e. **Intelligence Section**. In order to profit from intelligence not derived directly from the C&R system, an intelligence network is normally included in an air defence organisation. Within the C&R organisation, therefore, an intelligence section is established to receive and interpret intelligence from sources outside the sector in order to assist the AOC Air Defence in fighting the air battle. An example of an outside source of intelligence is the interception of enemy RT transmissions. The intelligence section is also responsible for collection and interpreting all information derived from within the C&R organisation and for advising the AOC Air Defence of positive trends in enemy tactics.

f. **Inter-Communication System**. An efficient, rapid, and secure system of inter-communication is essential to link the many components of an air defence system. No air defence system, however simple or complex, can function with any degree of efficiency without a means of passing information and instructions with the minimum of delay between the various parts of the organisation. Without such a means it can neither be alerted nor controlled as a coordinated whole. In addition to the RT link or landline network of communication, the system should ideally, carry the air situation picture instantaneously and automatically to all those who require it.

Fighter Interceptor Aircraft

6. The role of fighter interceptor aircraft is to destroy enemy aircraft before they reach WRL or divert them form their intended targets. The essential characteristics of an interceptor are quick reaction i.e. to be able to be airborne at short notice, high rate of climb, good manoeuvrability high speed and a combination of long range and close combat weapons.

Surface to Air Missile

7. The task of SAM system is essentially similar to that of interceptor fighters. However, it lacks the flexibility and multiple role of a manned fighter. The deployment of SAM depends on the performance of the system and the nature of the target or targets to be defended. To make the most efficient use of SAM they must be integrated with fighters in a common air defence system and must therefore come under the control of one air defence commander.

Anti-Aircraft Artillery

8. The role of anti-aircraft artillery is to provide medium and low altitude air defence to VAs and VPs. Its mission is to destroy attacking enemy aircraft, nullify their effectiveness and force them to abandon their mission. With the introduction of high speed aircraft and improved tactics and weapons; the task of AAA - because of its limited range, mobility and reaction time - has become very difficult. The AAAs are classified as:

a. **Light AAA**. These are used for LL air defence. Its maximum effective altitude is normally below 10,000 ft.

b. **Medium AAA**. These operate between LL to Medium Level. Its maximum effective altitude is normally between 10,000-15,000 ft.

c. **Heavy AAA**. These are used for high altitude cover and normally operates between 15,000 ft to 25,000 ft. With the introduction of SAMs, these type of guns are becoming obsolete.

Concealment and Deception

9. The aim of concealment and deception is to avoid being recognised as a target. On the ground, installations may be camouflaged or toned-down i.e. painted in drab colours or in shades that will help objects to merge in with natural surroundings. In the air, ECM can be used to conceal an enemy approach and deceive the defences. Decoy aircraft, and sometimes installations, can be used to confuse an enemy. However, decoys should be moved frequently if they are to be of lasting value. Dispersal either within airfield bound or to other locations is also element in concealment and deception planning.

Civil Defence

10. The task of civil defence is to keep the civilian morale high in the face of enemy attack and to reduce the scale of dislocation of services, casualties and destruction. A modern war is a total war where the civilian population also become target of enemy attack. Civil defence is therefore organised on a national level. Every district, area, city and town is organised into sectors with a distinct chain of command. Volunteers trained in peace time and mobilised during war to help organise civil defence. The organisation does not come under the operational control of the ADOC, but civil defence cells are established in each SOC. Thus, there is close liaison between the civil defence organisation and the air defence system. In this manner, the up-to-date information obtained from the C&R system and the intelligence section is available for civil defence purposes.

DUTIES AND RESPONSIBILITIES OF AIR DEFENCE PERSONNEL

Training Objectives. At the end of this chapter the student should know:

a. The duties and responsibilities of different persons working in air defence system.

b. The typical layout of an ADOC and a GCI unit.

Introduction

1. The duties and responsibilities described here provide a guideline to those employed in the Air Defence System. Bases and Units will draw up detailed duties and responsibilities of the individual positions showing the sequence of events and the action each individual is required to take on those.

Duties and Responsibilities of Higher Commander

2. **Air Defence Commander**. Air Defence Commander is responsible to the Government for all matters pertaining to the Air Defence of Bangladesh.

3. **Air Officer Commanding Air Defence**. The Air Officer Commanding, Air Defence is responsible to the Air Defence Commander for the following:

a. Conducting the air defence battle during war.

b. Exercising the fighter defence system and conducting air defence exercises.

c. Coordinating of training of different components of the air defence system during peace.

d. Ensuring that the operational standards of various components of air defence are kept up to the desired level.

4. **Director of Air Defence**. He is responsible to AOC Air Defence for the following:

a. Initial formulation of policy on air defence operational procedures and techniques.

b. Dealing with matters relating to air defence policy.

c. Preparation and issue of air defence manuals and their amendments.

d. Formulation of air defence operational procedures and techniques.

e. Planning of future requirements of C&R system.

f. Planning of air defence exercises in liaison with Director of Operations.

g. Liaison with the Army, Navy and Civil Defence on matters relating to air defence.

h. Liaison with Director of Training on the preparation and review of syllabi for training of C&R personnel.

j. Liaison with other directorates for the maintenance and operation of C&R installations.

Duties and Responsibilities of ADOC Personnel

5. **Officer Commanding ADOC/Chief Controller**. Chief Controller is a qualified controller having a minimum proficiency of 'Combat Ready' status. He is responsible for the efficient working of the C&R organization under his command. He is a link between the higher formation and the C&R organization within his area of responsibility. In addition to the above, he is to:

a. Supervise the overall operation of the ADOC.

b. Supervise the activities of the controllers and staff in ADOC.

c. Supervise the flow and display of the air defence data from all EW/GCI units and ensure an accurate and timely display of this information.

d. Coordinate with the higher command for the flow of air defence data.

e. Ensure that all orders and instructions issued by the Air Defence Commander, or his deputy are relayed, coordinated and carried out by all concerned.

f. Ensure cross training of all C&R personnel in ADOC.

6. **2IC /Senior Controller**. He is a qualified controller having minimum proficiency of 'Combat Ready' status. He is responsible to the Chief Controller for the following:

a. The efficient working of ADOC ops room.

b. Passing of orders and instructions to all concerned and ensure execution.

c. Ensure training of all air defence personnel in ADOC.

d. Supervision of the activities of Shift Controllers and Shift Supervisors.

e. Preparation of Standard Operating Procedures (SOP) and ensure its compliance by all.

7. **Duty Controller (DC)**. Duty Controller is responsible during his tour of duty to the Chief Controller or his deputy for:

a. The efficient operation of the watch.
b. Assessing the air situation and taking tactical decision.

c. Ordering fighter scramble or allocating other weapons for the interception of a raid.

d. Allocating interceptors to GCI units.

e. Ensuring fighter recovery through GCI units.

f. Alerting and coordinating air, sea and land rescue services.

8. **Assistant Duty Controller (ADC)**. Assistant Duty Controller is an assistant to the Duty Controller. He is responsible to the Duty Controller for:

a. Passing all control orders and instructions of the duty Controller to the appropriate agencies.

b. Assisting Duty Controller in scrambling the interceptors.

c. Maintaining Fighter Mission and Weapon Status Boards.

d. Observing correctness of other informations displayed on the Status Board.

e. Maintaining the Controller's log.

f. Filling in the Tactical Engagement Report form.

9. **Movement Identification Officer (MIO)**. Movement Identification Officer is responsible to the Duty Controller for:

a. Prompt and accurate identification of all tracks with the help of information available at the movement liaison section, track behaviour and by electronic means.

b. Checking with the Surveillance Section of a GCI station in case a track was expected to be picked up by it, but was not reported.

c. Checking with the FIC for any change of flight plan.

d. Presenting a clear and accurate picture of the air activity.

10. **Assistant Movement Identification Officer (AMIO)**. He is responsible to the Duty Controller to:

a. Assist the MIO in identifying the tracks promptly.

b. Display the following information for every known aircraft movement:

(1) Type of aircraft, time and place of airborne, its destination and estimated time of arrival (ETA), flight level.

(2) Time and position, the aircraft is expected to enter the area of responsibility of the ADOC.

11. **D/R Controller**. He is responsible to the Duty Controller to:

a. Draw tracks of all aircraft on the D/R board and calculate the estimated TOT (Time on Target) of the approaching raid.

b. Inform Army and Naval Liaison Officer and Civil Defence representative in determining the enemy aircraft position at any time so that the air raid warning can be given in time.

c. Keep duty controller informed about the D/R position of the approaching enemy raid, if not picked up by radar.

d. Maintain D/R position of all aircraft at every 5 minutes interval. If a track is not picked up at the expected position of the radar coverage of a radar station, to draw attention of the MIO.

12. **Movement Liaison Officer (MLO) (FCO)**. He is connected to different airfields, ATCs and FICs by secure means of communication. He is responsible for:

a. Receiving information on aircraft movement from the fighter airfield and from the ATC.

b. Filling the aircraft movement information in the Aircraft Movement Record Form (BAF Form - 10280).

c. Displaying of aircraft movement information on the movement board and its ready availability.

13. **Movement Liaison Clerk (MLC) (FCO)**.He is responsible for:

a. Tabulating all the information received by the MLO from different sources.

b. Assisting the MLO in receiving the flight plans.

c. Keeping a readily available record of all flight plans.

14. **Gun Control Officer**. He is a C&R officer, who is responsible to:

a. Receive gun control order and readiness state from the Duty Controller and pass those promptly to the Army/Navy Artillery Executives.

b. Display gun control order and gun state on the plotting board.

c. Inform Civil Defence Representative about approaching air raid and ensure that the air raid warning is sounded.

d. Inform respective bases about approaching air raid.

e. Maintain a log of all gun control orders.

15. **Air Defence Intelligence Officer**. He is responsible for:

a. Manipulating his monitoring set so that enemy aircraft R/T conversation can be heard clearly.

b. Recording R/T conversations of enemy aircraft.

c. Analyzing the R/T transmission of the enemy aircraft and inform Duty Controller of information of tactical importance.

d. Analyzing any unusual enemy air activity including ECM, AD exercise, new AD techniques and tactics etc.

16. **Floor Supervisor (FCO)**. He is responsible to the Duty Controller for:

a. Efficient working of Ops Room crew.

b. Keeping watch log, time checks, crew detailed in different duties, changes in the serviceability of communication system and all other information which pertains to the efficient working of the Ops Room.

c. Changing the crew duties at regular intervals.

d. Taking regular weather forecasts and getting them displayed on the status board.

e. Conducting OJT of the U/T crew.

f. Ensuring the availability of tools and equipment in the ops Room for the performance of duties of the Ops Room personnel.

g. Cleanliness of the operation room.

h. Reporting all major events, absentees, cases of sickness to the NCOIC/OIC Ops.

j. Rendering all possible help to the MIO in the execution of his duties.

k. Receiving information from various agencies and their correct display on the Status Board.

17. **Assistant Supervisor (FCO)**. He is responsible for the following:

a. To assist floor supervisor for smooth running of operations in the Ops Room.

b. To receive radar weather reports (RAREPS) from different radar units and get them displayed on the appropriate board.

c. To ensure any other information received by MLO such as weather forecasts, general weather, weather warning and aviation hazard are displayed on the board.

d. Ensure that plotter is adopting proper procedure while plotting.

e. Distributing operational items such as rags, pencils and all other instruments to crews on different positions.

f. Ensure that changes in strength, height and speed of aircraft are displayed on the board promptly and accurately.

18. **Plotter (FCO)**. He is to:

a. Plot position, direction and ancillary information on all tracks as received from Early Warning/GCI units using correct plotting procedure.

b. Pass the serial number and track ident, in addition to any instruction, back to the Early Warning/GCI units.

c. Ensure that a clear track is displayed at all times.

19. **Status Board Teller (FCO)**. He is connected to Status Board Operators and is responsible for:

a. Passing information on all identified tracks, including all changes and their correct display on appropriate Status Board.

b. Passing information and periodic changes on interceptor status and their correct display on appropriate Status Board.

20. **Status Board Operators (FCO)**. They are connected to the Status Board Teller, as well as to the Assistant Duty Controller. They are responsible for clearly and promptly displaying all information on the appropriate status board.

21. **Tracer/Recorder (FCO)**. Tracer/Recorder is to:

a. Track the interception and record times and ancillary information against the plots.

b. Record all vectors, pigeons and other instructions.

c. Reproduce the tracing with the help of recording sheet, in case minute to minute tracing is not done.

22. **Upward Teller (FCO)**. The upward teller is responsible to the floor supervisor for passing all established tracks, unless otherwise instructed to the higher command using GEOREF system and with appropriate profiles.

23. **Downward Teller (FCO)**. He is connected with the Search Radar Operator/ Plotter of a radar station by secure means of communication. He is responsible for passing only those tracks which have tactical interest for a particular radar unit.

Layout of a Typical ADOC

24. A typical layout of ADOC and various positions there in are shown in figure Fig 11.1.

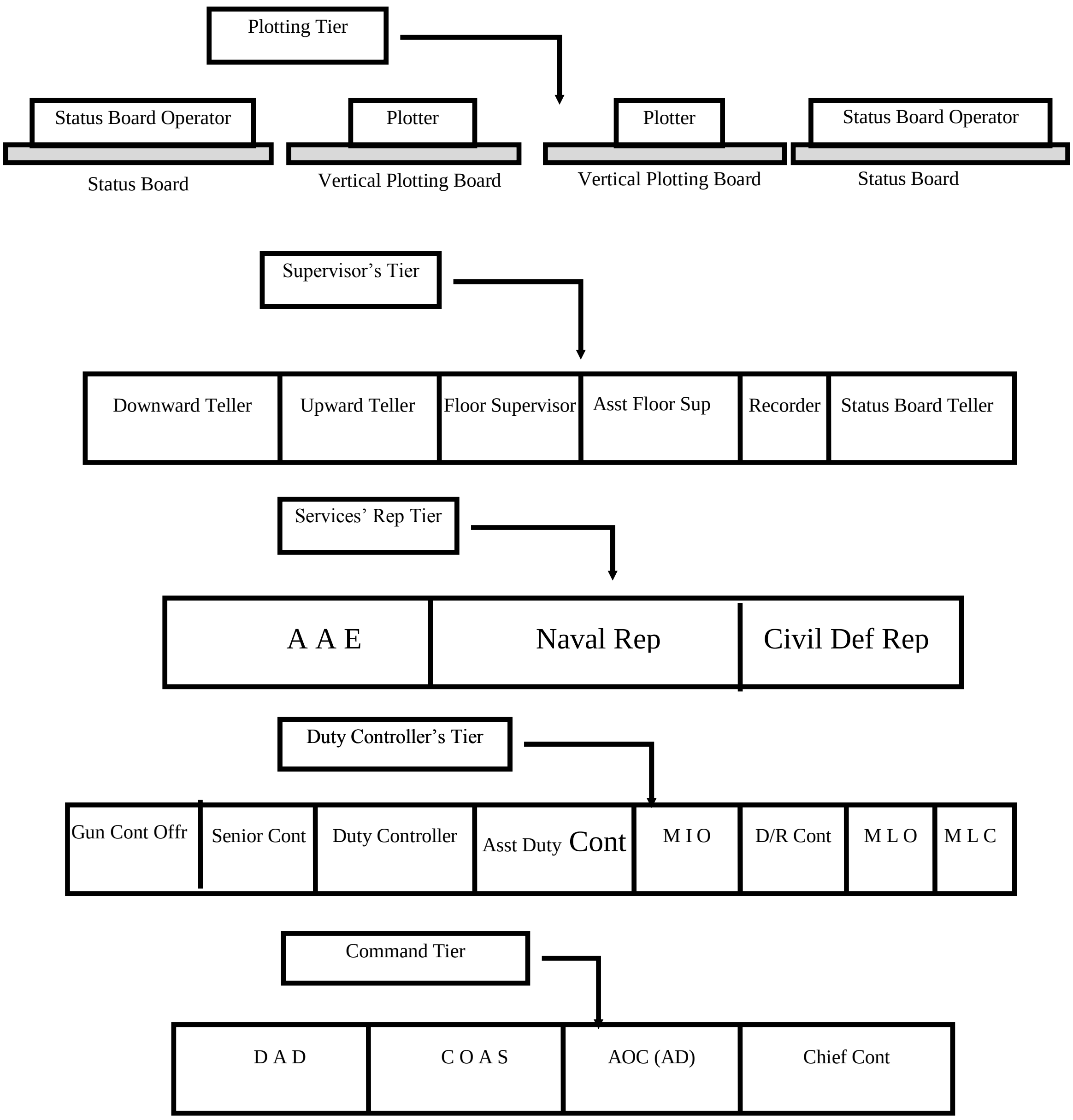


Fig 4.2: Layout of a Typical ADOC

Duties and Responsibilities of EW/GCI Station Personnel

25. **OC Unit/Senior Controller**. He is the senior most controller of the Unit and is responsible for:

a. Smooth functioning of the GCI Unit.

b. Supervising overall operation of the GCI Unit.

c. Coordinating with ADOC in receiving policy directives and ensure its execution.

d. Ensuring training of all air defence personnel in the Unit.

e. Ensuring that standard operating procedures are followed.

f. Supervising the technical and administrative staff so that operational commitments are fulfilled.

g. Carrying out any task assigned by the Air Headquarters.

26. **<u>2IC Unit</u>**. He is the 2nd senior most controller of the Unit. He is to assist the Senior Controller for the efficient working of the operation.

27. **<u>Duty Controller</u>**. He is responsible to the Senior Controller for:

a. Efficient operation of the watch.

b. Detailing interceptor controller whenever required.

c. Detailing ASO and change him at regular interval.

d. Ensuring that interceptors are handed over to appropriate authority.

28. **<u>Assistant Duty Controller</u>**. He is responsible to the Duty Controller for:

a. Passing of all orders and instructions to the appropriate agencies.

b. Maintaining Fighter Mission and Weapon Status Boards.

c. Observing correctness of all information displayed on the Status Board.

d. Maintaining the Controller's log.

e. Filling in the Tactical Engagement Report form.

29. **<u>Air Surveillance Officer</u>**. He is responsible to:

a. Maintain surveillance on all tracks within the area of responsibility.

b. Ensure correct plotting on the plotting Board.

c. Maintain listening watch on R/T.

d. Provide FFS when required.

e. Assist aircraft in distress/emergency as per the SOP.

30. **<u>Fighter Marshal</u>**. Fighter Marshal is responsible for:

a. Noting the scramble order and maintaining a constant check on the endurance of the interceptor fighters.

b. Controlling and positioning interceptor fighter prior to handing over to an interceptor controller.

c. Recovering interceptor fighter at the end of its mission.

d. Advising Duty Controller on the low endurance of interceptor fighter.

e. Maintaining a listening watch on the 'Guard' frequency.

f. Providing Flight Following Service and other assistance to aircraft in distress.

31. **<u>GCI Controller</u>**. He is responsible for:

a. Setting up the scope for intercepting the target allotted and establish target track on the scope.

b. Tactical Planning and preparing the mechanical positioning aid.

c. Establishing R/T contact and identifying the interceptor.

d. Carrying out interception as per the standard operating procedure.

e. Safe and expeditious recovery of his interceptor till handed over to Fighter Marshal/ATC.

g. Informing Duty Controller the result of the mission.

32. **<u>D/R Controller</u>**. He is responsible to:

a. Do D/R on all fighter, target and hostile tracks.

b. Assist interception controller during interception, if any track fades.

c. Work in conjunction with interception controller for accomplishment of the mission.

33. **<u>Supervisor (FCO)</u>**. He is responsible to:

a. Ensure smooth flow of operation in the Ops Room.

b. Ensure the correct adherence of procedure by all crew.

c. Ensure that crews are changed at regular intervals.

d. Maintain different log books of serviceability, weather, time checks etc.

e. Ensure the display of Wx forecast on the Weather status Board.

f. Ensure availability of operational equipment in the Ops Room.

g. Ensure cleanliness of the Ops Room.

34. **<u>Assistant Supervisor (FCO)</u>**. He is responsible to:

a. Assist supervisor at all times during operation watch.

b. Distribute items like rags, pencils and other instruments to crews at various positions.

c. Log AP/Jamming, if any, and pass those to ADOC.

d. Maintain serviceability and weather state board.

e. Help Control Technician, if needed.

35. **<u>Control Technician (FCO)</u>**. He is responsible to:

a. Remain with Interception Controller during interception.

b. Records R/T contact time, initial vector, height, fighter contact time and position, "Tally HO" time and position, result and cause of missed interception, if any, interceptor off GCI time, fighter's and controller's call sign etc.

c. Assist the interception controller in filling the interception report form.

36. **<u>Search Radar Operator (FCO)</u>**. He is to:

a. Check the serviceability of scope and plotting line.

b. Sit at the centre of the scope to avoid parallax error.

c. Pass all plots to the plotter, using correct telling procedure.

d. Note the idents of the track and comply with all instructions received through plotter.

e. Inform the supervisor in all cases of AP, jamming, unusual plots or defects in the scope.

f. Manipulate the control knobs to obtain maximum information from PPI.

37. **<u>Recorder (FCO)</u>**. He is to:

a. Monitor communication line from Search Radar Operator to plotter and record all information that passes in either direction.

b. Write the time in minutes and seconds in the case of initial plot and fade plot.

38. **<u>Plotter (FCO)</u>**. He is to:

a. Check the plotting line for serviceability.

b. Write all information in inverted writings.

c. Plot all information timely and accurately.

d. Pass serial number, idents and other instructions with proper procedure to search radar operator.

e. Give prompt acknowledgment to search radar operator.

f. Indicate all times along side track, the track designation and time, if needed.

TOPIC- 5
AIR DEFENCE PROCEDURES

RADAR WEATHER OBSERVATIONS

Training Objectives. At the end of this chapter the students should know:

a. What is RARAPS?

b. When it is to be originated?

c. How the Wx ecohoes are interpreted?

d. The reporting procedure of RAREPS.

Introduction

1. Timely and accurate radar weather reports (RAREPS) assist the meteorologist in making short range forecast. RAREPS are also of value to other military and civilian agencies in the interest of flying safety and protection of life and property. Besides, the weather reports have a direct bearing on the air defence mission. Therefore, those reports are to be provided whenever possible. The primary mission of the air defence is however, to take precedence over Radar Weather Observation. Controllers commanding a radar station are to train personnel in scope interpretation and implement the procedures outlined in this chapter.

Procedures for Reporting Severe Weather

2. When precipitation echoes are observed at a radar unit, the radar operator is to immediately contact the Supervisor and inform him of the condition. The Supervisor is then to designate a crew member to monitor the weather echoes. Surveillance stations are to transmit RAREPS directly to the ADOC/SOC for relay to the appropriate BAF forecasting station over the existing telephone line. Therefore, RAREPS are to be originated when one of the following changes occur.

a. The character of echoes change i.e. scattered echoes become solid or vice versa.

b. The intensity of the echoes changes from weak to strong or vice versa.

c. The direction of movement of previously reported echoes changes by 45 degrees or more.

d. The speed of previously reported echoes changes by 30 knots or more.

e. A new echo is observed, at a distance of 100 nautical miles or more from a previously reported echo.

f. The echo or echoes fade.

g. When an observation is requested by a forecasting station.

Echo Interpretation and RAREPS Composition

3. The accuracy and value of RAREPS depend upon the scope interpretation skill of the operator. The components of each RAREPS (i. e Character, intensity, tendency etc) are described below and are to be reported in the order shown:

4. **Character**.

a. **Isolated Echo**. Individual solid mass of echo either isolated or separated from other echoes by a distance greater than the diameter of the echo (Fig 12.1A).

b. **Scattered Area**. A group of echoes not forming a line, covering less than 5/10 of the area within a circumscribing circle (Fig 12.1B).

c. **Broken Area**. A group of echoes not forming a line, covering from 5/10 to 9/10 of the area within a circumscribing circle (Fig 12. 2A).

d. **Solid Area**. An area not forming a line, covering greater than 9/10 of the area within a circumscribing circle. This is distinguished from an isolated echo in that area to be observed is composed of a solid mass of the individual echoes (Fig 12. 2B).

e. **Scattered Line of Echoes**. A group of echoes covering less than 5/10 of the area within a circumscribing rectangles and forming a straight or slight curved line, (Fig 12. 3A).

f. **Broken line of Echoes**. A group of echoes covering 5/10 to 9/10 of the area within a circumscribing rectangle and forming straight or slightly curving line (Fig 12. 3B).

g. **Solid line of Echoes**. A group of echoes forming a solid straight or slightly curving line covering greater than 9/10 of the area within a circumscribing rectangles and forming a straight or slight curved line, (Fig 12.3C).

h. **Spiral Bands**. Echoes appearing in line which spiral towards a centre. These echoes are associated with hurricane or tropical storms. A spiral band is composed of scattered, broken or solid curved echoes. Some caution is necessary in describing echoes as spiral bands, unless a tropical storm is expected, or the formation remains evident for at least thirty minutes (Fig 12. 4).

j. In some cases echo patterns may be a combination of areas and lines, 'L' shaped lines or very widely scattered areas. In such cases, the pattern should be described in enough detail to cover the gross features without causing confusion.

5. **Pattern**. Echo patterns are to be classified as a 'Line' only if the echoes are arranged in a recognizable or organized line, such as might be reflected from a

squall line or front. This pattern should normally be at least five times as long as it is wide and is normally to be at least 20 miles long.

6. **Intensity**. Estimation and classification of the echo intensity as week, moderate, or strong is to be made from the appearance of the echo on the PPI scope with normal setting of the receiver gain. When many echoes are present, or when echoes are large, the receiver gain is to be adjusted to indicate the most intense area. ‘Weak’ echoes appear thin and gray in the PPI scope. Owing to the effect of range attenuation, any indication of an echo at ranges of 100 miles or more is to be classified as ‘moderate’. Exceptionally bright echoes, such as those received from violent thunderstorms or heavy frontal activity, are to be classified as ‘Strong’. Experience is necessary to determine the relative strength of echoes.

7. **Tendency**. Several consecutive observations of the intensity of an echo are necessary to determine the change in strength of echo. Changes are to be reported as ‘remaining steady’ or ‘slowly/rapidly increasing/decreasing’. Again the effect of range attenuation is to be considered, since the echo becomes brighter on the scope as it approaches the station.

8. **Position**.

a. **Azimuth and Range**. The azimuth angle is to be reported to the nearest five degrees and range in nautical miles from the radar site. At the discretion of the controller, GEOREF is to be used instead of range and azimuth. The position of solid echoes or areas of echoes are reported in terms of azimuth and range of the centre of the circumscribing circle (Fig 12.1 A, B&C). In reporting the position of solid area of echoes or spiral bands, four points are required to be passed (Fig 12.4).

b. **Width or Diameter**. The width or diameter of the echo is determined by circumscribing an imaginary circle or rectangle around the echo or group of echoes with the diameter or width being the minimum distance necessary to cross the area of echoes. This is reported to the nearest nautical mile.

9. **Movement**.

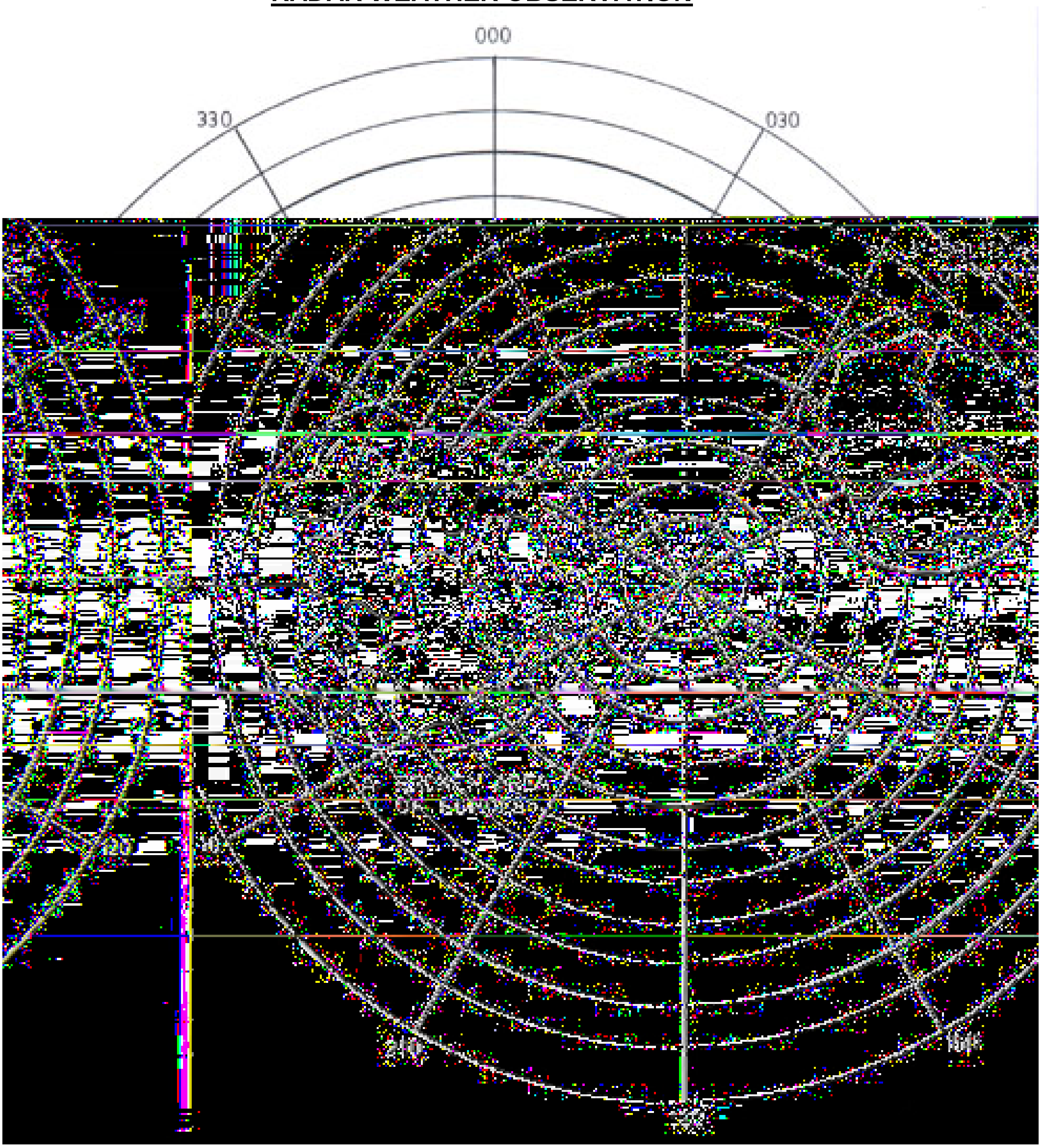
a. **Direction**. The direction of movement is defined as the direction from which the echo is moving and is to be reported to the nearest 10 degrees. The direction of movement is determined by plotting past and present position on the PPI. The direction of movement of line-echoes is determined by an imaginary line drawn perpendicular to the length of the line.

b. **Speed**. The speed at which the echo moves is to be calculated to the nearest KPH. A period of six minutes is usually sufficient to determine the speed. By using this time period the movement between plots is to be multiplied by 10 to obtain the hourly speed. In cases of long lines of echoes, it may be advantageous to report the speed of both ends.

10. **Height**. Where possible, the height of the echo is to be measured and reported in 1000s of meter.

11. **Remarks**. Remarks, appended in the RAREPS may include information concerning the freezing level, wind shear, turbulence or dust/thunderstorm, if reported by a pilot, radar or any other sources. Remarks are to be used to further describe this character, intensity, tendency, movement etc of the echo. Echoes apparently associated with a tornado are to be noted in remarks.

RADAR WEATHER OBSERVATION



A

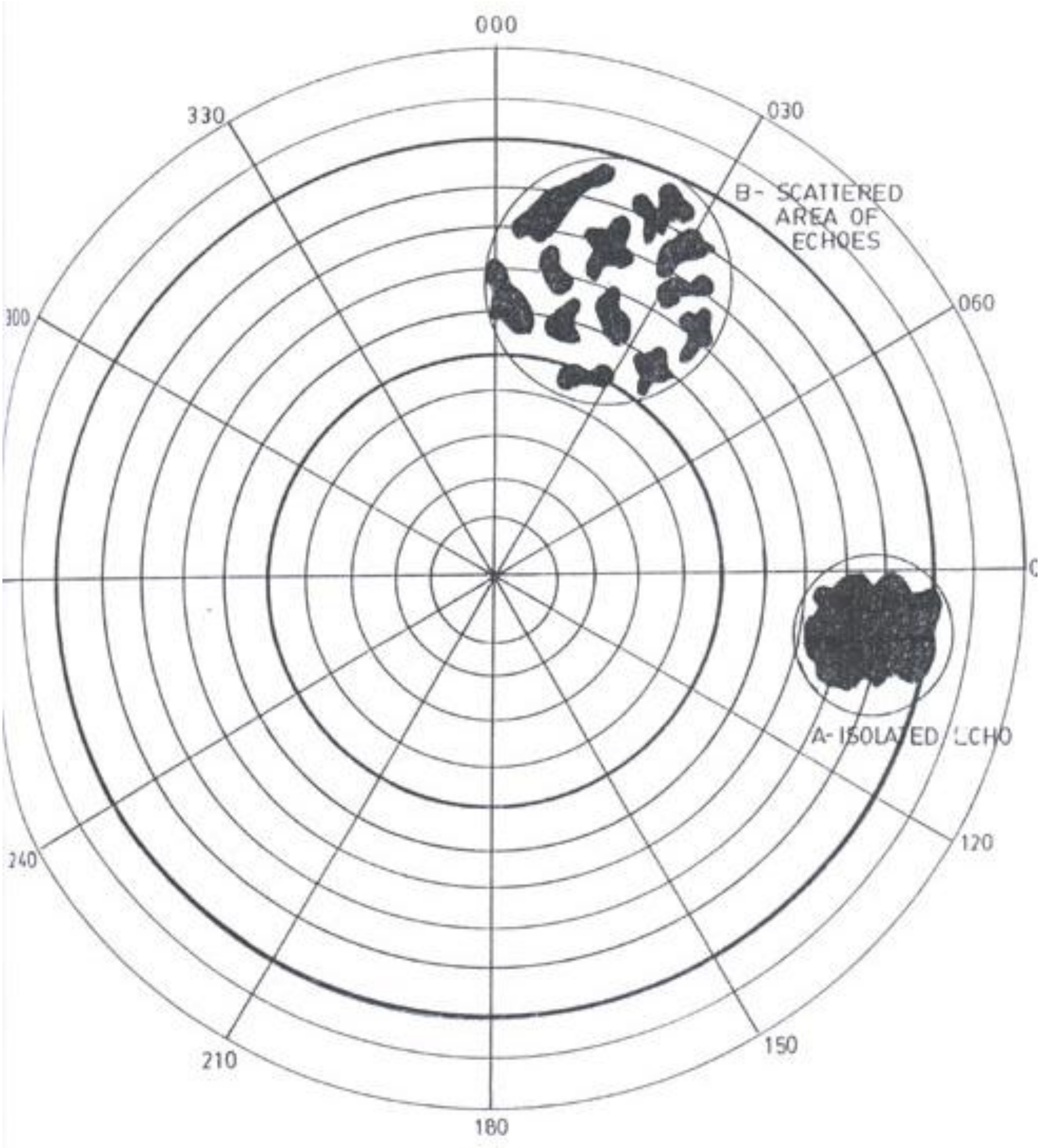
Isolated echo, Strong, Steady, Azimuth 100 Range 87, Diameter 40 moving from 200 at 20 kts.

B

Scattered area of echoes, weak, decreasing, Azimuth 020 Range 75, Diameter 60, ht 30/15, moving from 350 at 15 kts.

Fig 5.1

RADAR WEATHER OBSERVATION



A

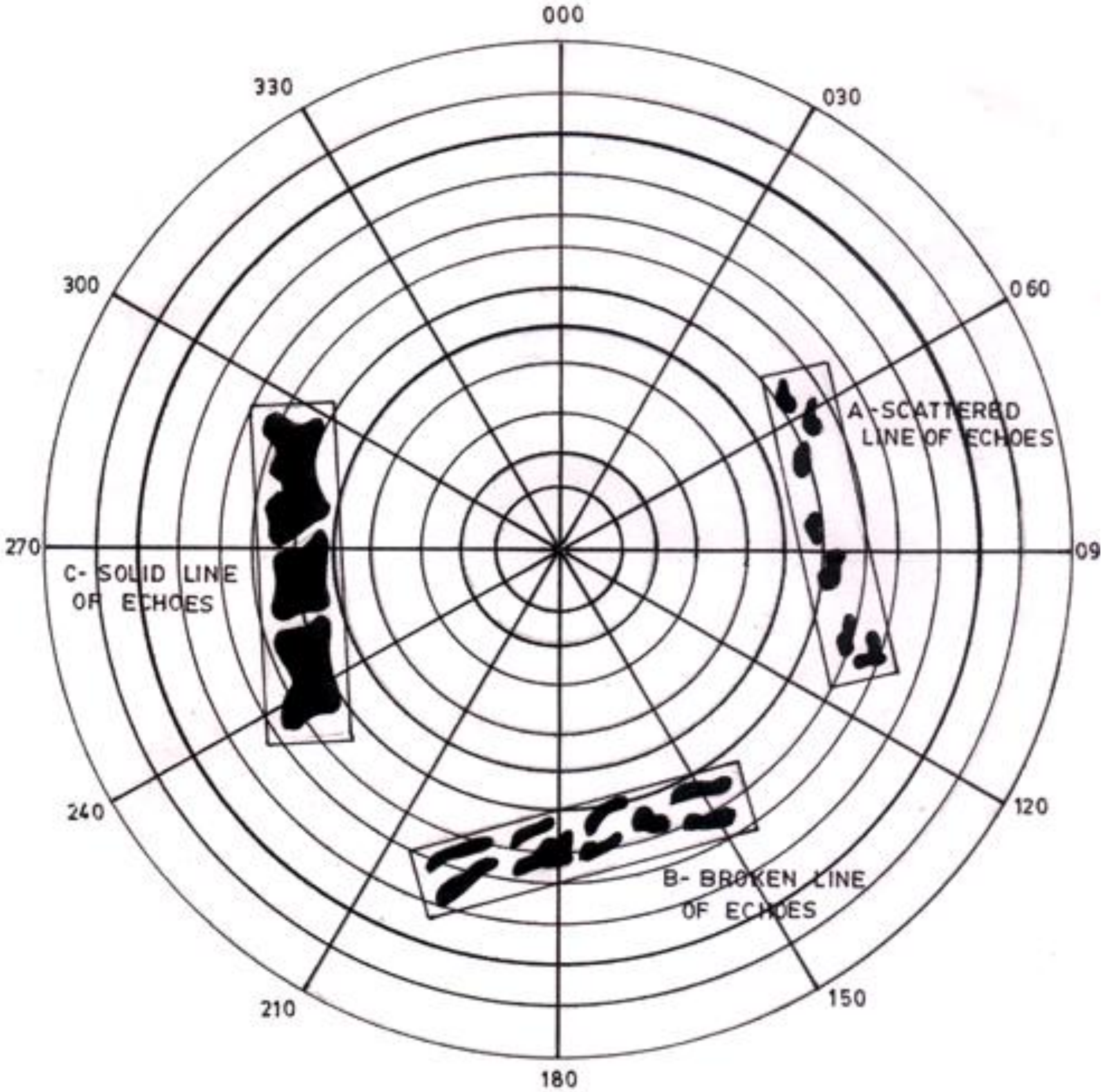
Broken area of echoes, Strong, increasing, Azimuth 270 Range 65, Diameter 80 moving from 330 at 30 kts.

B

Solid area of echoes, Strong, increasing rapidly, Azimuth 060 Range 65, Diameter 60, ht 45/15, moving from 100 at 40 kts.

Fig 5.2

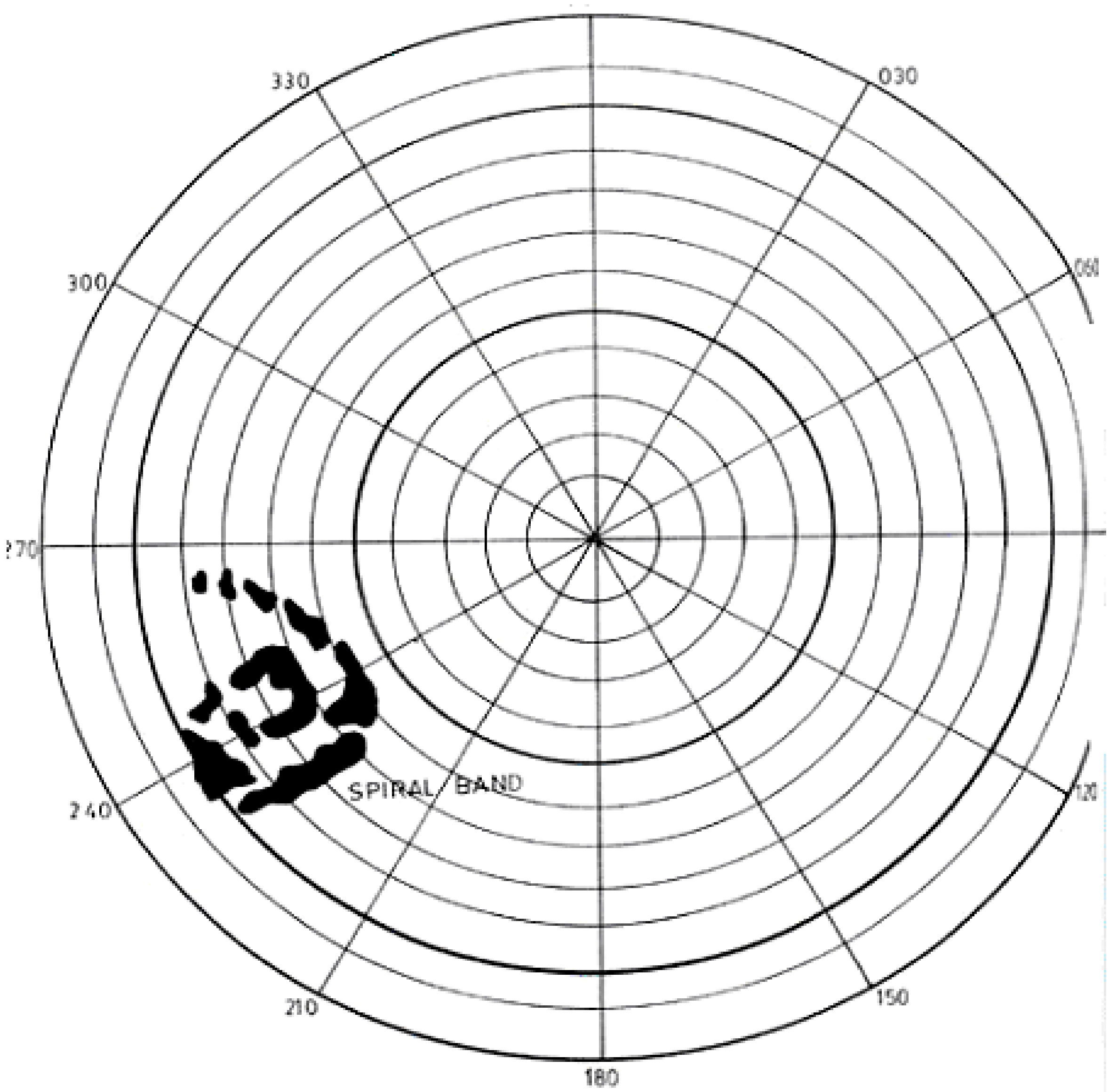
RADAR WEATHER OBSERVATION



A	B	C
Scattered line of echoes Moderate decreasing, Azimuth 035, Range 65, Azimuth 100, Range 75, Width 15, moving from 190 at 15 KTS.	Broken line of echoes Moderate Steady, Azimuth 135, Range 70, Azimuth 195, Range 90, Width 20, moving from 190 at 25 KTS.	Solid line of echoes Strong, Increasing, Azimuth 225, Range 70, Azimuth 290, Range 75, Width 18, Ht 40/20, moving from 180 at 25 KTS.

Fig 5.3

RADAR WEATHER OBSERVATION



Broken to solid Spiral bands, Strong, decreasing, Azimuth 260, Range 85, Azimuth 230, Range 55, Azimuth 220, Range 80, Azimuth 230, Range 100, ht 30/10, moving from 240 at 45 kts, Bands rotating approximate point at Azimuth 235, Range 82.

Fig 5.4

DATA HANDLING PROCEDURE

Training Objectives. At the end of this chapter the students should know:

a. What is threat recognition and why it is important?

b. Combat activities and its different stages.

c. What are the combat data and it's sources and the details of handling these data.

Threat Recognition

1. Threat recognition is the determination of an abnormality in the pattern of air activity. It must be accomplished if proper and timely air defence measures are to be taken. This has been termed as warning. The zone for this warning extends outward form the contagious radar cover towards potential hostile staging bases and includes all approaches through which hostile aircraft may pass. Threat recognition requires correct and timely information concerning hostile aircraft on which necessary defence actions are based.

Combat Activities

2. Combat activities consist of informing subordinates, lateral and higher commands of the enemy activities. These cover the enemy capabilities and intentions through intelligence, surveillance, tactical information battle damages, nuclear detonation and the adjustments of their weapon system. Combat activities will be passed as expeditiously as possible to all levels of command. This is especially important in the 'DURING' and 'POST' battle stages. Combat activities embrace the information on which decisions are based concerning the employment of weapons to destroy or to render hostile air attacks ineffective. Combat activities can be subdivided into 'pre-battle' 'battle' and 'post battle' stages:

a. **Pre-battle stage**. Pre-battle stageinclude the peace time or normal stage. The following information are required during this stage:

(1) Intelligence consisting of the enemies capabilities an intentions. This may be obtained from higher headquarters or derived from other intelligence sources.

(2) Surveillance information from the continuous radar cover of the defended area.

(3) Tactical information, including, weapon systems status from all units of the air defence system.

b. **Battle Stage**. Battle stage will be considered to have commenced upon recognition of hostile activities against Bangladesh and will continue till the cessation of such activities. Hostile acts are committed by airborne weapons surface weapons or direct land invasion. Threat recognition is to continue to be performed through out this period even though Bangladesh is under attack. It is, therefore, vital that information from the warning zones continue to flow at the highest rate compatible with other reporting requirements. All efforts are to be made to advise all concerned of the hostile activities to be expected and to present an overall situation (Within the air defence commander's area of responsibility) in the Air Defence Operation Centre. During this phase, information concerning local tactical engagement will be forwarded to the higher headquarters. Information pertaining to surveillance, battle damage, nuclear detonation and adjustments to the weapon system status are also to be forwarded to higher headquarters as and when required.

c. **Post Battle Stage**. Post battle stage is a period following hostile activities. The termination of this stage is to be determined by the Air Defence Commander. During this stage, in so far as Communications permit, assessment of damage and the re-deployment of available forces, if required are to be made and passed to all echelon.

Combat Data

3. **Definition**. The total information which the operation centre requires for proper performance of its mission and task is to be refereed to as combat data. The broad categories of these are:

a. Air Surveillance Data.

b. Tactical action data.

c. Status data to include weapons status information.

d. Battle damage information.

e. Nuclear Detonation Information.

f. ECM Information.

4. **Sources of combat Data**. Combat data has its sources in a great variety of activities. These include all military, civilian and government activities affecting Air Defence. The data is gathered by the data collecting agencies of the air surveillance stations and fighter interceptor squadrons of the air defence system. From the data collecting agencies the combat data is forwarded to different operation centres where evaluations are made as appropriate to the level of command.

5. **Air surveillance Data**. Air Surveillance Data consists of report of the systematic observation of the air space within the area of responsibility by visual, electronic, photographic or other means, for the purposes of detecting and identifying all airborne objects. Although the Air Defence commander's main interest lies in Air Surveillance reports, certain other activities corollary to air attacks, are required by the Air Defence Commander to predict decisions on the imminence of air attack. The air situation must be transmitted expeditiously to each level of command. They

are to be displayed on the tactical action data boards of the operation centres, for the use of the commanders in making timely decisions and taking appropriate air defence actions. It is, therefore, essential that each unit complies with the air surveillance procedure set-forth in this précis and employ all measures necessary to ensure the timely and accurate submission of all Air Surveillance data. Sources of surveillance report will include, but are not limited to the following:

a. Land Radar Installation of the Air Defence System.

b. Wireless Observation Units.

c. Airborne and Waterborne Sightings,

6. **Tactical Action Data**. Tactical Action Data consists of report and the result of the action taken. Tactical action data will be provided to the commanders at each echelon of command, since this information has a significant bearing on timely, effective evaluation
and supervision of the air defence battle. Sources for tactical action data are the echelons of command authorised to taken interception action.

7. **Status Data**. The successful conduct of the air battle is partially dependent on the timely and accurate submission of status report to the master GCI station. In accordance with this concept, it is mandatory that specific status data, which is required for the effective and safe conduct of air defence to be made readily available to the Chief Controller.

8. **Weapons Status**. Weapons status consists of periodic as well as special reports which concern the availability of all types of weapons employed under the operational control of the controller, e.g. Land based radar, fighter interceptor squadrons and air defence artillery status. Weapons system status information is to be graded 'SECRET' while passing in plain language.

9. **Battle Damage Information**. Battle damage information embraces reports of all damage from enemy action to the air defence weapons system, augmentation forces that are available air fields and to any other activity or equipment which is likely to affect adversely the Air Defence Commander's ability to defence against subsequent attacks.

10. **Nuclear Detonation Information**. Nuclear detonation information includes all nuclear and thermonuclear explosion occurring in or adjacent to Bangladesh as a result of enemy action. Nuclear detonation reports are to be forwarded immediately (through normal surveillance reporting circuits) when received by any air defence agency. Duplication in the reporting of detonations is to be eliminated by the Master GCI Station/ SOC by evaluating the reports before forwarding to higher Headquarters.

11. **Nuclear Detonation Report (NUDET)**. A one-time 'NUDET' report is to be submitted when detonations are detected (other than test detonation).

12. **ECM Information**. ECM information includes all reports on electronic or mechanical counter measures used by the enemy to reduce the effectiveness of the radar, Communications or other defence equipment dependent for their operation on

electromagnetic radiation. These reports are to form part of both surveillance data, related to hostile tracks or defence site and intelligence summaries listing the effectiveness and enemy tactics. ECM reported tracks fall into the classification of ‘unknown’ or ‘hostile’.

13. **ECM Reporting**. The presence of ECM activity is to be made known to the higher headquarters through telling/plotting channels. Radar sites are to report uncorrelated ECM activity in the appropriate form meant for ECM reporting, one-time jamming reports are to be sent as supplementary to surveillance and tactical action data.

FLIGHT FOLLOWING SERVICE

Training Objectives. At the end of this chapter you should know:

a. What is FFS?

b. What all FFS includes?

c. The procedures for providing FFS to VIP & Non VIP flights.

d. Actions by the controller for ac in distress.

e. Procedure for ac for getting FFS.

Introduction

1. All GCI stations are required to provide Flight Following Service to aircraft flying within their areas of coverage during peace time and at the discretion of ADOC during war also, depending on the air situation at the particular time.

Definition and Scope

2. FFS means 'Provision of navigational assistance in the form of information and guidance to enable an aircraft to carry out its projected flight safely and expeditiously. This includes the following:

a. To keep continuous radar track.

b. To provide flight information to.

(1) Establish position of the aircraft at specified intervals.

(2) Circum navigates Weather.

(3) Avoid collision.

c. To alert rescue service if necessary.

d. To assist aircraft in 'Distress or Emergency'.

e. To assist for diversion.

3. Flight Following Service is purely advisory in nature and does not imply positive control.

4. This service is to be provided as follows:

a. **VIP Flights**. Continuous radar track is to be maintained of all known VIP flights and services mentioned in para 2, sub-paras b (2) and (3), c and d are to provide whenever in the opinion of the GCI controller, these services will be of use to the pilot, irrespective whether a request has been received from the aircraft or not. The services mentioned in sub-paras b (1) and e are to be provided on request.

b. **Non VIP Flights**. On request made either through the flight plan or on radio.

c. **Aircraft in Distress**. Whenever a distress message either through R/T or IFF is picked up by a GCI station, it is mandatory for the controller on duty to record the position of the aircraft, give “Pigeons” for the nearest suitable airfield, follow the track of the aircraft, alert the rescue services and inform the respective FIC/ATC.

d. **Practice FFS**. Aircraft requiring FFS for practice purpose are to indicate this by including ‘request practice FFS’ in their message. The duty controller is to accept this request if he can do so without interfering with the normal air defence commitments.

5. With the exception of the condition specified in para 4 c above, a GCI station may not provide FFS if, at the specific time, the station is controlling a live interception on a hostile A/C and providing of this service is likely to interfere with the interception.

6. Provision of FFS is to be restricted to BAF aircraft only except that civil aircraft may be provided assistance in “Distress or Emergency”.

Procedures for Aircraft

7. When planning operation under conditions in which need for FFS is visualised, the captain of the aircraft is to incorporate the request for FFS in the flight plan. For flights not requiring flight plan, this request is to be communicated through the ATC of departing airfield.

8. In addition to the pre-flight request for FFS, all aircraft are to request on R/T whenever they want the service to commence. This message requesting FFS is to include the following information:

a. Callsign of GCI station.

b. Own callsign.

c. Position if known, otherwise general area.

d. The service required.

9. There after the pilot is to confirm to the instructions given by the GCI controllers for the purpose of identification only, unless compliance with such instruction is likely to endanger the safety of the aircraft.

Procedures for GCIs

10. All GCI stations are to maintain a continuous listening watch on the UHF and VHF frequencies specified for FFS. These frequencies will be known as ‘GCI common’ and will be so annotated in the relevant confidential orders.

11. On receipt of the request for FFS the senior controller will:

a. Decide whether FFS could be provided.

b. If unable to provide the FFS, inform the pilot by a message containing the following information:

(1) Call sign of the aircraft requesting FFS.

(2) Call sign of the GCI.

(3) Text containing the single word ‘Unable’.

c. If in a position to provide the service he is to allocate this responsibility to a GCI controller for the purpose.

12. On being allotted the responsibility for provision of FFS the GCI controller is to:

a. Acknowledge the message.

b. Identify the aircraft if it has not already been done.

c. Continue to provide the service requested.

d. When unable to continue the service, he is to indicate the same by transmitting a message containing the following information:

(1) Callsign of the aircraft.

(2) Test containing the word ‘Unable’ followed by the position of the aircraft at the time and any other information considered useful.

Circum-Navigation of Weather

13. The GCI stations have a certain capacity for detecting bad weather within their radar cover, and have been made responsible for providing information to all pilots for safe navigation through bad weather. The following procedures are to apply for obtaining assistance from GCI squadrons for navigation through bad weather.

Action by GCI Stations

14. Whenever bad weather is detected in its area of responsibility a GCI Station shall:

a. Advise pilots already utilizing FFS on GCI common frequencies the location of bad weather in relation to the pilot's position. Continue to provide all information pertaining to bad weather as requested by the pilot.

b. Take over control and issue instructions for safe navigation including circum-navigation if specifically asked to do so by the pilot.

c. Issue hourly weather warning to ATC and FIC giving:

(1) The location of bad weather.

(2) The extent and nature of bad weather.

(3) The direction of movement and trend of development.

This weather warning is to be issued half-hourly if the bad weather is moving towards an airfield at a high speed.

Action by pilots

15. While the pilot utilizing the FFS will automatically be provided bad weather information for safe navigation, all other pilots are to request for such information on appropriate FFS frequencies if required. A pilot at his own discretion may transfer the responsibility for safe navigation to the GCI squadron. Whenever a pilot decides to transfer such responsibility, he is to transmit the message containing the word 'Request Circum-navigation'. The GCI squadrons will then control and issue instructions for alterations of courses and heights if necessary. In absence of such request from pilots, GCI squadrons shall not assume responsibility and will supply information to the pilot which he may ask for from time to time. Pilots are permitted to use plain language for obtaining such information.

GCI-GCA LET DOWN

Training Objective : At the end of this chapter the student should know :

a. The GCI-GCA let down procedure followed in BAF.

b. The specific job done by a controller of a radar unit while carrying out GCI-GCA let down.

c. The action taken by ATC controller of a GCA radar and the pilot while executing the let down.

Introduction

1. As the facilities, layout, safety heights and safety zones vary from airfield to airfield, the GCI stations are to draw up detailed GCI-GCA let down procedures and penetration patterns for each operational airfield within coverage of their stations. The principle behind this type of let down is to bring the aircraft to a pre-determined point, called GCI gate at high altitude and then to instruct the pilot to set a certain power setting and control his rate of descent towards the GCA gate. This would enable GCA to pick up the aircraft at a suitable height and range and make it land safely in the shortest possible time.

GCI-GCA Let Down Procedures

2. Ground control approach is an instrument approach to landing in which an aircraft receives instructions transmitted from a ground environment. This facility is given to an aircraft through glide path radar coverage to have a safe landing. This let down procedure is a ground controlled recovery by a GCI station possessing air base glide path coverage. Clearance is given to a certain height and it is the pilot's responsibility to adjust his own angle of descent and have a smooth landing. While carrying out GCI-GCA let down the controllers are to take the following actions:

a. **Prior to Penetration**. Prior to penetration the controller is to:

(1) Ensure that the desired penetration is co-ordinated with the appropriate air traffic control agencies and that the GCA has been alerted.

(2) Vector aircraft as necessary to arrive at the GCA gate at the expected approach time.

(3) Warn GCA, give callsign of aircraft and obtain GCA channel of control.

(4) Give current weather, altimeter setting and runway information to aircraft.

(5) Give lost communication procedures to aircraft.

(6) Advise pilot to tune-in and monitor NDB or compass locator, as applicable.

(7) Give configuration, airspeed and minimum altitude for descent.

b. **<u>During Penetration.</u>** During penetration the controller is to :

(1) Vector aircraft and give rate of descent as necessary to arrive at desired hand-off point or at the GCA gate.

(2) Request altitude checks and instruct pilot to increase or decrease rate of descent as required.

(3) Repeat minimum altitude for descent after aircraft reports passing 5,000 ft AGL.

(4) Position the aircraft at the GCA gate. A position about 15 miles from the airfield, at a predetermined height and speed.

(5) Relay 'Pigeons' and GCA channel to the pilot just prior to the GCA gate.

(6) Ensure that aircraft is squawking the proper mode for GCA.

(7) Notify GCA when the aircraft is at the GCA gate, if not picked up by the GCA earlier.

(8) Standby on the GCI frequency untill assured that GCA has the aircraft under their control.

(9) 'Control' the aircraft as requested by the pilot, if the pilot cannot contact GCA, or returns to GCI frequency.

(10) Immediately initiate action to obtain aircraft clearance for the type of approach (NDB) requested by the pilot, if flight is being conducted under IFR conditions and the pilot cannot contact GCA.

c. **<u>Action by pilot</u>.** The pilot is to:

(1) Place the IFF to the assigned mode and contact GCA on the given frequency when directed by GCI.

(2) Give heading, altitude and type of approach desired on initial GCA contact.

(3) Follow GCA instructions (Unless deviations are required in the interest of flying safety).

(4) If under IFR conditions and no radio contact can be established with GCA, return to the GCI frequency and request clearance for the type of approach desired (NDB).

Ground Controlled Approach

3. This system is a ground interpreted aid which requires no additional airborne equipment. This system of approach can be used provided aircraft is equipped with the frequency of the GCA unit.

Ground Controlled Approach Procedures

4. The procedure for approach is as follows. (The GCA procedure is reproduced here for C&R Controller's information only).

a. Aircraft requests GCA approach from approach or aerodrome control.

b. Aircraft receives altimeter setting, aerodrome elevation, altitude to fly, heading to steer, the frequency to be used when to change frequency instructions to cover radio failure and if necessary, landing instructions.

c. During the initial approach, and upto the beginning of the final approach the pilot of the aircraft is to 'read back' all data received on which executive action is to be taken and which it is essential should be received correctly. A pilot is not to acknowledge any transmissions received during the final approach unless talk down controller specifically requested so.

d. At a pre-determined fix or holding point designated for the airfield, approach control will hand over the aircraft to the traffic director.

e. The aircraft will receive from the traffic director headings to steer heights to fly in order to position the aircraft on the QDM (Homing/Pigeon) of the final approach at a point approximately 7 miles form the touch down. From this point control will be exercised by the talk down controller.

f. During the final approach the talk down controller will give information as to the distance of the aircraft from the touch down point, and whether the flight path is to the right or left of the track, and whether the altitude is above or below the glide path. The aircraft will remain under the control of the talk down controller until visual contact with the ground is established or until reaching the break-off altitude whichever is higher.

GCI-GCA LET DOWN

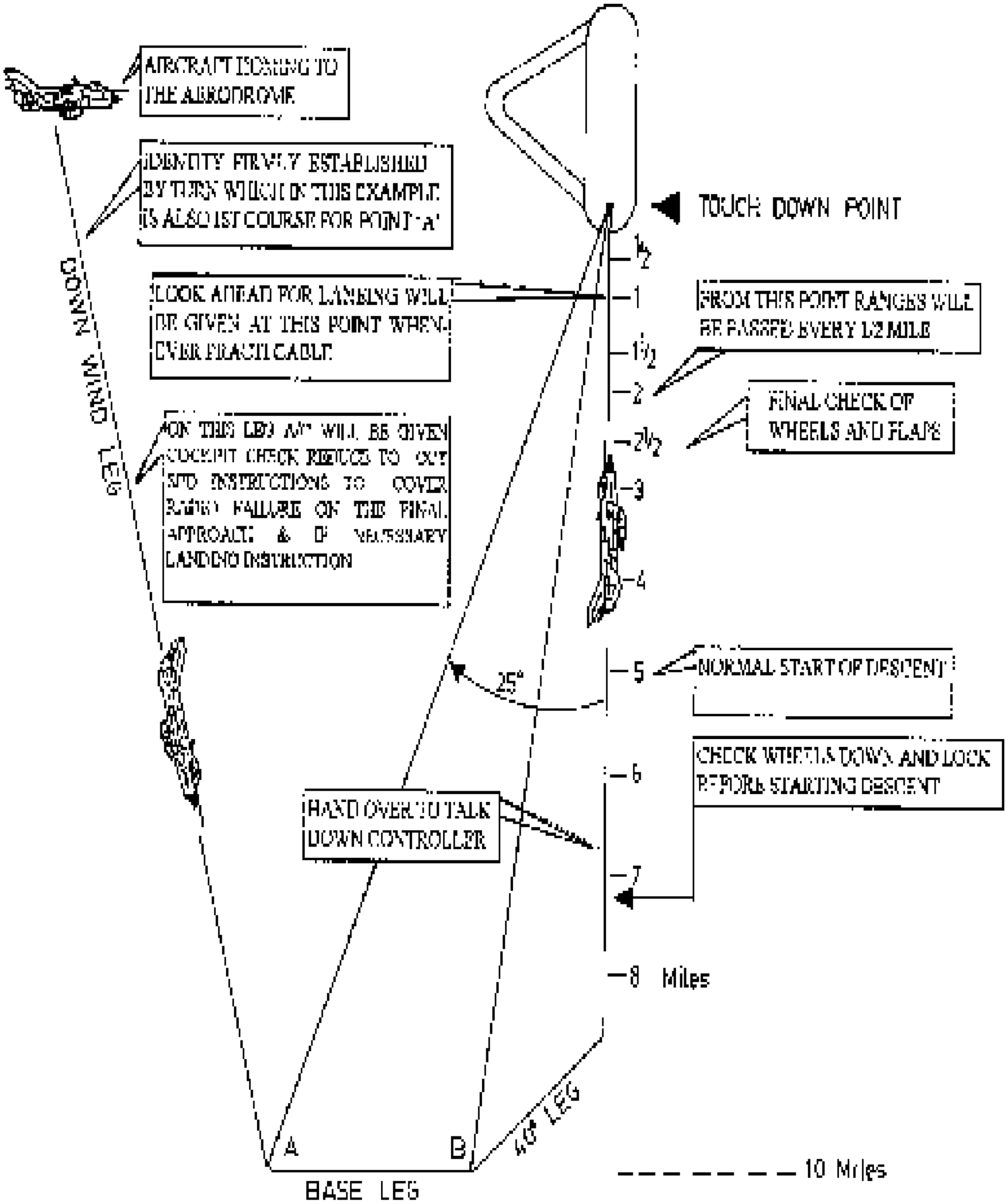


Fig 5.6

MOVEMENT IDENTIFICATION

Training Objective. At the end of this chapter the student should know how identification of an individual aircraft is done and depending upon the movement how aircrafts are classified in different groups.

Introduction

1. Having executed the first principle of air defence i. e. detection, we now proceed to the second principle called ‘Identification’. It is only through the fulfillment of this function that we are able to differentiate friendly aircraft from hostile ones. It is therefore imperative that all air traffic in the airspace of Bangladesh is to be identified. For this purpose the ops centre requires prompt movement information about all aircraft. In order to produce a clear picture of air activity, radar surveillance and information from other sources must be plotted and classified into three groups.

a. Friendly.

b. X-Raid/Un-identified.

c. Hostile.

2. It is essential to establish the identification of all airborne objects as early as possible to enable the air defence authorities to take appropriate action. This can only be done if the information about all friendly aircraft is available. The movement of all such aircraft, whether leaving or arriving in the country, or just flying locally must be reported to movement identification section concerned, so that this information can be made available to the movement identification officer. He will then tie up this information with the tracks appearing on the vertical plotting board and identify the same.

Means of Identification

3. a. **Physical Means**. IFF (Identification of friend or foe). Special radar equipment is used on the ground as well as in the aircraft to accomplish this.

b. **Visual Means**. Wireless Observer Units will report all aircraft that fly over their posts and give the type of a/c also.

c. **R/T and W/T Fixes**. With 2 or more R/T and W/T fixer stations ‘Position Line’ interception point could pin point an ac position in the air.

d. **Aircraft Under Control**. GCI stations controlling fighter aircraft will know exact position of these aircraft.

e. **Flight Plans**. Flight plans of all friendly aircraft operating in the country are filed with the ops centre. These are co-related with radar and wireless observer plots to establish identification.

4. **X-Raids**. Tracks that can not be tied up by the above means will be given this designation while check is made on the following:

a. Last minute change in flight plans.

b. Aircraft delayed by engine trouble, bad weather etc.

c. Aircraft leaving a large bomber formation or fighter squadron and returning to base in distress. The MIO must try to get the latest information on any change in friendly aircraft movements before declaring an aircraft as hostile.

5. **Un-identified (U)**. The difference between 'U' and 'X' track classification is that the former is more likely to be a friendly a/c and the latter more likely to be an enemy aircraft. Any aircraft on which complete information for positive identification is not available and whose height and speed are those of a combat aircraft or when following an international corridor or showing IFF, may be given this identification. It is only used in peace time.

6. **Hostile (H)**. Tracks are given this identification only under the following circumstances:

a. When there are no friendly movements that tie up with the tracks appearing on the vertical plotting board.

b. If the aircraft commits a hostile act or is identified visually by wireless observer unit.

c. Information received from intelligence sources.

d. Position of the aircraft reported by friendly pilot.

Air Movement Information

7. a. The following information is to be passed while reporting the aircraft movements to the Ops Centre by various agencies:

(1) Airfield of departure.

(2) Aircraft type and callsign

(3) Airfield of destination

(4) Route

(5) Height

(6) Ground speed

(7) Estimated time of Arrival

(8) Actual time of departure

b. Amendments in flight plans are to be reported immediately.

Procedure of Reporting

8. The following procedure is to be followed while reporting aircraft movement from different agencies to the Ops Centre:

a. All airfields in Bangladesh pass aircraft moves to FIC, Dhaka.

b. FIC, Dhaka is to pass the same to Ops Centre, Dhaka.

c. ATC Dhaka is to pass moves of all military aircraft direct to Ops Centre, Dhaka.

AOP Squadron Aircraft (Army Observation Post)

9. When operating from AOP aircraft Bases or other airfields movements are to be reported to the nearest BAF ATC, either by telephone before departure or by the aircraft R/T when in flight. BAF ATC concerned is to pass the same to Ops Centre, Dhaka through appropriate channels.

Local Flying

10. For aircraft engaged in flying in approved local flying areas or armament training over approved firing ranges, the following information only is to be reported:

a. Type of aircraft and strength.

b. Callsign of aircraft.

c. ETD/ATD.

d. Base of dep.

e. Mission and duration.

11. The information is preferably to be passed in advance (specially in case of firing and cross-country missions) or as soon as the aircraft are airborne. Later only the changes need to be reported.

Recording of Information

12. Flight Information Centre is to maintain appropriate record of all information passed on schedule and non-schedule flights. To enable them to check any discrepancies in reporting of movements, the movement Liaison Section at the Ops Centre is to:

a. Continue to maintain all flight plans information on the current aircraft movement form.

b. Give the serial number of the movement report and the name of the person receiving the report to FIC.

c. Maintain separate diary for recording the receipt of all non-schedule movements. Complete information is to be recorded serially on separate aircraft movement forms for each date. Such forms are to be endorsed 'Non-schedule Flight' in red ink.

13. Amendments to the information already recorded will be dealt with as under:

a. If the amendment relates to the postponement of flight to another date, the information is to be crossed out and transferred to the new date sheet, with cross reference in remarks columns of both sheets such as date-time of receipt of amendment, serial number of previous date etc.

b. If the amendment relates to any thing other than the date, it will be incorporated at the same serial no for minor changes, or at a new serial no of same date as necessary, with suitable annotations in the remarks column, such as time of receipt of amendment, previous serial number etc.

WIRELESS OBSERVER WING

Training Objective. At the end of this chapter the student should know:

a. Role and Task of WOW.

b. Organisation and deployment of the wing.

c. Reporting procedure of WOS.

Introduction

1. Wireless observer units are employed in order to cover certain blind areas in the radar coverage. These units are highly mobile and can be deployed in any part of the country.

2. **Function of WOW**

a. **Primary**. To obtain information aircraft movements with ancillary information by audio-visual means and passes it to ADOC for display on the plotting board.

b. **Secondary**.

(1) Report to higher Organisation on airborne troops landing.

(2) Report on aircraft in distress, forced landing, crashes, and render any necessary help to crew.

(3) Report Wx conditions of the area.

(4) Help air land rescue in finding missing aircraft.

3. **Organisation**. The wireless observer wing (WOW) consists of several squadrons located at different parts of the country. Each squadron has its headquarters and several MOUs (Mobile Observer Units) spreaded all over the area entrusted to the squadron. Each MOU is a self sufficient unit. It consists of 4 or 5 crews with wireless sets in Jeeps or boats. They also have other necessities of life with them and need little help from squadron headquarters. Organizational lay-out of wireless observer wing is shown below:

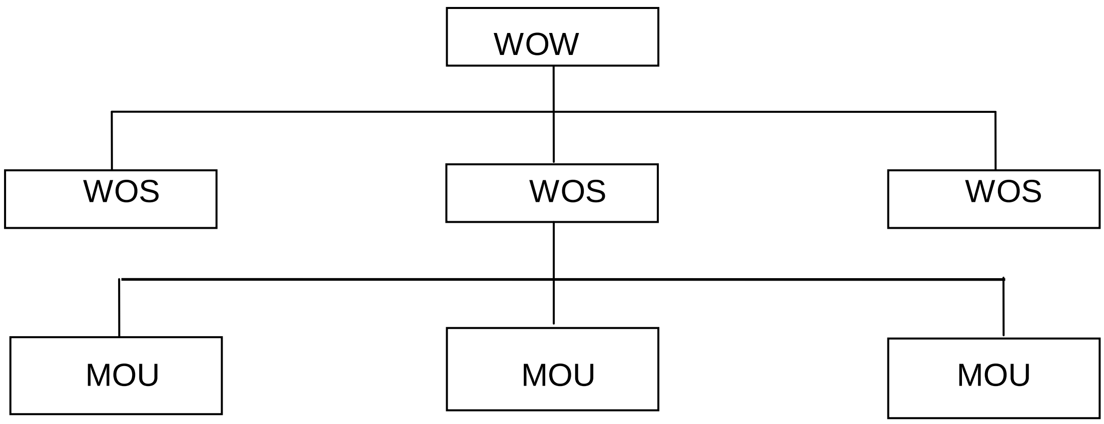


Fig 5.6: Organization of WOW

4. **Deployment**. The MOUs are deployed near the border areas where very low and low level penetration by hostile aircraft is expected and where low level radar coverage is inadequate. The Mobile Observer Units are deployed in belts and normally 2 or more belts are deployed to cover a particular approach. The observer units in a belt are deployed normally 5 to 10 miles away from one another and the belt to belt distance is 20/30 miles. All the observer units have their individual call sign prefixed by their belt call sign. The units of the second belt are deployed in between the two units of first belt; so that gaps, if any, in the first belt is covered in the second belt. A third belt may be similarly deployed, if necessary. The actual deployment of the units will very greatly due to the nature of the terrain, admin, logistic and technical considerations. A typical deployment of WOW is shown in Fig 17.1 of this chapter.

5. **Communication**. Each MOU maintains W/T, R/T contact with squadron headquarters and passes the information to the headquarters. This information is then plotted in the squadron Operation Room and from there it is filtered and passed to the ADOC following the a/c reporting procedure. The time delayed between the actual observation and display in ADOC must not exceed 2 minutes.

6. **Reporting Procedure**. Following procedure is adopted while reporting the aircraft to the Ops centre by WOS.

a. **Observed Report**.

(1) Call sign of MOU passing report.

(2) Direction of observation with distance.

(3) Direction to which the aircraft flying.

(4) Type of aircraft with strength.

(5) Estimated height in the following terms:

(a) Low : Height below 1000 feet.

(b) High : Form 1000 feet to 10,000 feet.

(c) Very High : Above 10,000 feet.

(6) Time of observation in two digits (Min passed the hour).

Example: AL, NE 3, SE, MIG-21(2), High, 17

b. **Unknown Type Report**. When the aircraft cannot be identified by the mobile observer then the type of aircraft will be passed using the following terms:

(1) USP – Unknown single-engine piston aircraft.

(2) UMP– Unknown multi-engine piston aircraft.

(3) USJ – Unknown single-engine jet aircraft.

(4) UMJ– Unknown multi-engine jet aircraft.

Example: AL, NE 3, SE, USP, Very High, 17

c. **Heard Report**. If the observer cannot see the aircraft but hears the sound, then a heard report is passed using the following codes:

(1) U H P = Unknown heard piston.

(2) U H J = Unknown heard jet.

In heard report ancillary information on the plot will be passed as available.

GROUND-BASED AIR DEFENCE WEAPONS AND ARTY (GBAD)

Training Objective. At the end of this chapter, the student will know about:

a. Aim, task and control orders of AAA.

b. Technical characteristics of AAA used in Bangladesh Air Defence.

c. Limitation of AAA in modern warfare.

Introduction

1. Ground-based air defence weapon is a major consideration in aerial mission planning. They are mainly Air Defence Artillery (ADA) and Surface to Air Missiles (SAM) of various calibre and capacity. Enemy aircraft avoids areas of heavy ADA and SAM concentrations. Radar controlled and computerised fire control systems assist gun crew in aiming their weapons and resulting in high degree of accuracy. Since World War II, the trend in aircraft manufacture has been towards either considering high speed and high altitude or extremely low-level operations, in the hope that AD weapons could be avoided. However, the importance of AD weapons has not been nullified. Rather, new and more powerful AD weapon systems have been developed. Radar guided quick firing light ADA deters low level raiders, while SAMs deal with attackers coming at medium and high altitude. A combination of guns and missiles form a vital component of air defence weapons system.

2. **Mission**. ADA's mission is to destroy enemy aircraft/missile, nullify their effectiveness, or force them to abandon their mission.

3. **Task** The task of ADA is to provide medium and low altitude air defence to VAs/VPs of national importance. These VAs/VPs will mainly comprise of the following:

a. Key military installations.

b. Airfield and landing grounds.

c. Communication centres.

d. Lines of communication.

e. Ordnance factories and depots.

f. Selected maintenance/supply points.

ADA Responsibility

4. Air Defence (AD) is a joint services responsibility. Bangladesh Air Force is primarily responsible for the AD of the country. Short range Air Defence missiles should be with the Bangladesh Army and Bangladesh Navy while medium range Air Defence missiles should be with the BAF. Field formation should have more shoulder based Air Defence (SAM) weapon, on the other hand Bangladesh Navy

(BN) should focus to enhance their maritime Air Defence operation capabilities and may have short range missile for low altitude Air Defence in a limited scale. Bangladesh Army (BA) should take care of all ground based Air Defence of static installation while BN and BAF should guard their respective ground installations. Guns and missile should be integrated to maximize the AD system.

5. In Bangladesh Army, 6 independent ADA Brigade is responsible to provide low Level and Medium Level Air Defence. It has 4 LAA Regt, 3 MAA Battery and one SAM Battery.

6. **State of Readiness**. The state of readiness of AD weapons prescribes the level of preparedness at which a defence layout is to be maintained. The states of readiness are: High, Medium and Low.

a. **High**. It is ordered only when warning cover is poor or there are indications that an attack is imminent.

b. **Medium**. This will be the normal state of readiness when deployed, and it must permit necessary rest, servicing and routine activities.

c. **Low**. It is ordered at night; or in bad weather with low air activity, or in rear areas where good warning is available.

Control Orders

7. Control orders are originated by the ADOC to fix the status of the AD wpns at a particular time, to impose any restriction or otherwise on opening fire at aerial targets. Control orders applied to the height limit of effective fire are as follows:

a. **Weapons Free**. Weapons may open fire on all aircrafts other than those recognised or designated as friendly.

b. **Weapons Tight**. Weapons will not open fire on any aircraft unless that aircraft is recognized as hostile or it commits a hostile act and provided the fire will not endanger any friendly aircraft.

c. **Hold Fire**. This is an emergency executive order which temporarily terminates the action status of AD weapons regardless of enemy action. The meaning of the order "HOLD FIRE" is to stop firing (in case already firing) or do not open fire. The weapons should continue laying/tracking, so that it can resume firing without wasting time in case the order "HOLD FIRE" is cancelled. The order "HOLD FIRE" is only cancelled by the order "Cancel HOLD FIRE". On receipt of the order "Cancel HOLD FIRE" the weapons revert to the control order in force prior to the issue of the order "HOLD FIRE".

8. The ADA executive passes the control orders originated at the ADOC to ADA command posts, and each order remains in force until cancelled by a fresh one. If communication fails, each AD wpn shall revert to control order laid down in the SOPs.

Light AD Artillery

9. The following are some of the type of LAA guns. AD Arty guns listed below have been in use at different times for Air Defence purpose. The data is presented below so as to give the students an idea of performance and statistics of various AD Arty guns. AD Arty guns are gradually giving way to Surface-to-Air-Missiles which are more effective as well as a better deterrent. However, study of the data of the guns listed below will help the students to understand the basic need of AD Arty guns in the Air Defence system

10. **Types**.

a. **37 mm LAA Gun (Chinese)**. The 37 mm Twin AD Arty Automatic Gun Type 1965, a small calibre anti aircraft gun with fair combat efficiency, is an effective weapon for firing against low-flying aerial targets and conducting mobile operations. This gun is easy of operation and quick of data computation. It has high rate and great density of fire, and is capable of loading and firing rounds automatically and continuously with a rate of fire (Twin Guns) of 160 to 180 rds/min. This gun is convenient for conducting mobile operations. Its total weight is 2650 kgs. It is not provided with all weather fire-control equipment. Principal data of 37 mm LAA Gun (Chinese) is given below:

Maximum vertical range	:	6700 m
Maximum horizontal range	:	8500 m
Effective vertical range	:	3000 m
Effective slant range	:	3500 m
Point-blank range	:	950 m
Maximum rate of fire	:	320 - 360 rounds/min
Normal rate of fire	:	160 - 180 rds/min
Maximum elevation	:	85 degrees
Maximum depression	:	10 degrees
Muzzle velocity (H.E shell)	:	866 m/sec
Calibre	:	37 mm
Weight of round, shell H.E	:	1.6 kgs
Complete weight of gun (travelling position)	:	2650 kgs

b. **14.5 mm Quad AA MG (Chinese)**. This anti-aircraft machine gun can shoot at aircraft below an altitude of 2000 metres. It can also destroy light armoured ground targets and concentrated live objects either exposed or hidden behind light field within a range of 1000 metres. While firing objects in the air, its effective range is 2000 metres ; at ground objects, 1000 metres. Within its effective range, it can pierce armour 15-20 mm in thickness. Each gun body of the gun is equipped with a metal linked belt with a capacity of 150 rounds and each belt consists of 15 sections which, when used, are joined together by means of cartridges themselves. It’s designed rate of fire is 2200 rounds per minute, combat rate of fire is 600 rounds per minute (total of the four gun bodies). The gun is operated by a gun crew consisting of squad loader, layer, range setter, two loaders and ammunition handler. When travelling the gun is towed by a truck at a speed of 50 kilometres per hour. Principal data of 14.5 mm Quad AA MG (Chinese) is given below:

Calibre	:	14.5 mm (0.5709 inch)
Weight	:	2100 kgs (4500 lbs)
Elevation limits	:	-10 degrees to +90 degrees
Muzzle velocity	:	990/1000 metres per second
Rate of fire	:	550 rds/min per barrel
Maximum opening	:	2500 metres (2735 yards)
Maximum effective range	:	2000 metres (2190 yards)
Operational ceiling	:	2000 metres (6555 feets)
Weight of complete round	:	API - 0.188 kgs (.414 lbs)
Length of complete round	:	API - 15.55 cms (6.12 inches)

11. **Manning State (37 mm Twin AA Gun)**

Manning state	Strength	Control Order	Guns state
A	09	GUNS FREE	High
B	06	GUNS TIGHT	Medium
C	03	HOLD FIRE	Low
D	01 (Sentry)	-	-

12. **Manning State (14.5 mm Quad MG)**

Manning state	Strength	Control Order	Guns state
A	06	GUNS FREE	High
B	04	GUNS TIGHT	Medium
C	02	HOLD FIRE	Low
D	01 (Sentry)	-	-

13. **Deployment Concept**. Normally AD guns are deployed in a ring pattern in pairs (distance between gun is 75m). Distance of the gun from the centre of VP is 400-500m or 200-300m from the outer edge of the VA/VP. Each pair of AD gun has a definite arc of fire or area of responsibility (AOR), which intercepts the arc of fire of the neighbouring pair of gun. CPO (Command Post Officer) sits in the CP (Command Post), who has got the executive control over the AD battery. This CP is the nerve centre of AD battery. Battle is initiated with the warning received from ADOC.

Medium Air Defence Artillery

14. **Mission** To provide medium altitude AD to vulnerable areas and vulnerable points of national importance.

15. **Capabilities**.

a. Can provide medium altitude AD to vulnerable areas and vulnerable points.

b. Can reinforce the fire of other units in the vicinity.

c. Can be effectively used against soft skinned vehicles in ground role.

d. Capable of redeployment being fully mobile.

e. Can maintain liaison with Air Force and Civil Aviation.

16. **Equipment**.

a. 8 X 57 mm AD guns.
b. 1 X Fire Control Director.
c. 1 X Fire Control Radar.
d. 1 X Surveillance Radar.
e. 1 X power unit for Fire Control Director and guns.
f. 1 X power unit for Fire Control Radar.
g. 1 X Central Distribution Box.
h. 1 X Command Box.
j. 1 X Battery Commander's Telescope.
k. 2 X 1 m Range Finder.
l. 1 X Aiming Circle.
m. Communication equipment.
n. Transport.

17. **Technical Data.**

Calibre	:	57 mm
Maximum slant range	:	12000 m
Maximum effective range	:	6000 m
Muzzle velocity (with new barrel)	:	1000 m/sec
Maximum rate of fire in auto firing method	:	105 - 120 rds/min
Normal (Manual) rate of fire	:	50 / 60 rds/min
Elevation angle	:	-2 degrees to +87 degrees

18. **Manning State (57 mm Medium AD Gun)**.

Manning state	Strength	Control Order	Guns state
A	08	GUNS FREE	High
B	06	GUNS TIGHT	Medium
C	03	HOLD FIRE	Low
D	01 (Sentry)	-	-

19. **Deployment Concept**. Normally, the guns are deployed in a ring pattern at a distance of 50m from the centre of VAs or VPs. The guns face the base direction. Accordingly Fire Control Radar and Fire Control Director are deployed immediately behind the gun Pring. The deployment of SR is within the framework of the Bty. The gun generator is deploy out side the gun ring. Central distribution box distributes the power supply to the gun & Fire Control Director. The command post is set-up beside the fire control director from where the Bty commander control the fire of the gun. The generator of fire control radar is separate which supplies power to radar. In fact, all the equipments are placed close, to maintain command control and concentration of fire as well.

Surface To Air Missile

20. **Types of SAMs**. There are many types of SAMs around the world, but they can be classified with reference to their guidance system. The major ones are listed below:

a. **Command Guidance systems**. It is based on ground guidance commands which is transmitted to the missile via a data link. Such as RAPIER, BLOWPIPE, JAVELIN, RBS 70, LASERFIRE, STARSTREAK.

b. **Homing Guidance Systems**. A homing missile contains a receiver capable of detecting a target and establishing the line of sight from the missile to the target. There are 3 variations of homing guidance: Active Homing, Passive Homing & Semi-Active Homing. Such as shoulder-launched heat-seekers like REDEYE, STINGER; SA 7, 14, 16, AND 18; Longer range semi-active system such as BLOODHOUND.

c. **Mixed Guidance System**. Such as PHOENEX and PATRIOT (which include ACTIVE and SEMI-ACTIVE phases of guidance).

21. **Height Bands**. In general the following nomenclatures are used to indicate the different height bands of engagement of various SAM (or SAGWS):

a. Ultra Low Level : Below 150m AGL.

b. Low level : 150-600m AGL.

c. Medium : 600-7,500m AGL.

d. High Level : Above 15,000m AGL.

22. **Range Classification**. In general SAMs may be classified according to its range:

a. Short range : Up to 5 km (slant range). Such as SA-7, STINGER etc.

b. Medium range : 5-20 km. Such as SA-6, SA-8, RAPIER, SPARROW etc.

c. Long range : 20-40 km.Such as BLOODHOUND, SA-2 etc.

d. Very long range : More than 40 km.

23. **Role of SAMs in Various Types of AD**. Ground–based Air Defence (AD) systems were originally based on the use, of guns. The onset of the SAMs has enabled far greater radii of action, with improved accuracy and higher probability of kill (Pk). SAMs offer an effective way of destroying incoming aircraft, particularly at ranges in excess of the AAA coverage. SAMs can be employed for point defence, forward air defence and area defence.

24. **Point Defence**. Point defence means the protection of a limited area or vital installation i.e VP. Say for example, only the airfield, Radar station, an important Bridge. According to NATO's Air Doctrine Manual, for point defence, weapons should possess few characteristics such as:

a. An extremely first reaction time.

b. An extremely short range of engagement i.e combat time should be minimum.

c. A high degree of accuracy.

d. A lesser degree of flexibility, because when the warhead (of the enemy air weapons) is in the close vicinity of the target, there is hardly any time for the incoming weapon to manoeuvre.

So these requirements are almost met by the ground based Surface to Air Weapons, which includes AAA and SAM. As AAA has more limitations than SAM, SAMs mix is the best weapon choice for point defence. A mix of say, shoulder launched missile and Rapier would be effective for point defence of many third world countries like Bangladesh. In the battles over Falklands, when attack fighters were visible for only 3 to 7 seconds due to hills, low cloud and poor visibility, 14 attackers were shot down by launching 20 Rapiers.

25. **Forward Air Defence**. Here forward means the placing of friendly army troops along with borderlines or line of battle area. Friendly troops, armoured concentration, vehicles convoy, rail/road bridges and forward HQs are the likely target of enemy air attack. So these are to be protected from air attack. Fighters can provide such defence to ground forces but 24 hours coverage may not be possible due to financial constraint and non-availability of adequate interceptor aircrafts. To shoot down enemy aircraft in the forward battle area, SAM deployment through man-portable surface to air defence i.e MANPAD in the battlefield would

force the enemy aircraft operate from their own territory thus reducing their ability to monitor friendly activities in the rear echelons. The SAM can make enemy's FGA mission difficult.

26. **Area Defence**. Area defence means the defence of a big area usually a national air defence scenario, for example, whole Dhaka, Chittagong area. For area defence, defence-in-depth is essential. Interceptor fighters such as Mig-29, F-7 aircraft are the ideal weapons for area defence because of their inherent flexibility, mobility and reusability. They can cover a wide area within a very short time. But today with the advent of long range, sophisticated guidance and control system, high kill probability of SAMs like BOMARC etc can be employed for area defence. But still it would not be possible to discard the requirement of fighters, simply because of missile cannot identify targets positively.

27. **Significance and Advantages of SAMs**. SAM technology has today advanced to such an extent that SAM can effectively provide us the best possible solution to meet a superior threat. In general SAM system have a number of advantages:

a. SAMs can be readily deployed.

b. SAMs have a very short reaction time, a high lethality and high kill probability (pk)

c. SAMs are more cost-effective than both the manned interceptors and AAA.

d. SAMs are available for round the clock operation.

e. Many modern SAMs are automatically operated by a computerised system without the needs for any human operation.

f. SAMs can operate either with or without EW/GCI radar networks.

g. Modern SAMs have increasingly high ranges.

h. Acquisition and operations of SAMs are relatively simpler.

i. SAMs can engage several targets at once and ensure all weather defence against massive air attacks.

j. Modern SAMs are usable for both point and area defence.

k. SAMs maintenance is easy and cheaper.

Limitations of AD Guns and Missiles

28. The anti aircraft guns have the following limitations:

a. Effective anti aircraft gun fire cannot be brought on target approaching very low and those against which no early warning is available.

b. Rates of traverse/elevation and maximum opening ranges are rather limited. With modern jet aircraft speed, sighting system and improved tactics, the anti aircraft gun has a difficult job to perform.

29. In general SAM system has some weaknesses which are as follows:

a. Medium and long range SAM tend to be ineffective at very low altitudes (below 1000 feet) because it is difficult to get good radar coverage at those altitude, especially at distances from the site greater than several miles.

b. The brain of the system is the computer, which may malfunction in case of system overload.

c. Medium and long range SAMs are normally radar depended, which is susceptible to active ECM.

d. Each site has a limited number of rounds available for immediate use and it takes some times for reload.

e. Generally one SAM battery cannot engage more than one target at a time when other may continue approaching towards the VA/VP. However, these weaknesses are complemented very well by provisioning an intelligent ECCM within the SAM system and combining certain ADA elements with the SAM system to make a very effective defence.

Conclusion

30. Ground-based AD weapons have a difficult function to perform. Our guns and missiles are quite dated compared to the modern attack aircraft that are in our neighbours' inventory. The numbers of guns and missiles are also limited because of resource constrained. Yet, when properly sited and aggressively used these weapons could do a fair amount of damage to attacking aircraft at low and medium altitude. These weapons are deterrence to low level raiders; thus force raiders to come at higher altitude. As such, they it allows the radars earlier detection that provide more early warning time for engagement with other weapons.

TOPIC-6

RADAR TECHNOLOGY

RADIO PROPAGATION

Training Objectives. At the end of this chapter the students should know:

a. Characteristics of electromagnetic waves.

b. Polarization of waves.

c. Principal modes of radio wave propagation.

Electromagnetic Waves

1. Radio energy is propagated by means of electromagnetic waves, which travel at the speed of light without the need of any supporting medium. The waves consist of two transversely oscillating fields: one electric and the other magnetic, which occupy planes at right angle to one another. As the waves are three dimensional, it is difficult to portray them realistically. Fig 19.1 is a graphical representation in which the wave is reduced to a single dimension. The diagram represents a single axis of the wave originating from the source of radiation and shows the way in which the two fields vary along the wave path at an instant in time. In this particular case the electric (E) field occupies the vertical plane and the magnetic (H) field the horizontal plane, but in fact the two field can lie in any two planes at right angles to one another. At any point on the wave path, for example at the point 'A,' it would be possible to detect and measure the two oscillating fields. The phase of the oscillations varies progressively along the wave path, and in this way causes the wave envelope to move away from the source.

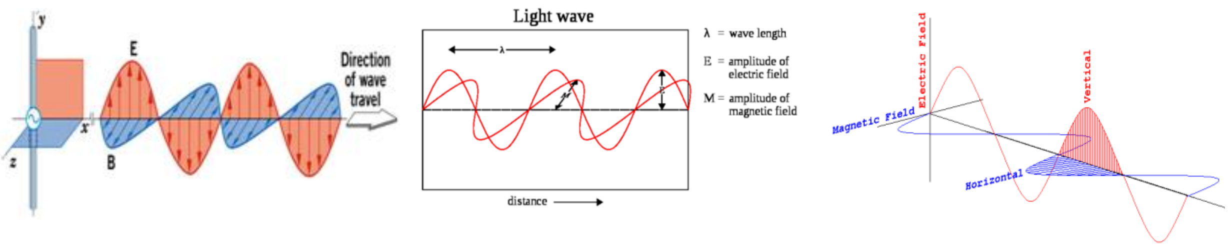


Fig 6.1: Electromagnetic Waves

2. The relationship between the velocity of propagation, wavelength and frequency of a radio wave is: $\lambda = c/f$

Where, λ = Wavelength (metres).
c = Velocity of propagation (3×10^8 metres/sec)
f = Frequency (cycles/sec)

Generation of Radio Waves

3. A moving electron produces a moving electric field, and since a moving electron is in fact a current, a magnetic field is also produced. In a resistive circuit these two fields are in phase, but at right angles to each other. With an alternative current the electrons are continually changing the velocity, going from zero to maximum speed in one direction, back to zero and to maximum speed in the opposite direction.

4. Thus the electrons surging up and down the wire of the half wave dipole cause electric lines of force as shown in Fig 19.2 (a). The direction of this E field is, by convention, from positive to negative. Since potential across the aerial is alternating, the E field will fall from maximum intensity in one sense, through zero to maximum intensity in the opposite sense. However, the E field is spread some distance away from the wire and so its collapse will lag on the current which is causing it. Thus when the current changes direction and a new E field of opposite sense begins to build up, the original E field will still be present. This is illustrated in Fig 20.2 (c): the first E field is forced outwards in the form of a closed loop because the two fields repel each other. The detached E field moves away from the aerial in the direction shown, with the speed of light (3 X 10^8 metres/sec).

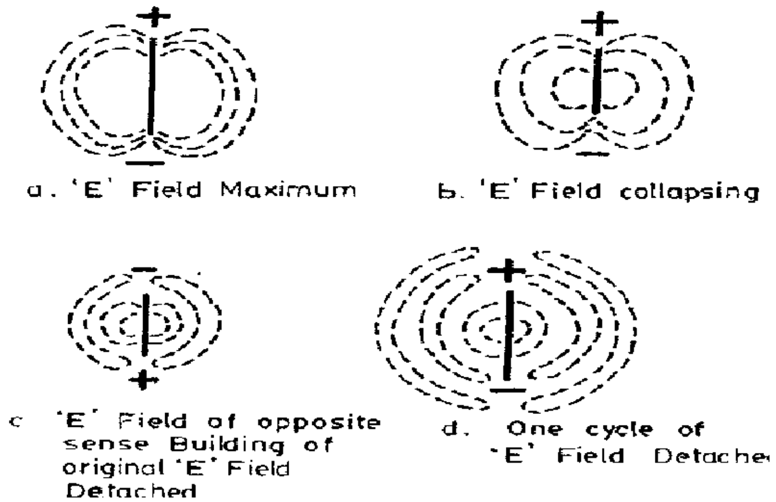


Fig 6.2: Generation of Radio Wave

5. A changing or moving E field causes a magnetic field and so the energy radiated from the aerial is in the form of electric (E) and magnetic (H) fields, in phase with each other, but in planes at right angles to each other (known as in space quadrature).

Polarization

6. The polarization of electromagnetic waves is determined by the direction of the lines of force in the electrostatic field. If this direction is perpendicular to the Earth's surface the wave is said to be vertically polarized and if this direction is parallel to the ground it is said to be horizontally polarized.

Radio Spectrum

7. The position which radio waves occupy in the electromagnetic spectrum is not entirely arbitrary. The lower limit is determined by the size and efficiency of the aerials required and the upper limit by the attenuation and absorption of radio waves

by the atmosphere. As shown in Fig 6.3, it is convenient to divide the radio spectrum into frequency bands, each band normally covering one decade of frequency. Radio waves at frequencies higher than 1,000 MHz (1 GHz) are usually termed microwave.

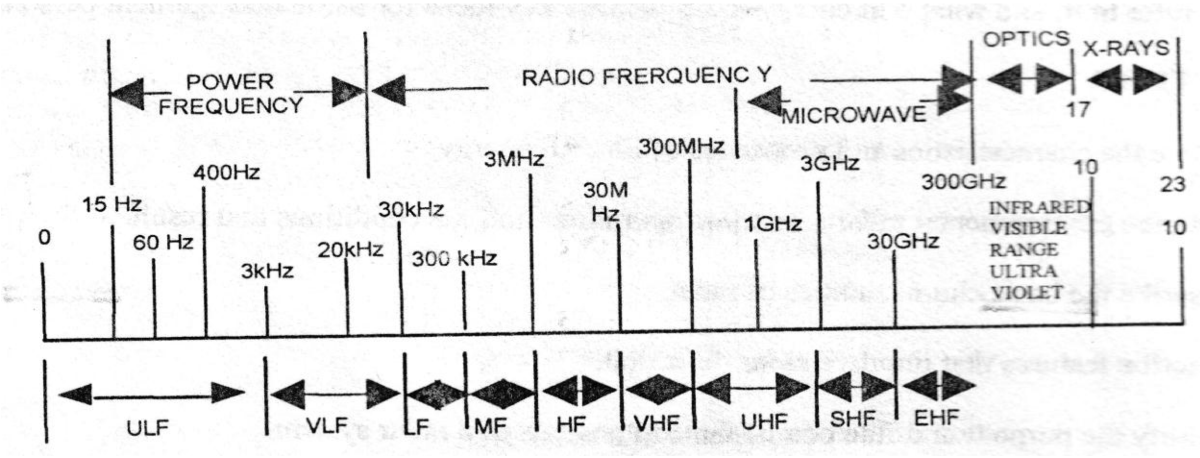


Fig 6.3: Radar Frequencies and the Electromagnetic Spectrum

Propagation of Radio Waves

8. Fig 19.4 shows the principal paths which radio waves may follow between a transmitter and a receiver:

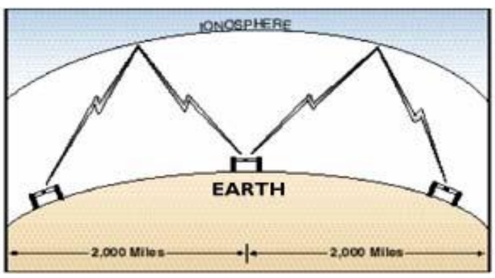
a. The surface wave, which follows the Earth's contour.

b. The sky wave which returns after reflection from the ionosphere.

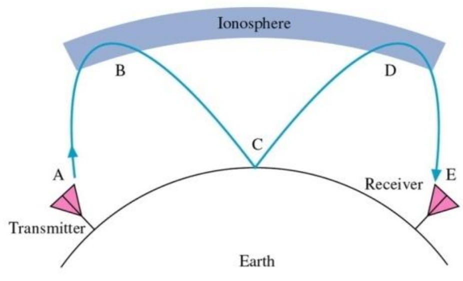
c. The space wave which travels in a direct line.

The ground wave is a combination of the space wave and surface waves.

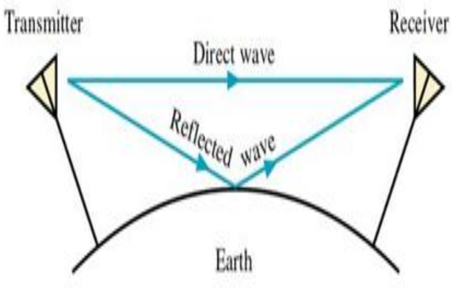
9. The radio energy reaching a receiver may be made up of components following any one or more of these paths but, depending on the part of the spectrum concerned, one of the three will usually predominate. Very roughly, radio waves from the lower part of the radio spectrum are propagated mainly by surface wave, from the middle of spectrum by sky wave, and from the upper of the spectrum by space wave.



Surface Wave



Sky Wave



Space Wave

Fig 6.4: Principal Modes of Radio Wave Propagation

Surface Wave Propagation

10. Because of the phenomenon known as diffraction, the surface wave follows the Earth's curvature. This diffraction is assisted by the Earth's attenuation of the radio energy. Therefore, the wave front in the direction of motion will lag at the surface. Surface wave propagation can only take place within a few wavelengths of the ground and is of practical importance only in the VLF, LF and to some extent in the MF bands.

Sky Wave Propagation

11. Sky waves are these, which ascend into the upper atmosphere and encounter a region containing electrically charged particles (the ionosphere) where they are refracted sufficiently to be returned to Earth. When a wave is refracted it changes direction due to a change in velocity. They may then be reflected upward and travel again to the ionosphere. The process may be repeated a number of times and it is multi-hop transmission of this type which makes it possible to communicate with points on the other side of the globe at HF. As shown in Fig 19.5, the distance between the transmitter and point of reception of the first reflected sky wave is known as the skip distance. The area between this point and the limit of the ground wave is known as the dead space.

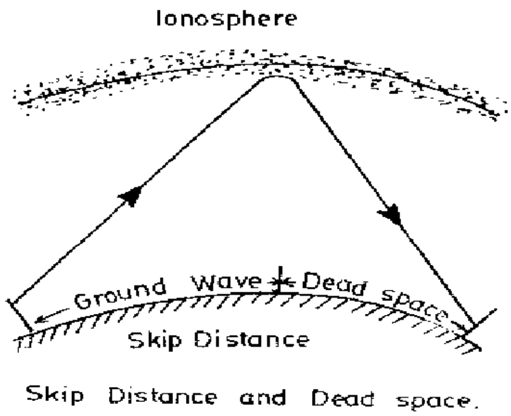


Fig 6.5: Skip Distance and Dead Space

Space Wave Propagation

12. Transmissions at VHF and above cannot propagate by either surface or sky wave, and so at these frequencies, energy can normally only reach a receiver by a direct path plus an Earth-reflected path. The combination of the two components is called the space wave. Propagation by this mechanism is of special importance because of its application to most forms of radar.

Duct Propagation

13. Under certain abnormal climatic conditions temperature can increase while humidity decreases with height. When this occurs the refractive index may decrease with height much more rapidly than is normal and a duct is formed between the Earth and a hundred or so feet above it. Radio wavelengths which are small compared with the duct height (usually metric and below in temperate latitudes) are then sufficiently refracted to be returned to the surface and progress in a series of reflections, in the manner shown in Fig 19.6. The trapping of radio energy in this way results in marked anomalies in performance and the strong signals which may sometimes be received well beyond the normal radio horizon are often a source of nuisance, particularly in a radar. A marked high level inversion can sometimes produce an elevated duct.

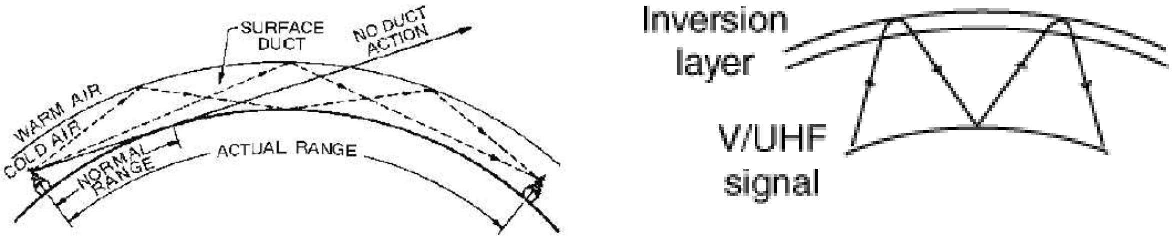


Fig. 6.6: Duct Propagation

Scatter Propagation

14. A radio wave penetrating upward into the atmosphere encounters regions of turbulence within which there are minor local variations in refractive index which cause a small proportion of the energy to be deflected away from the main wave path. Most of the deflected energy is contained within a conical volume lying the wave axis with its apex in the main scattering region and, provided the elevation of the wave path is sufficiently low, some of the deflected energy will be returned to earth. The signal level in the returned wave may be as such as 100 dB below the free space signal for the direct path. To exploit this form of propagation for point-to-point communication, it is necessary to employ highly directive transmitting and receiving aerials. These aerials are oriented so as to intersect at a small angle in the optimum scattering region. Two such regions exist: the first, in the troposphere where the effect is marked in the UHF above 500 MHz, and the second, in the ionosphere where the scattering is confined to a relatively narrow band of frequencies in the VHF between about 30 and 50 MHz. As shown in Fig 19.7, the resultant geometry dictates fairly distinct limits to the usable transmission distance, the troposphere links normally operating over distances of 300 - 500 kms (160 - 270 nm) and ionosphere links out to about 2000 kms (1100 nm).

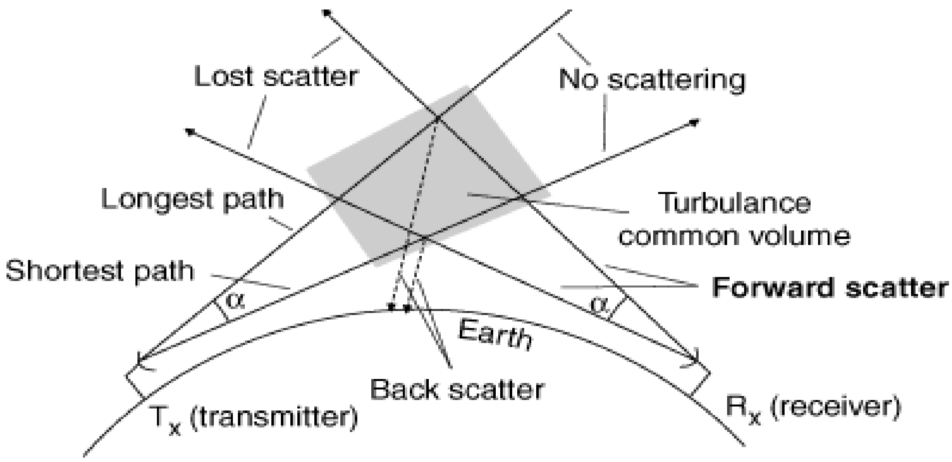


Fig 6.7: Scatter Propagation

INTRODUCTION TO RADAR

Training Objectives. At the end of this chapter the students should be able to understand:

a. Types of radar.

b. Principle of radar operations.

c. Functional block diagram of radar.

Introduction

1. The name radar describes any system, which is capable of detecting or locating objects by means of reflected or automatically transmitted radio waves. The presence of moving or stationary objects such as aircraft, missiles, ships, and landmasses can be detected by means of radar. In addition, information concerning the exact position of the object (usually referred to as the 'target'), its speed and course, where applicable, can be obtained. However, radar can see through darkness, haze, fog, rain, and snow. In addition, radar has the advantage of being able to measure the distance or range to the object.

2. The word 'RADAR' was coined by US Navy in 1941 for Radio Detection and Ranging. If you carefully watch the word radar you will see that it reads the same both ways.

R A D A R

In fact, the principle on which radar works, known as echo principle, is hidden in the word itself. An elementary form of radar is shown in Fig 20.1. Electromagnetic energy is radiated from the radar aerial to the desired directions. A portion of the transmitted energy is intercepted by a reflecting object (target) and is re-radiated in all directions. The energy re-radiated in the back direction is again received by the antenna. The received energy is processed and displayed on the radar scope/console.

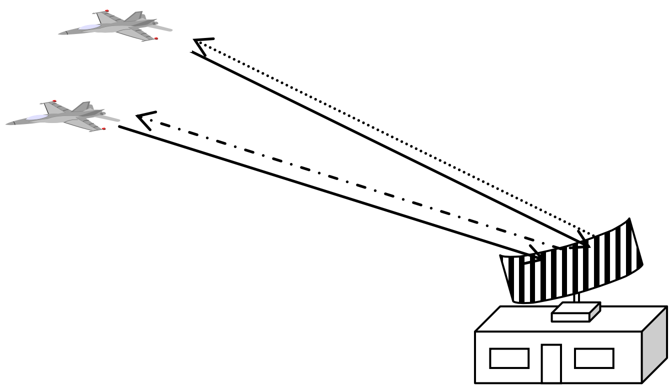


Fig 6.8: Elementary Radar

3. The distance to the target is determined by measuring the time taken for the radar signal to travel to the target and back. The direction, or angular position, of the target may be determined from the direction of arrival of the reflected wave.

Types of Radar

4. There are several ways of classifying radars and the first is the distinction between primary and secondary radars.

a. **Primary Radar**. Primary radar (Fig 20.2) is the most familiar form in which the detection of a target depends on receiving a direct echo of the transmitted signal. It is characterized by the fact that the transmitted energy traverses the path between the radar and target twice. Primary radar basically depends on Radar Cross Section (RCS) of the reflected object and it can, therefore, be employed with equal facility against friendly, hostile or any target. Examples of the use of primary radar are:

(1) Long range, Medium range & Short range (LRR, MRR, SRR).

(2) Low Looking Radar (LLR).

(3) High Power Radar (HPR).

(4) Early Warning (EW) radar.

(5) Height Finding (HF) radars.

(6) Gap Filler (GF) radar.

(7) Over the Horizon Radar (OTH).

(8) Weather radar.

(9) Monostatic, Bi-static & Multistatic radars.

(10) Two Dimension (2D) & Three Dimension (3D) radars.

(11) Conformal radars etc.

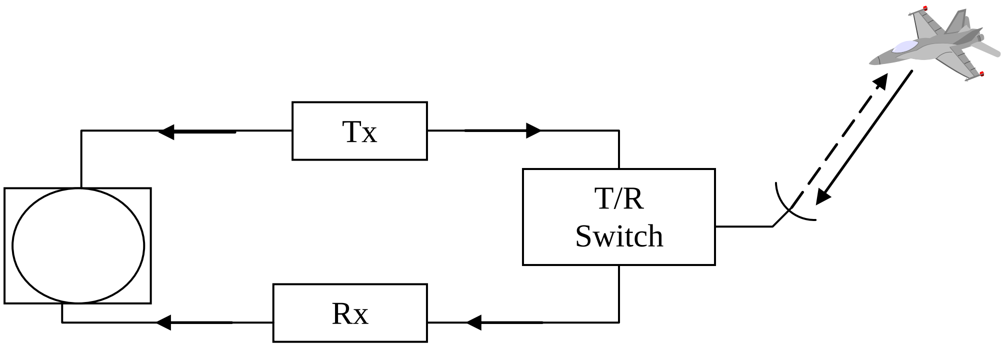


Fig 6.9: Primary Radar

b. **Secondary Radar**. Secondary radar system consists of either a transmitter-receiver (Interrogator) on the ground or a transmitter-receiver (Transponder) in the aircraft or vice versa. The interrogator transmits an interrogation signal to the transponder which transmits back a reply on a different frequency. Such a system is used in the airborne Distance Measuring Equipment (DME). Rapid identification of aircraft is required either by a defence or air traffic control radars where a transponder in the aircraft is interrogated by a ground transmitter. Secondary radar system is normally operated in conjunction with primary radar and the two systems are complementary. Primary radar depends upon the reflection of radio signals from the aircraft; whereas identification systems transmit a return signal to ground which is independent of target size. Greater range can be achieved with less power because the signals from the ground to air and air to ground have to survive only on one-way transmission path. There are two secondary radar identification systems in use; the military Identification Friend or Foe (IFF) system, mainly employed with military air defence radars and the civil secondary surveillance radar (SSR) system, employed with air traffic control ground radars. Both systems operate basically in the same manner. The essential requirements of IFF are:

(1) A transmitter-receiver (Interrogator) on the ground.

(2) A ground station aerial system that produces a rotating beam, narrow in azimuth and wide in elevation.

(3) A transmitter-receiver (Transponder) carried in the aircraft.

(4) An Omni-directional aerial mounted on the aircraft.

(5) Means of extracting and displaying the information received at the ground station.

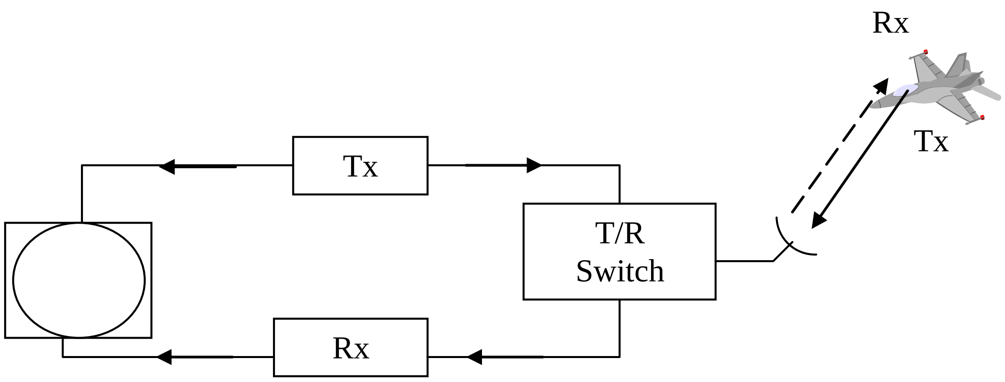


Fig 6.10: Secondary Radar

Familiar examples of secondary radar are IFF, distance-measuring equipment such as TACAN and, perhaps less familiar systems for tracking missiles and satellites. Secondary radar normally forms with the combination of Tx and Tx at both ends. Secondary radars are used for various purposes, some examples are:

(1)	Ground base:	Eureka beacon, BAPs equipment & IFF Interrogator etc.
(2)	Airborne:	Rebecca MK-4, ILS radar & IFF Transponder ctc.

Measurement of Range

5. In pulse radar the transmission is concentrated into vary short pulses which are separated by sufficiently long intervals to permit all echoes from targets within the operating range to be received from one pulse before transmission of the next. Targets are resolved in range by virtue of the different times of arrival of their echoes and the degree of resolution being determined by the band of the pulses. Range measurement is made by observing the elapsed time't' between the transmission of a pulse and reception of an echo. If 'R' is the target range and 'c' the velocity of propagation then:

$$t=2R/c \quad \therefore \quad R=ct/2$$

This 'R' is actually the slant range of a target.

Measurement of Height

6. The aerial used for height finding, radiates a beam which is narrow in the vertical direction, but spreads horizontally. The beam is nodded up and down between the limits to be scanned. This gives the slant range 'R' and the angle of elevation θ (Fig. 20.4). The height and the ground range can be calculated from the following formula.

Height = R Sin θ $\quad\therefore$ Ground range = R Cos θ

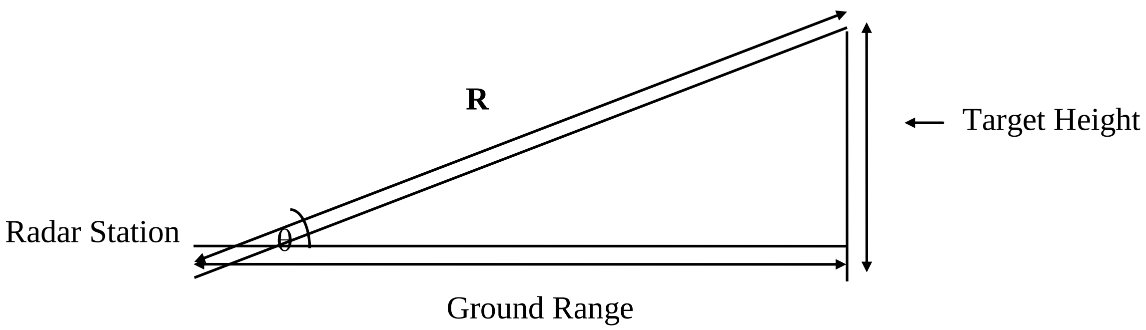


Fig 6.11: Measurement of Height

Description of a Pulse Radar

7. Fig. 20.5 shows a systematic block diagram of a typical pulse radar system. The functions of the various stages are as follows:

a. **Master Timer**. The timing pulses produced by the master timing circuit control the pulse repetition frequency (PRF) of the radar. Master timer is used to:

(1) Trigger the transmitter operation in the modulator at precise and regular interval.

(2) Generate and synchronize the start of the CRT trace with the operation of the transmitter.

b. **Modulator**. The output from the modulator switches the transmitter on and off and so controls the pulse length, of the transmitter output.

c. **Transmitter**. The output from the transmitter consists of a very high power pulse of short duration.

d. **T/R Switch**. The T/R Switch (Duplexer) automatically connects the transmitter to the aerial for the duration of each output pulse and connects the aerial to the receiver for the interval between pulses.

e. **Aerial**. The aerial focuses the radiated energy into a beam of the required shape and picks up the echoes reflected from the targets. Scanning can be achieved by moving the complete aerial structure in azimuth and/or elevation. Such movement is conveyed by synchros or servo-mechanisms to the indicator.

f. **Receiver**. The receiver, which is usually a superheat, amplifies the very weak echoes and presents them to the indicator in a suitable form for display on the CRT.

g. **Indicator**. The type of CRT display used will vary according to the requirements of the system. One, two or all three target parameters (range, azimuth and elevation) may be displayed.

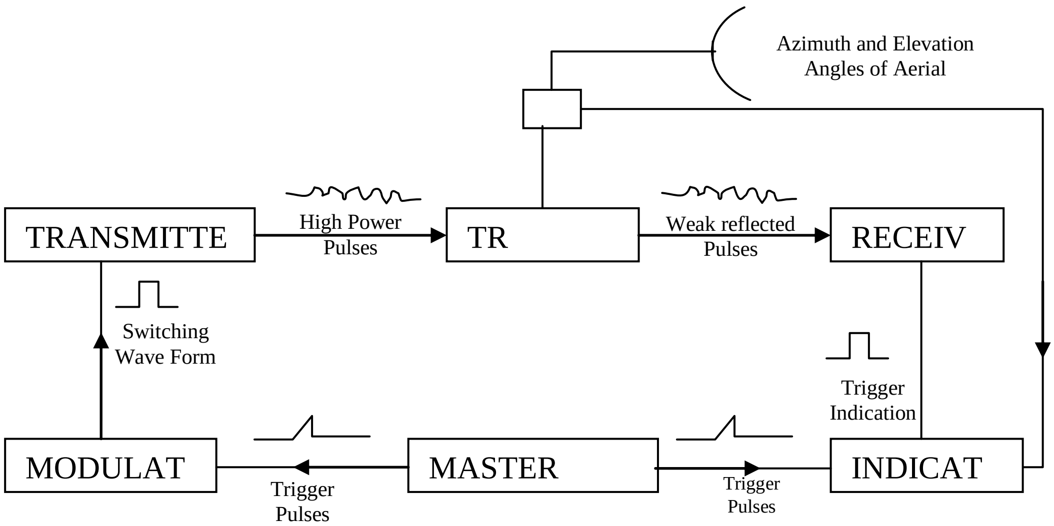


Fig 6.12: Block Diagram of Typical Pulse Radar

Pulse Radar Parameters

8. The basic parameters of a pulse radar, are illustrated at Fig 20.6:

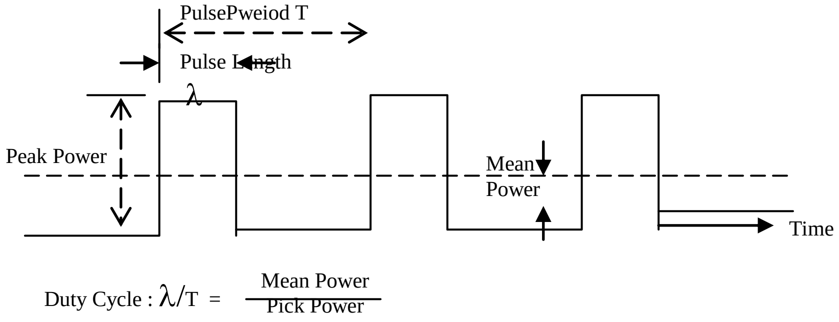


Fig. 6.13: Pulse Radar Parameters

9. The pulse repetition frequency (PRF) is defined as the number of pulses occurring in one second. Notice that the time between pulses, T (often called the pulse interval, or pulse period) is the reciprocal of the PRF. Thus for a PRF of 500 pulses per second (PPS), the pulse interval is T = 1/500 second or 2,000 microseconds (ms). In pulse radars, the PRF normally lies between 200 and 6000 PPS.

10. The pulse length 't', is the length of time for which the radar is transmitting in one pulse. It normally lies between 0.1 and 10 ms.

11. The ratio of the pulse length to the pulse interval (t /T) is known as the duty cycle.

Notice that,

Duty Cycle=t /T =tf_R

The order of magnitude of the duty cycle is typically about 0.001.

12. The power transmitted during the pulses is called the peak power, P. Now if the transmitter were running continuously and emitting the same total amount of energy, the output power level would be much lower, and this equivalent continuous power output is called the Mean Power P_m (see Fig. 2-6). There is a simple relationship between P and P_m, since P is transmitted for a duration must be equivalent in total energy to P_m transmitted continuously for a time T. Hence:

$Pt = P_m T$

or, P_m=P(t/T)=P.Duty cycle

13. The components of a radar transmitter, provided they can handle the short peaks of voltage generated during the pulses, can be chosen on the basis of the mean power they have to dissipate. However for a given operating wavelength there is a limit to the peak power which the wave guide can handle, and or when this limit has been reached, the only way to increase the mean power, which is the real determinant of radar performance, is to increase the duty cycle. Further, the amount by which the duty cycle may be raised is limited by the problem of range ambiguity, due to excessive shortening of the pulse interval T, or loss of range resolution due to excessive lengthening of the pulse length.

Range Ambiguity

14. Range ambiguity occurs if the pulse transit time 2R/c exceed the pulse interval T. It is therefore necessary to choose a value of T sufficiently high to permit all possible echoes from a pulse to be received before transmission of the next. Since the maximum range which can be measured without ambiguity occurs when 2R/c = T, it follows that.

$$R_{unamb} = cT/2 = c/2\ PRF$$

where R_{unamb}=maximum unambiguous range

A typical long-range search radar may operate at 250 pulses per second permitting unambiguous range measurement up to about 330 NMs. Where the operating range is more restricted, as in AI and SAM radars, the repetition frequency might be 1,000 pules per second giving an unambiguous limit of 80 NMs.

Radar Resolution

15. Resolution is defined as the ability to distinguish between two closely spaced targets. The distance between two resolvable targets must be defined in each of the dimensions of measurement, which are typically for a radar range, azimuth, elevation and velocity.

Range Resolution

16. Range resolution is determined by the pulse width. Figure 2-7 shows that if the pulse width is large the returns from the two targets will overlap and hence they will not be resolved. If the pulse were made shorter, as in Figure 4-7, resolution would take place. The down range distance between targets R_r is given as:

$$R_t = c\tau/ 2$$

where c is the velocity of light,

For τ =1μs, For example, R_τ=150 m

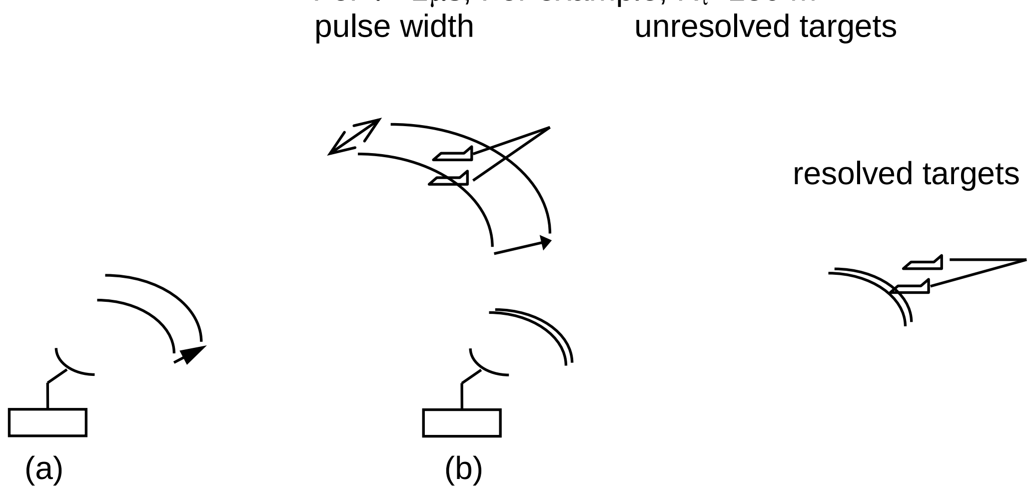


Fig. 6.14: Radar resolution by pulse width.

17. If two targets are separated in range by less than half the radial distance occupied by the pulse, they are seen by the radar as a single echo. Pulse length is therefore the fundamental factor determining the ability of a radar to resolve targets in range, and it also imposes a theoretical limit to the minimum range down to which

the radar can not operate. The extent to which the range resolution depends on pulse length can be visualized from the fact that a pulse occupies 300 meters for every microsecond of duration. Thus a radar using pulse of 4 microseconds would only be able to discriminate between two targets provided they were separated in range by more than 600 meters. Similarly, provided the receiver could begin to function at the instant the pulse transmission ceased, the smallest range the radar could measure would be 600 meters. In radar systems required to give high resolution (e.g. ground mapping, SAM, and AI radars) pulse lengths may be in the region of a microsecond or less, but this is only feasible if the PRF can be high. The pulse length in long-range search radar is normally considerably greater in order to offset the low PRF, and the range resolution capability of such radar is correspondingly poor. In the majority of pulse radars these pulse length and repetition frequency limitation mean that the duty cycle lies in the region of 0.001.

Angular Resolution

18. The angular resolution in azimuth and elevation is determined by the antenna beam width θ and the range. The targets are just resolved when their cross range distance apart R_θ is given by:

$$R_\theta = r\theta$$

The antenna beam width is given by $\theta = K\lambda/a$ so that:

$$R_0 = rK\lambda/a$$

where K is the beam width factor , λ is wavelength and a is antenna size. For the 5 GHZ medium range radar, analysed in which had a 2m antenna diameter, θ is about 1.7°, giving R_θ=1,224m at 40.8 km range.

Velocity Resolution

19. In simple terms the target return is frequency shifted by a moving target. If this frequency shift is measured by passing the signal through a series of filters or velocity gates, analogous to the range gates, a velocity measurement can be made. The resolution of the velocity measurement is defined as how far apart in speed two targets must be to go into adjacent velocity gates. This is an important method of target discrimination when the targets occupy the same range gate and are not resolved by the antenna beam width. The velocity resolution R_V is dependent on the width of the Doppler filters. The Doppler shift f_D is given by $f_D = 2v/\lambda$ where λ is the wavelength and v is the radial target velocity. For a Doppler filter of width f Hz, the target velocity difference for resolution R_V is thus given as:

$$R_V = f\lambda/2$$

For f=100Hz, R_V =3 m/s at 10 GHz (λ= 0,03).

Radar Accuracy

20. Radar accuracy is defined as the difference between a target's actual position or velocity and that indicated by the radar. It is critically dependent on resolution. It is clear that narrower pulse widths, beam widths and velocity gates can give improved

accuracy. As radar measurements are subject to noise-like perturbations, accuracy must be specified statistically.

Accuracy is best expressed in terms of the standard deviation, $\sigma_{R,}$, of the error in each parameter being measured. Sixty-six per cent of all measurements will be within one standard deviation of the correct result. The accuracy is given by:

$$\sigma_R = CR/\sqrt{(S/N)}$$

where C is a constant that depends on the detailed design of the radar . R is the resolution in either range, angle or velocity. It is thus clear that low errors require good resolution and a good signal to noise ratio. These two conditions sometimes conflict and require compromise in design. If the above radar has C=1 and S/N 36 , the standard deviation in the range measurement is 25 m and in angle is 204 m.

Pulse Repetition Frequency

21. The PRF, selected for particular radar depends upon several factors; the most important being summarized below:

a. **Maximum Required range**. Each pulse must be given time to travel to the most distant required target and return before the next pulse is transmitted, otherwise there will be a risk of confusion on the display. For smaller range the time intervals are less and the PRF. may be increased. Thus the longer the required range the lower must be the PRF.

b. **Scanning Speed**. If the aerial scanning speed is high and the PRF. is low some targets may be missed; because in the time interval between pulses, the aerial will have turned through a certain angle. Thus the higher the scanning speed the higher must be the PRF. and vice-versa.

c. **Improved Definition**. The more PRF that are transmitted per second the more pictures are painted on the CRT. per second. This means a brighter and clearer display and improved definition.

Pulse Duration

22. The pulse duration selected for particular radar depends upon several factors, the most important being summarized below:

a. **Minimum range**. Short duration pulses are needed for short range working.

b. **Target discrimination in range and azimuth**. Short pulse duration are needed for good target discrimination in range; in the same way very narrow beams are needed for good discrimination in azimuth.

c. **Frequency used**. The lower the frequency the longer is the pulse duration to ensure an adequate number of RF cycles in each pulse.

d. **Receiver bandwidth**. The shorter the pulse duration the greater is the band of frequencies associated with the pulse and the greater must be the bandwidth of the receiver acceptability of such pulses.

Receiver Bandwidth

23. As with any other form of modulation, the effect of transmitting in short pulses is to cause the transmitted spectrum to be spread across a range of frequencies, and the shorter the pulse the greater is the extent to which the pulse energy is spread in frequency. For this reason all pulse radar must have large receiver bandwidths, and this particularly applies in high-resolution system where the pulse is short. Depending on its function, the bandwidth of a pulse radar might be between one and ten MHz.

Pulse Compression

24. The performance of radar in terms of maximum detection range, will depend on the returned signal energy. Now the energy in a radar pulse depends on the peak power Pp and the pulse length t, so that to obtain a good detection range it is necessary to you a large peak power, or a long pulse length or both (Fig 4-8).

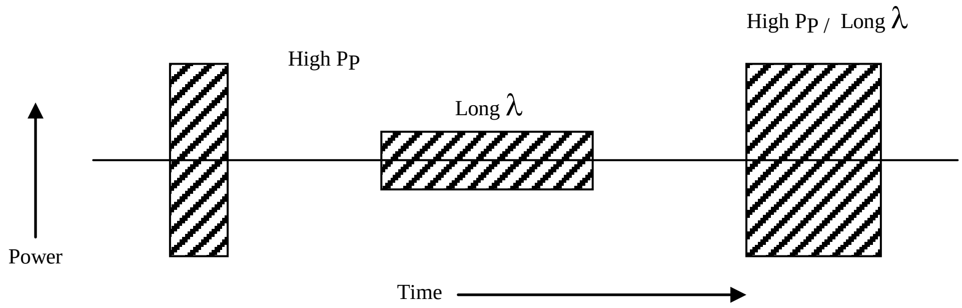


Fig 6.15: Ways of Increasing the Energy in a Pulse

25. In practice the pulse length is usually limited by the operational specification for range resolution so that the required pulse energy may only be obtained by increasing the peak power. However, as has already been emphasized (paragraph 15), it may not be possible to increase the peak power to the required level because of voltage breakdown problems. In limited peak power, the energy in the pulses can only be increased by making the pulse length longer with consequent degradation in range resolution. This is a fundamental dilemma in the design of pulse radars. Pulse compression is a specialized radar technique, which overcomes this dilemma by using long pulses, but retaining the resolution characteristics of a short pulse transmission.

26. Pulse compression is achieved by transmitting long pulses in which the frequency is modulated, and processing the echoes in a filter which has frequency characteristics matched to the modulation and which compresses the pulses in time. In Fig 2.7 a, b & c, the amplitude and frequency characteristics of the modulated transmitted pulse are shown. When the frequency-modulated echoes are received they are passed through a filter which is designed to delay the low frequencies to a greater extent than the high frequencies. On emerging from the filter, therefore,

the higher frequencies in the trailing edge of the pulse will have caught up with the lower frequencies in the leading edge, and the energy will be compressed into a shorter pulse with greater amplitude.

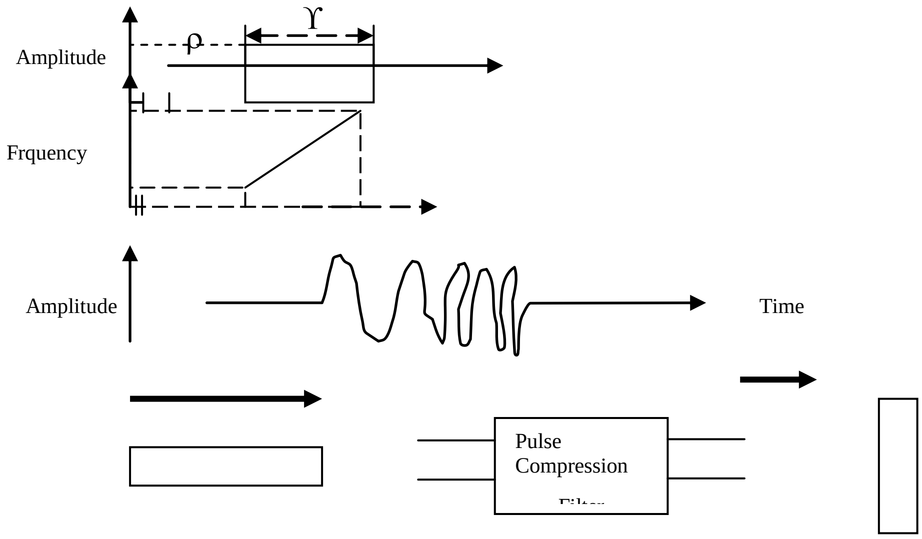


Fig 6.16: Pulse Compression

Radar Frequencies

27. Conventional radars generally operate at frequencies extending from about 220 MHz to 35 GHz, a spread of more than seven octaves. These are not necessarily the limits since radars can be, and have been, operated at frequencies outside either and of this range. Sky wave HF over-the-horizon (OTH) radar might be at frequencies as low as 4 or 5 MHz and ground wave HF radars as low as 2 MHz. At the other end of the spectrum, millimetre radars have operated at 94 GHz. Laser radars operate at even higher frequencies.

28. Early in the development of radar, a letter code such as S, X, L, etc. was employed to designate radar frequency bands. Although its original purpose was to guard military secrecy, the designations were maintained, probably out of habit as well as the need for some convenient short nomenclature. This usage has continued and is now an accepted practice of radar engineers. Following table lists the radar-frequency letter-band nomenclature.

Standard Radar Bands	Frequency	Wave length	NATO Bands	Frequency	Wave Length
VLF	300Hz-30KHz	-10Km	-	-	-
LF	30-300KHz	10-1Km	-	-	-
HF	3-30MHz	100-10m	A	0-250MHz	-
VHF	30-300MHz	300-100cm	B	250-500MHz	120-60cm
UHF	0.3-1GHz	100-30cm	C	0.5-1GHz	60-30cm
SHF	3-30GHz	10-1cm	-	-	-
EHF	30-300GHz	1cm-1mm	-	-	-
L	1-2GHz	30-15cm	D	1-2GHz	30-15cm
S	2-4GHz	15-7.5cm	E	2-3GHz	15-10cm
C	4-8GHz	7.5-3.75cm	F	3-4GHz	10-7.5cm

X	8-12GHz	3.75-2.5cm	G	4-6GHz	7.5-5cm
Ku	12-18GHz	2.5-1.6cm	H	6-8GHz	5-3.75cm
K	18-27GHz	1.6-1.1cm	I	8-10GHz	3.75-3cm
Ka	27-40GHz	1.1-0.75cm	J	10-20GHz	3-1.5cm
MM	40-100GHz	0.75-0.3cm	K	20-40GHz	1.5-0.75cm
-	-	-	L	40-60GHz	0.75-0.5cm
-	-	-	M	60-100GHz	0.5-0.3cm

Table 6.1: Standard Radar Frequency Letter-band Nomenclature

Letter band is not a substitute for the actual numerical frequency limit of radars. The specific numerical frequency limits should be used whenever appropriate, but the letter designations of above table may be used whenever a short notation is desired.

TYPES OF SCAN AND COMMON RADAR TERMS

Training objectives. At the end of this chapter the students should be able to know:

a. Different types of radar displays and their functions.

b. Some common terms used in radar system.

Introduction

1. Radar can be termed as an electronic eye. We hear a radio communication, but in a radar set the information is displayed on a Cathode Ray Tube (CRT) screen for seeing the targets. There are many devices to present the target information in terms of range, bearing, height and other coded indications. The most common types of display scans are given below.

'A' Scan Display

2. This type of display is used only to indicate the range. In this scan, the horizontal line across the screen, produced by the time-base circuit represents the 'X' axis in terms of geometrical co-ordinates. The target appears as a vertical displacement along the line. This line is calibrated in terms of feet or miles and the range of the target can be easily recorded from this type of scope (Fig. 21.1).

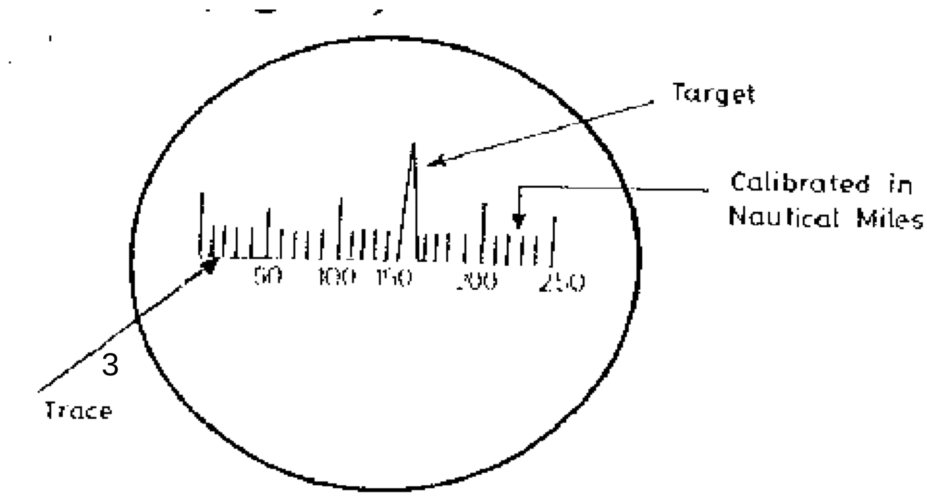


Fig.6.17: 'A' Scan Display

‘B’ Scan Display

3. In this display the vertical displacement indicates the range and the horizontal displacement represents the bearing. The display presentation is shown in Fig. 21.2.

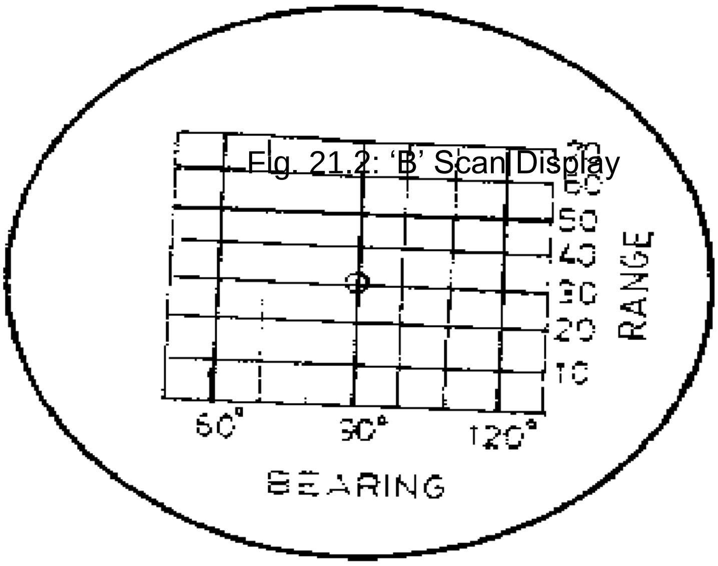


Fig.6.17: ‘B’ Scan Display

'L' Scan Display

4. The display is generally used in aircraft indicators to find the range and bearing of the aircraft from a ground source such as Instrument Landing System (ILS). The vertical trace is calibrated to give range in nautical miles or 1000 of feet. The ratio of the amplitude of the signals displayed on either side of the vertical trace gives the bearing. The vertical trace is taken as the pre-determined course. An aircraft can home on to the base airfield by steering in such a way that the amplitude of the signal on either side of the vertical trace is equal. The distance of the trace from the horizontal line gives the range, which can be read directly. The presentation of ‘L’ scan display is shown in Fig 21.3.

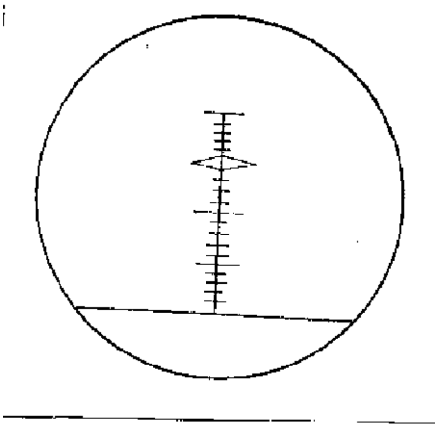


Fig. 6.19: ‘L’ Scan Display

P.P.I Display

5. P.P.I stands for plan position indicator. This type of display is most commonly used in ground radar equipment for finding instantaneous range and bearing of a target. Concentric circles are range markers and appear at 5 or 10 miles intervals from the centre of the display. The direction of the aerial sweep gives the indication of bearing. The circular edge is calibrated in degrees indicating the bearing. The presentation of PPI is shown in Fig 6.20.

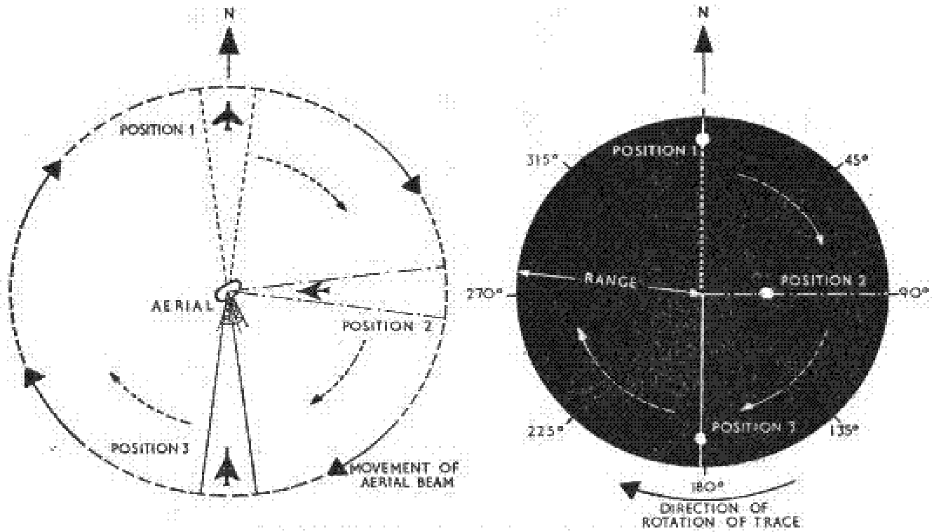


Fig 6.20: PPI Display

Elevation Scan Display

6. This type of display is used to indicate height and range simultaneously. This display is the modification of ‘A’ scan display. If the ‘A’ scan trace is caused to pivot about its origin through an angle which is a function of the angular vertical sweep of the nodding aerial and synchronized with it, the elevation scan display is made. Graphical presentation is shown in Fig 21.5.

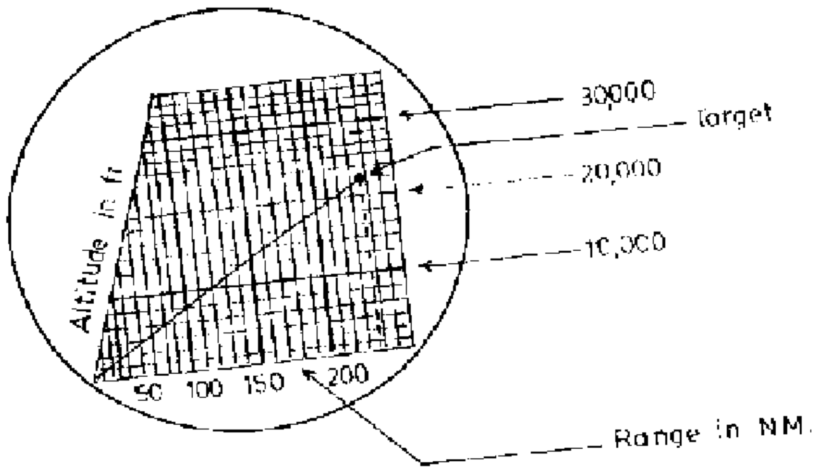


Fig 6.21: Elevation Scan Display

Common Terms Used in Radar

7. Following are some of the common terms used in radar technology:

a. **Radar Mile**. It is twice the distance of an ordinary mile. In this case, the pulse has to reach the target and return to the point of origin. Radar mile is expressed in terms of microseconds. 10.735 microsecond cover a statute radar mile and 12.4 microsecond cover a nautical radar mile.

b. **Pulse**. Radar energy is transmitted in short bursts and is called pulses.

c. **Echo**. The reflected radar pulse, which appears on the screen, is called echo.

d. **Pulse-Width**. The duration of a pulse is called pulse width and is written as ‘PW’. Pulse width is also measured in microseconds. It determines the minimum range and resolving capacity of radar.

e. **P.R.F**. This is the abbreviation of the term pulse recurrence frequency. It indicates how many pulses are being fired in each second. PRF also determines the maximum range of radar.

f. **Pulse interval**. Pulse interval is the time between two consecutive pulses.

g. **P.E**. Permanent echo is abbreviated as P.E. Echoes appearing from hills or any permanent features in the radar range are known as P.Es.

h. **M.T.I.** M.T.I. stands for moving target indicator. It is an electronic device, which allows only the moving target to appear on the screen and blanks the P.Es.

AERIALS, POLAR DIAGRAMS AND POLARIZATION

Training Objectives. At the end of this chapter the students should be able to know:

a. What is the requirement of antenna?
b. What is polar diagram?
c. What are aerial lobes and nulls?

Introduction

1. An aerial may be defined as device used for the efficient transmission and reception of the electromagnetic (em) energy. They are generally metallic conductors. The aerials are designed in many different ways according to the requirements of radio and radar services.

Half -Wave Dipole

2. A simple transmitting aerial is a conductor, usually a wire, which is designed to radiate em wave as efficiently as possible. The simplest form of aerial is a half-wave dipole. This is a wire which is a half-wavelength long of the frequency of the current being carried by the wire, e.g. if the frequency is 30 MHz (10 metres wavelength), a half-wave dipole for use at this frequency will be 5 metres long.

Polar Diagram

4. Polar diagram is a graph indicating the relative radiation in all directions from the aerial. The polar diagram can be drawn as follows:

a. Straight lines are drawn from the aerial in all directions keeping the length of these lines proportional to the radiation field strength in that direction.

b. The end points then are joined to give the polar diagram. In practices it is a three-dimensional figure having a vertical view, horizontal view and a complete three-dimensional view.

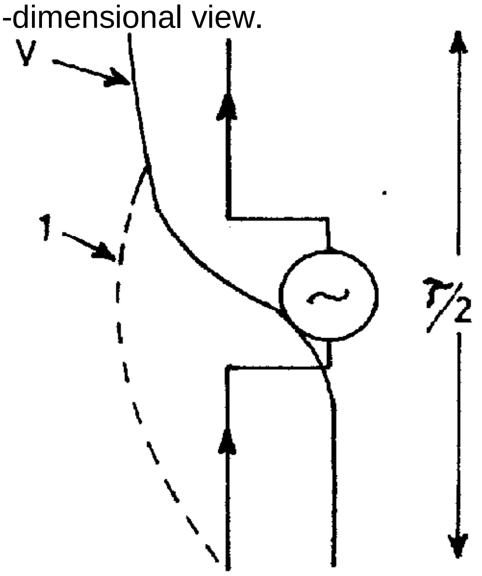


Fig 6.22 : Half-Wave Dipole

Polar Diagram of a Half-Wave Dipole

5. The vertical polar diagram (VPD) of a vertical half-wave aerial is a figure of 8 in the vertical plane as shown in Fig 6.23 (b). The horizontal polar diagram (HPD) is a circle in horizontal plane as shown in Fig 6.23 (c). The three dimensional view of a complete polar diagram can be obtained by combining the above three dimensions as shown in Fig 6.23 (d). In other words by rotating the VPD through a circle we can get the three-dimensional polar diagram.

6. The analysis of the polar diagram of a simple half-wave aerial Fig 6.23 (a) shows that energy does not radiate equally in all directions. It radiates maximum

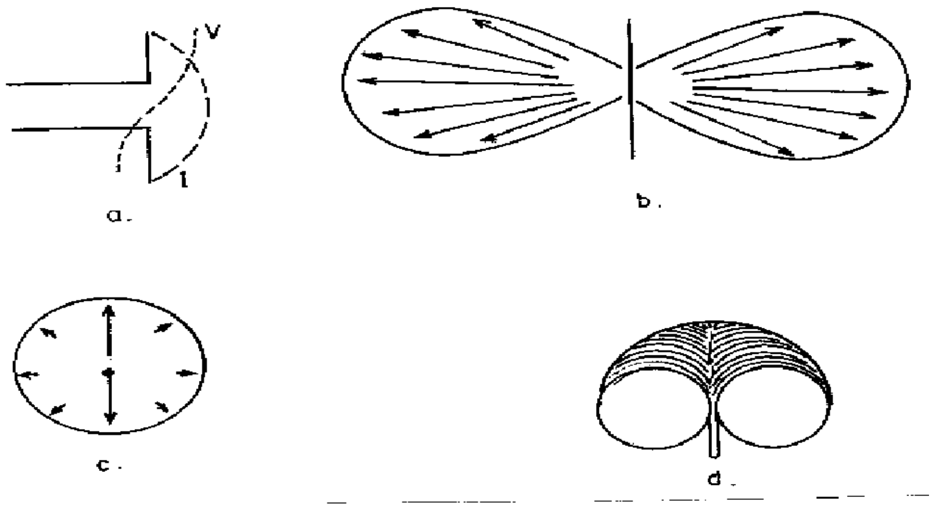


Fig 6.23: (a) Vertical Half-Wave Dipole. (b) Vertical Polar Diagram.
(c) Horizontal Polar Diagram. (d) 3-D View of Complete Polar Diagram.
Aerials Lobes and Nulls

energy from its centre in all directions perpendicular to it, with very little or no radiation towards its end. Therefore, polar diagram of an aerial gives an idea as to how much energy is radiated in a particular direction. Thus, by studying the polar diagram, we can determine the direction of maximum transmission and reception.

7. The rounded projection of a polar pattern representing maximum radiation are commonly known as lobes and the portion of the pattern representing minimum or no radiation are called nulls.

Gaps

8. One of the main problems in all ground equipment is that of gap filling. In the polar diagram of an aerial array there are number of gaps caused due to nulls at different angles of elevation. Any target appearing in these null zones or gaps will not be picked up. The lowest of these gaps is at zero angle of elevation which means that any target at ground level or slightly above the earth's surface will not be seen by radar. The angle of elevation of the lowest lobe can however be decreased either by raising the height of the aerial or decreasing the wavelength.

9. The higher gaps are more troublesome and must be filled if complete coverage is required. The usual method of gap filling is to use a second aerial at a

different height above the ground. If the heights of the main aerial are correctly chosen, maximum of ground reflection lobes of the main aerial will correspond with the minimum of the lobes of the higher aerial and vice versa. Thus by switching from one aerial to another it is possible to see a target from all angles of elevation.

10. Another method of gap-filling at higher elevation is to use two aerials, one above the other, but instead of switching from one to the other, it recovers the phase of either of the upper or the lower aerial. The combined polar diagram of the two aerials when fed in anti-phase has a maximum which corresponds to the minima of the combination when they are fed in phase. Thus by switching from phase to anti-phase the gaps can be filled.

Marconi Aerial.

11. It was Mr. Marconi who suggested the use of half-wave aerial vertically by earthing the lower half. This is popularly known as Marconi aerial (Fig 6.24).

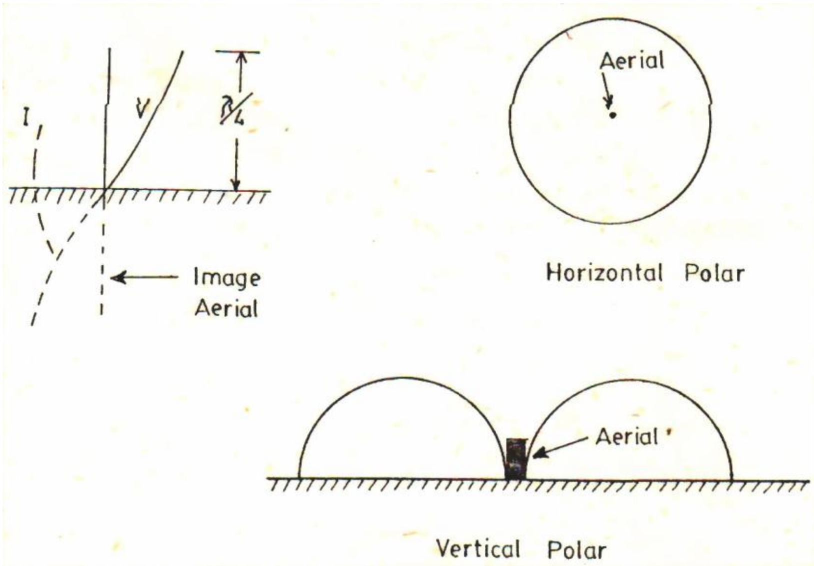


Fig 6.24: Marconi Quarter-Wave Aerial

Parasitic Element

12. A secondary aerial coupled to the driven aerial will re-radiate electromagnetic energy and will therefore effect the directional properties of the driven aerial. This effect produced by such parasite element depends on its length and position with respect to original aerial.

a. **Reflector**. Reflector is a parasitic aerial longer than the driven aerial. Thus it provides directional property away from itself.

b. **Director**. It is a parasitic aerial shorter than the driven aerial. In this case the directional property is achieved towards the parasite.

Yagi Aerial

13. This type of aerial is used to give directional properties. This aerial consists of one driven aerial, one reflector and a number of directors (Fig 22.4).

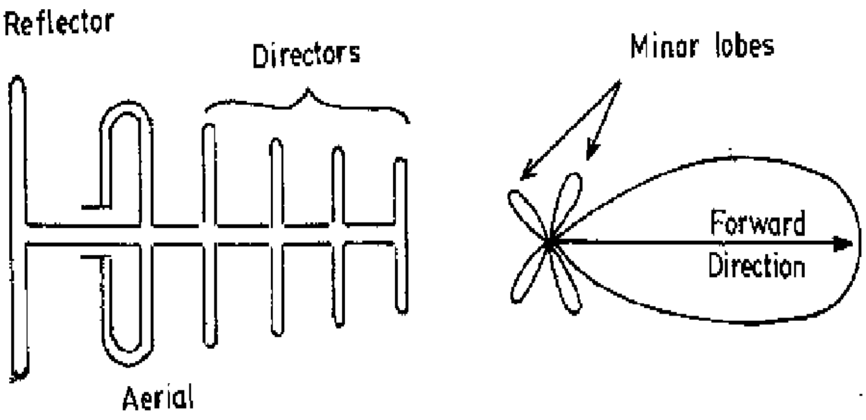


Fig 6.25: Yagi Array with its Polar Diagram

Parabolic Reflector Antennas

14. One of the most widely used microwave antennas is the parabolic reflector (Fig 22.5). The parabola is illuminated by a source of energy called the feed, placed at the focus of the parabola and directed toward the reflector surface. The parabola is well suited for microwave antennas because any ray from the focus is reflected in a direction parallel to the axis of parabola. The distance travelled by any ray from the focus to the parabola and by reflection to a plane perpendicular to the parabola axis is independent of its path. Therefore, a point source of energy located at the focus is converted into a plane waveform of uniform phase.

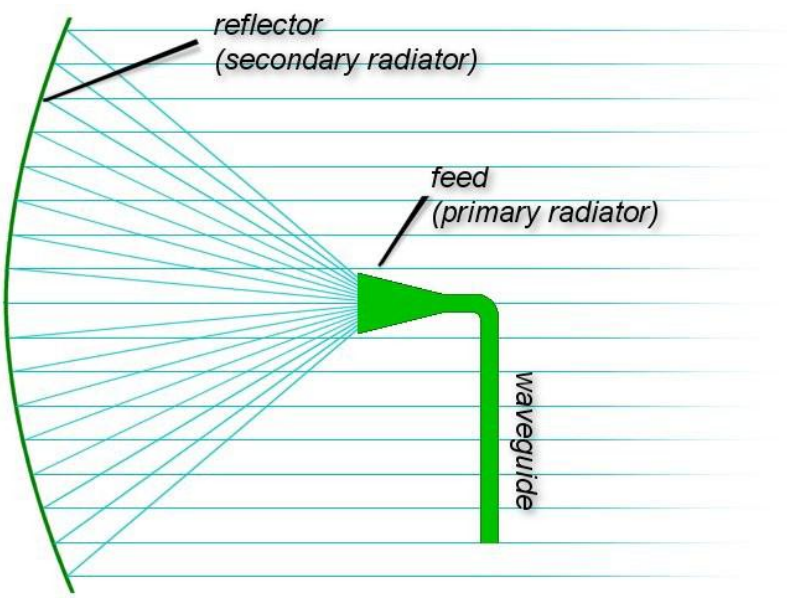
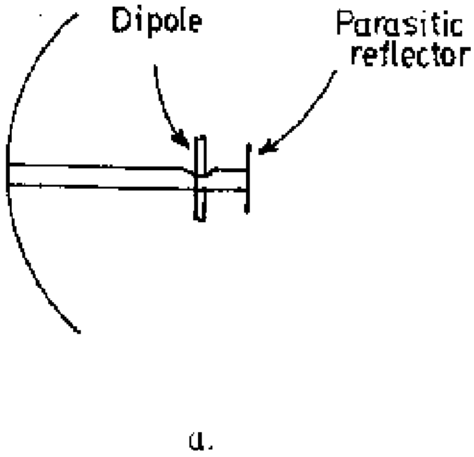


Fig 6.26: Parabolic Reflector Antenna

15. A simple half-wave dipole or a dipole with a parasitic reflector can be used as the feed for a parabolic. The wave-guide horn, as the feed for a parabolic, directs the energy better than a dipole and the phase characteristic is usually good for radiation. The wave-guide horn is the most popular method of feeding parabolic antenna for radar application. Fig 23.6 shows the arrangement of feeding the antenna by a dipole and wave-guide horn.



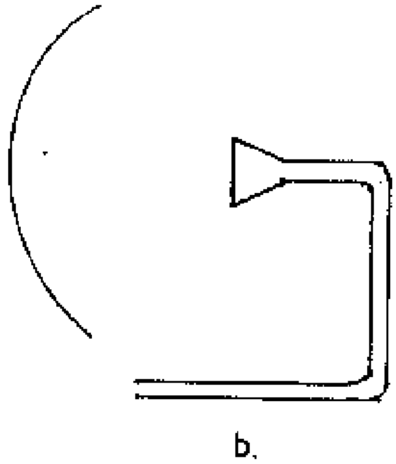


Fig.6.27: (a) Dipole feed Parabolic Reflector. (b) Horn feed Parabolic Reflector.

TOPIC- 7
DEPLOYMENT AND SITING OF AIR DEFENCE RADAR

PLANNING OF AIR DEFENCE

Training Objective. At the end of this chapter the students should be able to know the various considerations to plan a suitable air defence.

Introduction

1. Planning involves locating air defence units and deployment of air defence weapons to achieve maximum tactical advantage in providing defence to VAs and VPs. This planning has to be meticulously carried out to meet all contingencies of both war and peace and to allow no loophole, which the enemy might exploit to her advantage.

2. Since interceptor operations demand a high degree of teamwork between the interceptors and the aircraft control and warning system, careful planning is necessary. Time is at a premium because interceptors must be in the air and ready for combat before the enemy can approach too close to the target. To give you a better understanding of what is involved in planning for air defence, picture a hypothetical sub sector and plan for the defence of certain targets in it.

Factors Governing Air Defence Planning

3. Main considerations that dictate the pattern of air defence planning are the following:

a. **Threat**. Correct assessment of threat is necessary to plan effective defence and to exercise economy of effort. The strategic deployment of forces should therefore, be based on reliable intelligence of enemy concentration, deployment of enemy forces, performance of enemy weapons and equipment. Constant review of threat and corresponding changes in plan are the requirements of effective air defence.

b. **Targets to be Defended**. Having been allocated targets to be defended, the deployment of forces should be planned to ensure destruction of attacking force as far away from the target as possible and to provide maximum defence in depth. Even the choice of weapon should be based on this consideration.

c. **Availability of Resources**. This is more of a limiting factor in the planning of air defence. However, no plan can be realistic and practicable without due consideration of this fact. That means, within the limitation of available resources, defence should be planned to achieve as much tactical advantage as possible and to provide as complete and effective defence as practicable.

Principles of Air Defence Planning

4. In planning any air defence system, whether it is made up of interceptors or antiaircraft artillery, six principles are followed:

a. **Select vital objectives**. Begin by selecting one objective or group of objectives that is worth defending. It is impossible to establish an air defence system that will protect equally well every farmhouse and hamlet, or even every factory, city, and military post---even though all these may be more or less important to the economy and war effort. In planning for the air defence of a sub sector, you need not be concerned about deciding what objectives are to be defended. Such a decision is made at a higher level. All you need to know is that higher commands believe that certain objectives in your sub sector need air defence. You can also assume that an aircraft control and warning system, interceptor units have been assigned to this defence in proportion to the need.

b. **Give Comprehensive Coverage**. Having been committed to the defence of an objective or group of objectives, you must defend all approaches. You cannot assume that the enemy will attack from one direction and then build your defence system to protect this approach. Once such a system, were in place, the enemy would plan his attack to exploit all its weaknesses.

c. **Provide Defence in Depth**. A perimeter type of defence would permit the enemy to range behind the line of defence with relative impunity once ' he had broken through it. The advantage of defence in depth is that the hostile aircraft can be kept under constant attack for a relatively long, period. Ideally, this would mean from the extreme range of the defending forces until the objective is reached, but it is often necessary to settle for something less than that.

d. **Concentrate forces**. At the same time that you must have an all-round defence, you must concentrate your forces at the targets to be defended. This means that you must deploy interceptors and antiaircraft weapons so that they are mutually supporting and that the maximum amount of firepower, is brought to bear on hostile aircraft. To deploy interceptors to best advantage, it is necessary to have an adequate system of air bases.

e. **Plan for a defence in being**. You cannot hope to build an interceptor defence today with the equipment you expect to receive tomorrow.

f. **Keep the defence progressive and flexible**. The plan for the defence must allow for changes in equipment and tactics. Provisions must be made so that new equipment can be incorporated into the system to advantage as soon as it is made available.

Concepts of Air Defence Planning

5. Over the years, several air defence planning concepts have emerged. The two concepts that have endured are Area Defence and Local Defence.

a. **Area defence**. Area defence is based on the concept of locating defensive units to intercept enemy attacks remote from and without reference to individual vital installations, complexes or their target areas. Area defence weapons normally receive direction, information from a network of systems which can continuously track the enemy attack and guide the defence weapons to counter the attack. Area defence missions are conducted for the defence of a broad area using a combination of weapon systems. There can be specialized applications of area defence when friendly assets are dispersed over a large geographical area with defined threat boundaries.

b. **Local defence**. Local defence, on the other hand, is committing weapons to the defence of specified geographical areas, cities and vital installations.

c. **Self-Defence**. Self-defence missions are conducted by friendly units to defend themselves against direct attack or threat of attack through the use of organic weapons and systems. Inherent to all ROE and weapon control procedures is the right of self-defence.

d. **High Value Airborne Asset (HVAA) Protection**. HVAA protection uses fighter aircraft to protect critical airborne theatre assets such as AWACS, RIVET JOINT, and JSTARS.

6. As the advanced defence weaponry and equipment became available, the Local Defence concept was replaced by Area Defence concept, but in this concept both Area and Local Defence weapons are employed. The use of both weapon have certain advantages. The local defence weapons have a very high rate of fire and can generally operate autonomously. The area defence weapons are designed to operate at comparatively longer range than more limited local defence weapons. Area defence weapons have sufficient range to reach out and disrupt enemy attack planes, cope with decoys and electronic countermeasures. LAA and LL SAM are used in local defence; interceptor and Long range SAMs are the weapon for area defence. The appropriate mix of are and local defence weapons is the building block of Defence-in- Depth or Layered Air Defence.

Defence in Depth

7. The word “depth” generally refers to geographic expression of a place/ country while defence in depth focuses on the deployment of various weapons systems in a way which will allow friendly forces to gain time, cause delay to enemy advance and inflict maximum attrition to the enemy. However, all the countries do not have equal geographic expansion so as the natural depth. Therefore, the concept of artificial defence in depth came in to being. This concept embraces the technological advancement to ensure early warning system entered inside the enemy territory and employment of various kinds of weapons in different “time space” definition.

8. The US Department of Defence (DOD) defines defence in depth as “the siting of mutually supporting defence positions designed to absorb and progressively weaken attack, prevent initial observations of the whole position by the enemy, and to allow the commander to manoeuvre the reserve”. The defence in depth strategy is particularly effective against an attacker who is able to concentrate his forces and attack a small number of places on an extended defensive line. The disadvantages of defence in depth are that it may be unacceptable for a defender to plan to give ground to an attacker. This may be because vital military or economic resources are close to the front line or because yielding to an enemy is unacceptable for political or cultural reasons.

9. Defence-in-depth is invaluable to DCA. Early warning of enemy attack is vital if defence-in-depth is to be obtained. Airmen develop defences to permit the destruction of intruding enemy aircraft and missiles as early as possible and as far away as feasible. To maximize attrition to the enemy force, the engagement process is continuous throughout the threat’s approach, entry to, and departure from the friendly operational area.

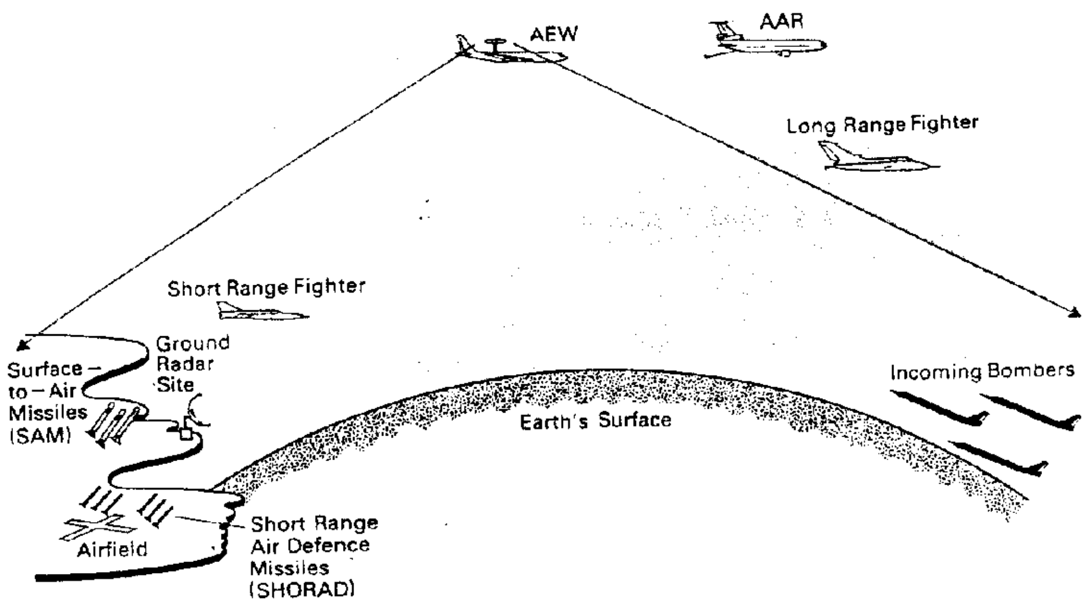


Figure 7.1: Defence in Depth

10. An air defence planned on the concept of area defence must have defence in depth. The ideal defence in depth would be an air defence system that could apply increasing fire power on the enemy as it approaches the target area. An all round defence in depth will be difficult to obtain, because of the high cost in human and material resources. However, it is possible to cover certain probable enemy approaches. To calculate the desired early warning (EW) coverage to achieve defence in depth, we need to be familiar with certain factors which are highly variable.

a. **Combat Time**. It is the time taken by the interceptor force to destroy the enemy. Combat time will depend on the type, numbers and armament of the interceptors, size of the attacking force, quality of the controllers etc.

b. **Speed**. The second major factor to be considered is speed. The speed of the enemy multiplied by combat time gives combat distance or combat zone. This is the distance enemy travels during total engagement time.

c. **Enemy Weapons**. The third element in the defence in depth is enemy weapons. Supposing a free falling bomb travel about 10 NM after release, trajectory line must be drawn around the designated target impact point. This line, the weapon release line (WRL) is the last point at which the enemy must be destroyed if the target is to be saved.

CONSIDERTATIONS FOR DEPLOYMENT OF RADAR

Training Objective. At the end of the chapter, the student will have fair idea on various considerations prior to deployment of Air Defence Radar.

Introduction

1. One of the biggest problems with radar in air defence is: Where should the sets be placed? It would be advantageous if our government had unlimited resources. Radar could be sited all along the coast/border lines, around cities and larger towns. A large number of trained operators could be deployed to operate the radar 24 hours a day. There wouldn't be any need for the MOUs or for intelligent placement of radar sets. This being impracticable, the limited number of available radar sets will have to be deployed to derive maximum operational benefit.

2. Placing or siting of radar is done in two steps. First, general deployment must be considered, what areas must be covered by radar? Then, when the area has been generalised, specific locations must be selected to obtain maximum performance from each set.

3. Deployment is not concerned with which hill or valley the set should be on, or whether surrounding terrain would set up too much ground return interference. It is basically concerned with the general area in which the set should be sited and the radar coverage desired. The deployment of Air defence radar requires the consideration of two major factors:

a. Critical Range Requirement.

b. Technical aspects

Critical Range Requirement

4. Before discussing this subject, however, it would be best to clarify three terms which must be used.

5. **Minimum Line of Interception (MLI=GDA/WRL+Combat Time)**. Minimum line of interception is the point of critical penetration. The minimum line of interception is that point of critical penetration at which enemy forces must be intercepted and is determined by two factors, which are:

a. The anti-aircraft (AA) defended area around the vulnerable area.

b. The combat time required to destroy the enemy. Combat time is the calculated time required for interceptors to successfully attack and destroy the enemy. It is converted into distance, based on the speed of the hostile aircraft. This distance, added to the radius of the AA defended area, determines the MLI.

As an example, if the AA defended area is 20 nautical miles in radius, and the combat radius converted is 24 nautical miles based on a combat time of 4 minutes and a speed of three hundred and sixty knots, or six nautical miles per minute for the hostile aircraft, the MLI, is 44 NM from the target. To take advantage of the MLI interceptor must be in position to fire at the hostile bomber 44 NM from the target, to assume the necessary time-space factor for destruction of the bomber before it reaches the AA defended area (GDA).

6. **<u>Control Radar Coverage (CRC = MLI + Manoeuvre Time)</u>**. Control Radar Coverage (CRC) requirement line establishes radius of internal control. The CRC requirement line establishes the radius of internal control radar. CRC range is depended on range, azimuth, and altitude data provided by search and height finding radar. It consists of the radius of the MLI, plus manoeuvre time (the time needed to position your interceptors for attack), which is converted to distance based on speed of the hostile aircraft. Manoeuvre time, like combat time is a figure determined by higher formation after careful study, and practice. If the manoeuvre time is 5 minutes, and the speed of the hostile bomber is 6 NM/minutes, the internal control radar must have a range of 74 NM (44 NM radius of MLI, plus 5 minutes multiplied by 6 NM = 30 NM). In this example, interceptor positioning on the hostile target must begin when the enemy aircraft is 74 NM from the target to allow the interceptor to begin firing by the time the enemy reaches the MLI.

7. **<u>Minimum Line of Detection (MLD)</u>** Minimum line of detection determines early warning coverage. The MLD or early warning radar coverage requirement line is determined by the distance flown by the hostile aircraft during:

a. The radar lag time required for sighting and identifying the plot of the hostile aircraft. A scope operator notes the hostile aircraft on his scope, and after observing it for perhaps $^{1}/_{2}$ a minute to be sure it is a moving object, calls it to the plotter. He further checks to determine its direction and speed, and reports the additional data to the plotter. Now the SOC movement identification has one minute to identify the plot. This radar lag time is usually from two to three minutes. The enemy of course, is still flying to the target.

b. The scramble time required for all interceptors to become airborne after the scramble order is given. This time depends on the alert status of the aircraft at the time the scramble order is given. The time required for an aircraft to become airborne on standby or readiness depends on the physical layout of the field. If the order can be relayed to the pilot quickly and the pilot does not have to taxi his aircraft too far to the runway, he can become airborne quite quickly. If a pilot cannot be airborne from a readiness status within five minutes of or standby status within two minutes, then there is something wrong with the system or physical layout.

c. The interceptor’s level flight time to the MLI which will depend on the type of aircraft. This should be figured for slowest interceptor in use.

These three perimeter lines, which must be understood to comprehend the radar deployment, are a pre-requisite knowledge requirement to actual area choice. Conception of these parameters in an ideal situation should be some thing like these as shown in Fig 7.2.

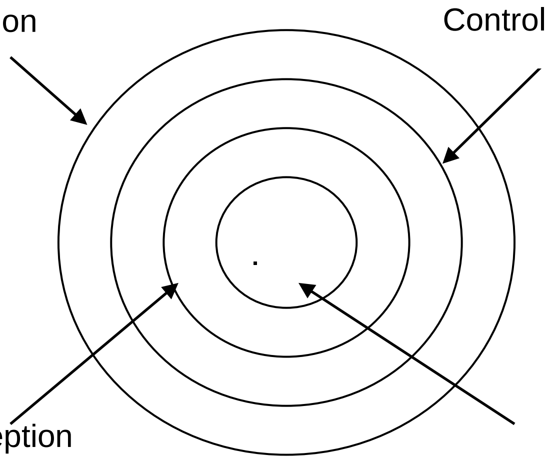


Fig 7.2: Ideal Air Defence Perimeters

8. If the example of calculation of Critical Ranges when target is adjacent to Airfield and when target is not adjacent to Airfield are given it will be easier for the student to understand.

<u>Calculation of Critical Ranges when target is adjacent to Airfield</u>

9. Matters would be somewhat easier if ideal conditions like this could count on, but distorting factors enter in. Let us look at an example intercept from the moment of detection and then go over some of the distortions which will affect the intercept pattern. Figure 7.2 explains the same assuming that the following conditions exist:

a.	A.A. defended area	10 NM.
b.	Combat time (based on bomber's speed).	4 min, or 24 NM.
c.	Manoeuvre time (based on bomber's speed).	5 min, or 30 NM
d.	Enemy bomber altitude	30,000 ft.
e.	Enemy bomber airspeed	360 knots (6NM/min).
f.	Radar lag	2 minutes.
g.	Scramble time	2 minutes.
h.	Interceptor's rate of climb	20,000 ft per minutes.
j.	Interceptor's speed during climb	300 knots (5 NM/min).
k.	Interceptor's level-flight speed	420 knots (7 NM/min).

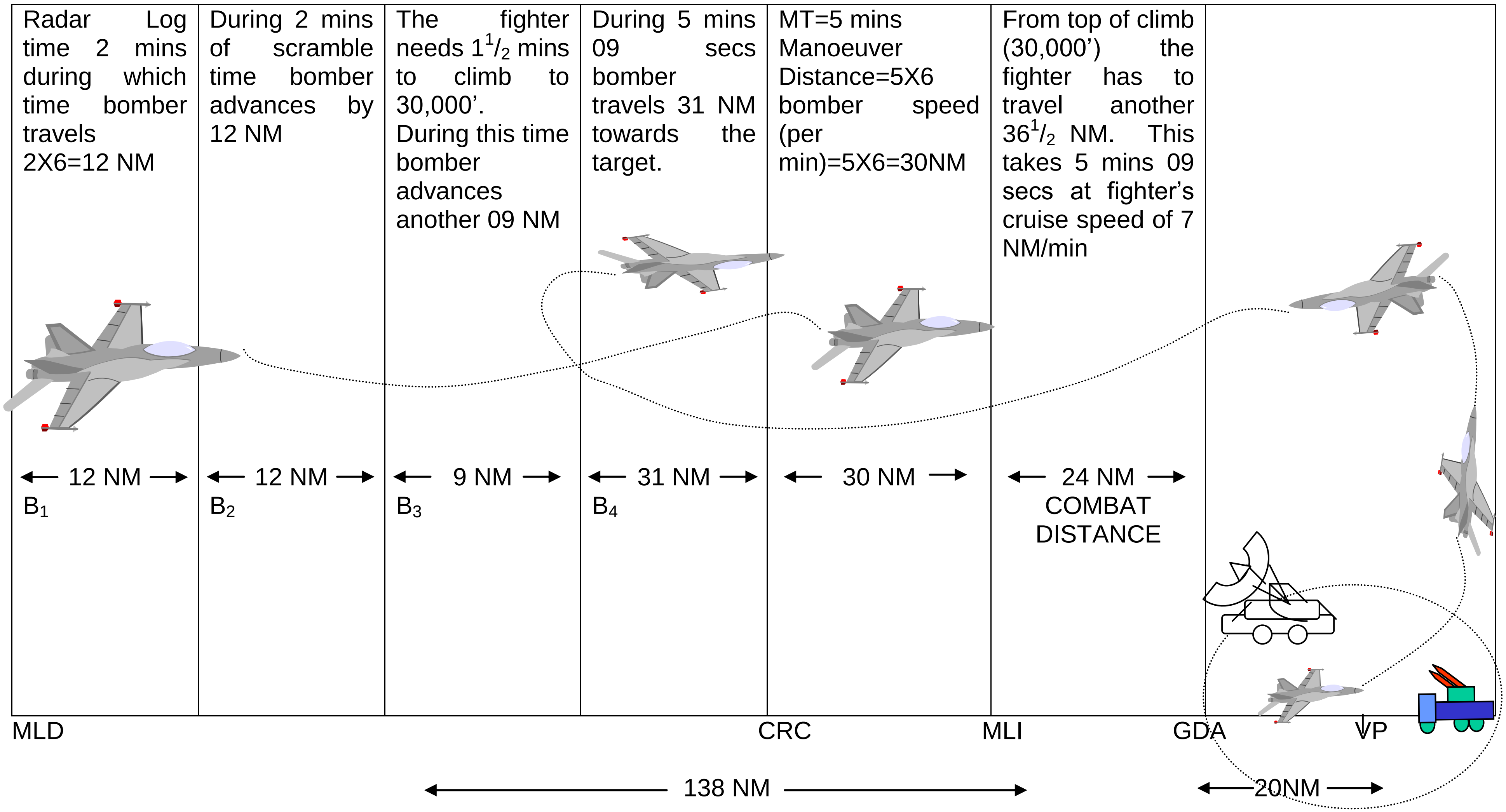


Fig-24.2: Fig Showing Typical ADGE

10. For the purpose of this example we will assume that the SOC, and the airfield from which our interceptors will operate, are at or near the target, and that there is no prevailing wind.

11. A scope operator in an early warning station notes an object on his scope at the minimum line of detection (MLD) at B_1. Two minutes later it is displayed and identified in the SOC as an enemy air formation. During those two minutes of radar lag, the hostile bomber has flown 12 NM. It's position is now at B_2. At this time fighter is still on ground at ORP indicated by F_2.

12. Interceptors are scrambled, and it is 2 minutes before the wheels of the last aircraft leave the ground. During this scramble time the enemy bomber is another 12 NM closer, at B_3 and fighters at F_3.

13. The interceptors climb on course at 30,000 feet at a rate of 20,000 feet/min. This requires $1^1/_2$ minutes at the interceptor's climbing time, and the enemy is now another 9 NM closer to the target.

14. The interceptors travel at a ground speed of 5 NM/min. While climbing at 20,000 feet/min, ie $1^1/_2$ minutes climb to 30,000 feet the interceptors travel $7^1/_2$ NM towards the hostile bombers. The interceptors level off and attain a level flight speed of 420 knots or 7 NM/min. They must fly another $36^1/_2$ NM further to reach the MLI. At their speed it takes 5 min 09 sec to reach the MLI. During the level flight time the bombers travel to 31 NM further, or to within 30 NM of the MLI.

15. The total lapsed time between initial detection and the interceptions arrival at the MLI is 15 min 39 secs. Converted in to distance (using the bomber's speed), it is found that a minimum range of approximately 94 + the MLI ie 44 NM = 138 NM of early warning coverage is required.

16. The interceptors are at the MLI with the enemy 5 minutes flying time away. The interceptors want precise height information on the bombers at this time, so they can position for attack. The height finder must read the bombers from the CRC line. There are 5 minutes for the interceptors to make adjustments for altitude and position for attack. In these 5 minutes the enemy has reached the MLI, and the interceptor pilots are ready to fire.

17. The interceptors may need 4 minutes of combat time, if at the end of the 4 minutes they have not destroyed the bombers, the AAA can take over, for now they are at the AADA.

18. In figuring the coverage for every azimuth, various factors must be considered. With the interceptor's home base located at or near the target and with no prevailing winds, the MLI, CRC, and MLD would be perfect circles around the target. A pictorial presentation of MLD, CRC, MLI and GDA is given in Annex A for easy understanding. However, it is unlikely that a defended object is always be collocated /adjacent to interceptor base. If their home base is located some distance away the situation will be different. A detail discussion is made in subsequent paragraph in this regard. The prevailing wind too should be considered in computing the coverage, for their effect on the bombers and the interceptor's ground speed. A 50 kts wind from the north will increase the ground speed of a bomber flying south by 50 Kts. If any of the variables

enter in, it can be seen that when the MLI, CRC and MLD lines are drawn around a target, they will not be perfect circles, but irregular, egg-shaped patterns.

Calculation of Critical Ranges when target is not adjacent to Airfield

19. The problem becomes more complex as the distance between the defended objective and the airfield increases; in our second computation we picture the airfield as being about 45 nautical miles north of the city at Point X (Figure 10). Note that moving the airfield does not change the position of the bomb-release line or the minimum line of interception. These lines are related only to the objective and the minimum combat time, which have not changed. The only difference is in computing the minimum line of detection.

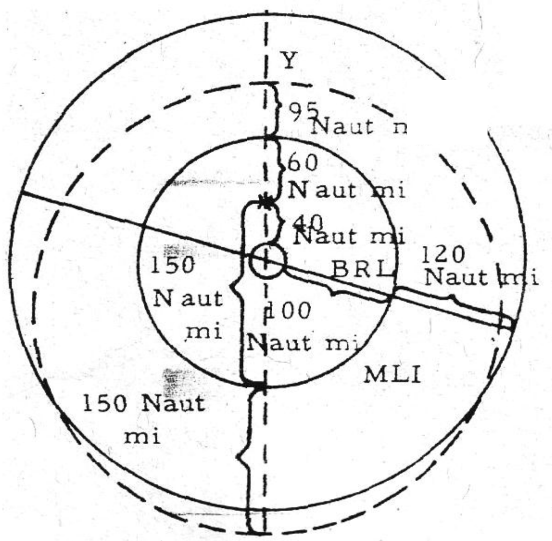


Figure 7.: Airfield Not Adjacent to Target (Single target)

20. Island defence: the minimum line of detection (MLD) when the target is the same the minimum line of interception (MLI) remains the same.

21. A broken line is drawn north and south through the new airfield location and the centre of the target area and extended both ways so that it bisects the circles. On this line the airfield is at Point X only 60 nautical miles from the nearest point on the minimum line of interception. We can now compute the early warning required in this direction in the same manner as before:

	Nautical miles	Minutes
Lag time……………………………….		10
Time to climb…………………………		03
Distance covered during climb………	15	
Remaining distance to MLI…………..	45	
Speed of interceptor per minute…….	08	
Time to MLI…………………………..		06
Total time required for early warning		19

22. To convert 19 minutes into distance, we multiply it by 5 nautical miles per minute, which is the speed of the enemy bomber. Therefore early warning is needed 95

nautical miles beyond the minimum line of interception to the north at Point Y, or 100 nautical miles north of the target centre.

23. The greatest distance to the minimum line of interception is to the south. The distance adds up as follows: 40 nautical miles to the bomb-re-lease line, 10 across the target area, 100 more to the minimum line of interception. This makes a total of 150 nautical miles from the airfield to the farther-most point on the minimum line of interception. As before, the time and distance for minimum detection are computed in this way:

	Nautical miles	Minutes
Lag time……………………………….		10
Time to climb…………………………		03
Distance covered during climb………	15	
Remaining distance to MLI…………..	135	
Speed of interceptor per minute…….	08	
Time to MLI…………………………..		17
Total time required for early warning		30

24. The 30 minutes of time is converted into 150 nautical miles, since the enemy bomber travels at a speed of 5 nautical miles per minute. Therefore, 150 nautical miles south of the minimum line of interception or 255 nautical miles south of the centre of our defended city, we mark Point Z on our broken line. Then we find the midpoint between Y and Z. With the midpoint as a centre, we swing a circle with a broken line, which in the new minimum line of detection, or MLD. Actually MLD would not be a circle, as shown. Since the lag time is constant, a series of points measured in all directions would form an ellipsis instead of a circle, but the circle is accurate enough for our illustration. It is clear that the greater the distance the airfield is from the defended target, the farther the minimum line of detection pattern shifts in the opposite direction, which means the greater is the warning coverage needed in the opposite direction.

25. **Radar Location**. A word of caution is necessary about the location of the radar. Do not assume that the above calculations show where the principal radar installation should be placed. Even if the terrain were perfectly flat, one radar placed at the exact centre of the minimum line of detection circle in the first problem would not quite meet the requirement for 225 nautical miles of early warning coverage in all directions. In the second problem more coverage is needed to the south than in any other direction. Actually the early warning coverage of our radar cannot be safely estimated at more than 200 nautical miles even though the design range is 250 nautical miles. It is necessary to make allowances for many factors that affect radar and its human operators.

26. No additional allowance of early warning coverage would need to be made for alerting anti-aircraft artillery, if it were used to provide point defence of the target. As explained in the next chapter, any early warning that is adequate for interceptors is, in most cases, adequate for anti-aircraft artillery. Therefore it is usually possible to plan the warning system on the basis of the interceptor defence alone.

27. The same radar might be estimated to have a range of about 100 nautical miles when used for control. Even under the best conditions, however, with a minimum line of interception set at 100 nautical miles, it would not be safe to assume that one radar in a direction centre could control all interceptions. Control would be limited by the number

of scopes available and the adequacy of the voice communications channels. Further, there is always the possibility that the enemy will jam the equipment or that it will go off the air when it is needed most. Additional radar is at least needed as back-up for use in an emergency.

28. Since many factors enter into the choice of radar sites, figures such as those given in the problems can only show the amount of coverage needed in all directions. The figures are then used as the basis for more detailed planning, which takes into consideration such factors as the terrain, the equipment, and the ground observer system.

29. **More Than One Target and More Than One Airfield**. To plan a defence for a complex of targets with several adjacent airfields requires a series of separate computations like those already made. Three cities---1, 2, and 3---may all be likely targets for the enemy (Fig.7.5). Two of them (1and3) have airfields adjacent to them. We are also assuming that the interceptors based at I have the primary responsibility for the defense of City 2. The minimum line of interception and the minimum line of detection for each target are computed separately. Note how the minimum line of detection for City 2 is displaced in the direction opposite to that of the airfield at 1, which defends it.

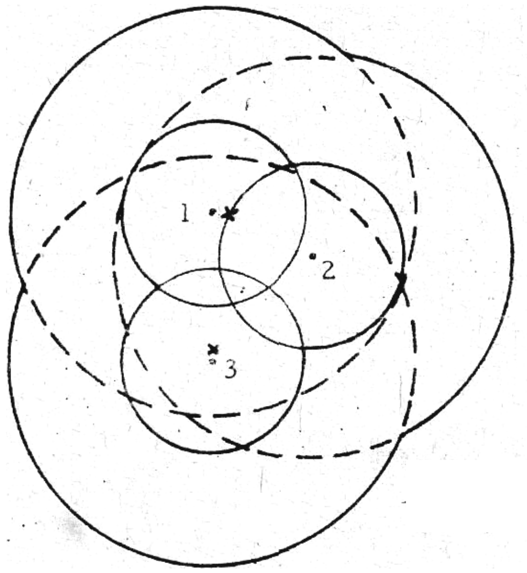


Figure 7.5 More Than One Target and More Than One Airfield

Area Defence

30. Pattern formed by the minimum line of interception (MLI) and the minimum line of detection (MLD) when the interceptors based at one target (City 1) defend both that target and another (City 2). City 3 has an interceptor base for its own defence. Interceptors from both bases would unite in the defence in an emergency.

31. By connecting the outer perimeters of the minimum line of detection circles with heavy lines, as indicated, it is possible to get a picture of the radar coverage needed for the defence of the complex. If hostile planes are detected anywhere along this greater perimeter, all interceptors: units in the defence system might act as one team. Planning would be based on the ability of at least one unit to make contact with the enemy at the minimum line of interception. Other units would reinforce the first unit a few minutes later, if necessary.

32. Need for Extended Coverage. We have designated the control and surveillance coverage as minimum. Every effort should be made to extend capabilities so that the enemy can be kept under attack for the maximum length of time and in this way the fullest possible use can be made of all interceptors within an area. Whenever forces are limited, it is especially necessary to gain time.

33. By and large, the main limitation of interceptor defence is not in the range of the aircraft themselves. Interceptors have ranges considerably greater than the radii of the minimum lines of interception shown in Figs 24.3, 24.4 and 24.5. The chief limitation is in the range of radar and the number of radar sets that can be allocated to the defence of a given subsector. Even if a subsector is located in the interior of the country and, being surrounded by defence systems of other subsectors, can get extended early warning coverage, the subsector defence must still cope with the limitations of its own height-finding and interceptor control radar. More range is needed for radar used for height finding and interceptor control so as to allow more time for combat. Radar coverage which would exploit the maximum ranges of interceptors should be the goal in planning any air defence system.

Technical Aspects

34. **Propagation under Standard Conditions**. When radar energy is propagated certain effects results from the inter action of this energy and gases, moisture and particles which comprise the atmosphere. In siting of radars, these effects can mean the difference between an effective site and a useless one. Radar stations have been and are even now being moved to other locations because propagation conditions were not properly evaluated. Refraction, the most important affect of the atmosphere on propagation, is responsible for additional effects significant to siting problems-such as the use of the '4/3 earth' for calculation of paths of rays.

35. **Index of Refraction**. Refraction is the bending of a ray as it obliquely crosses the boundary between two media possessing different speeds of propagation. For example, light bends as crosses the boundary between air and water. The amount of refraction (n) which will make take place can be predicted by use of the index of refraction, a quantity defined for a particular medium as:

$$n = \text{velocity in vacuum } (300\text{x}10^6 \text{ meter/sec}) \ / \text{ velocity in medium}$$

Notice that the smallest possible value 'n' can attain is 1. This can only happen when velocity in the medium is the same as that in a vacuum. This quantity is then applied in 'Snell's Law', the equation which relates the direction of the ray in the two media to the corresponding refractive indices. Snell's Law is as follows:

$$n_1 \cos\alpha_1 = n_2 \cos\alpha_2$$

Where, n_1= refractive index of the first medium.

n_2 =refractive index of the second medium.

α_1 =angle which the ray in leaving the first medium makes with the boundary.

α_2 =angle which the ray penetrating the second medium makes with the boundary.

Calculating the Index of Propagation

36. The value of the index for radar frequencies at any particular point in the atmosphere can be determined from measurements or calculations of pressure, temp, and water vapour pressure, by subtracting these values in the formula:

$$n = 1 + \left\{ 79/T \left[P + 4800e/T \quad 10^{-6} \right] \right.$$

Where, the temp T is measured in ^{0}K and the pressure and water vapour pressure p and e are measured in millibars.

37. As the previously pointed out, the smallest value 'n' can attain is 1. All other values must be greater, since the speed of light in vacuum is the maximum attainable. In air the index seldom reaches values higher than 1.000325. But this is an unwieldy number, and to simplify calculation it is preferable to use only the part of this number the changes: 325. We designate this part of the index with a capital 'N' and modify 'n' by subtracting the number 1 and multiplying by 10^6, as follows:

$$n = (n-1)\,10^6 = 79/T \left[P + 4800e/T \right]$$

Now, as example, let's calculate 'N' at sea level from the values given for a standard atmosphere:

$$N = 79/15^0C + 273\ (1013\text{ mb} + 4800\text{x}10\text{mb}/15^0C + 273)$$
$$= 0.274\ (1.013+167) = 323$$
$$\text{or, } n = 1.000323$$

38. In addition to this standard value for sea level index of refraction, we find that 'N' under standard conditions changes by 12 units every thousand feet. Thus at 1000 ft N=311; at 2000 ft N=299, etc.

Curvature of Rays in a Standard Atmosphere

39. If we were to assume that the index of refraction stays constant for a 1000 foot layer, then jumps to a new value (12 units less) for the next 1000 foot layer, etc. Then we could draw a picture of the atmosphere as in the figure below:

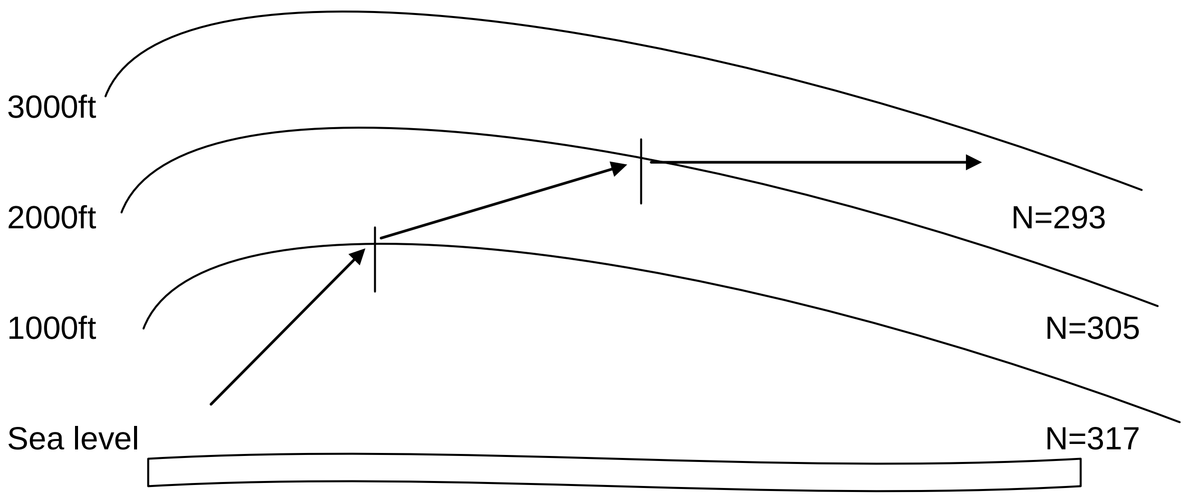


Fig 7.6 Curvature of Rays in a Standard Atmosphere

40. Notice that the radar ray is refracted it passes from one layer to another. This is because as the decrease of index of refraction indicates, propagation speed is faster in each higher layer. Actually, off course, the index does not jump from one value to another but decreases continuously. Therefore, we must modify the picture to show a constantly curving ray as in the figure below:

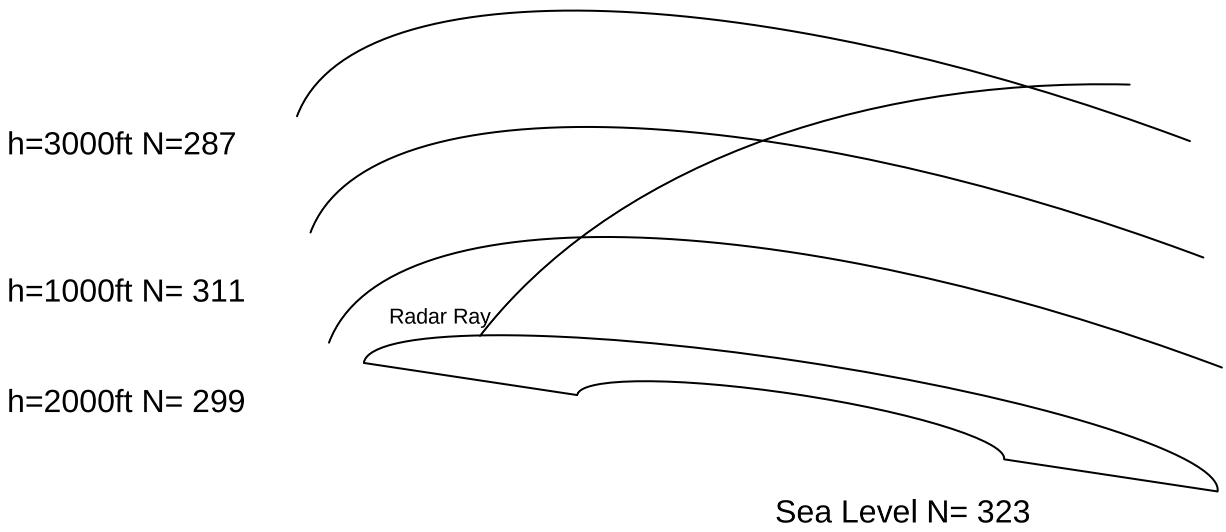


Fig 7.7: Constantly Curving Ray

41. Exactly how much does this ray curve? Is really a significant amount of curvature? Yes, the curvature is very significant. If we draw the circumference of the earth as a circle and label it's radius '3438 NM', then we can draw this radar ray in a standard atmosphere as a larger circle with radius four times the earth's radius, as below:

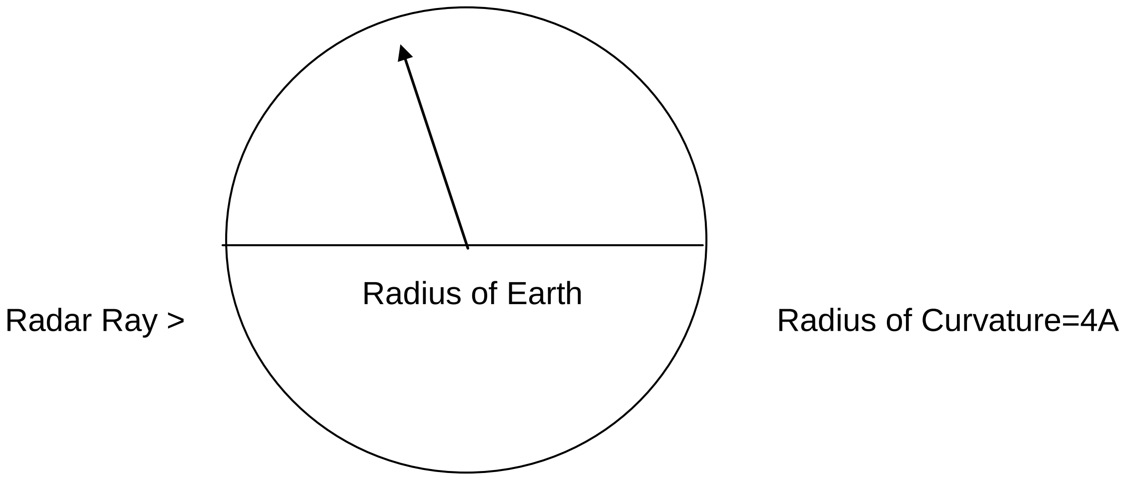


Fig 7.8: Earth Radius

42. With this much curvature we could introduce serious error into calculations of ray paths if we were to draw rays as straight lines on a normally curved representation of the earth. Fortunately, it is easy enough to get around this problem by flattering out both the earth's curvature and the radar ray until the ray is a straight line. The earth's curvature will not be as great as it was before, but it is very enough to calculate this 'new' or 'effective' earth's radius. There are two diagrams representing the conditions before and after straightening of the radar ray:

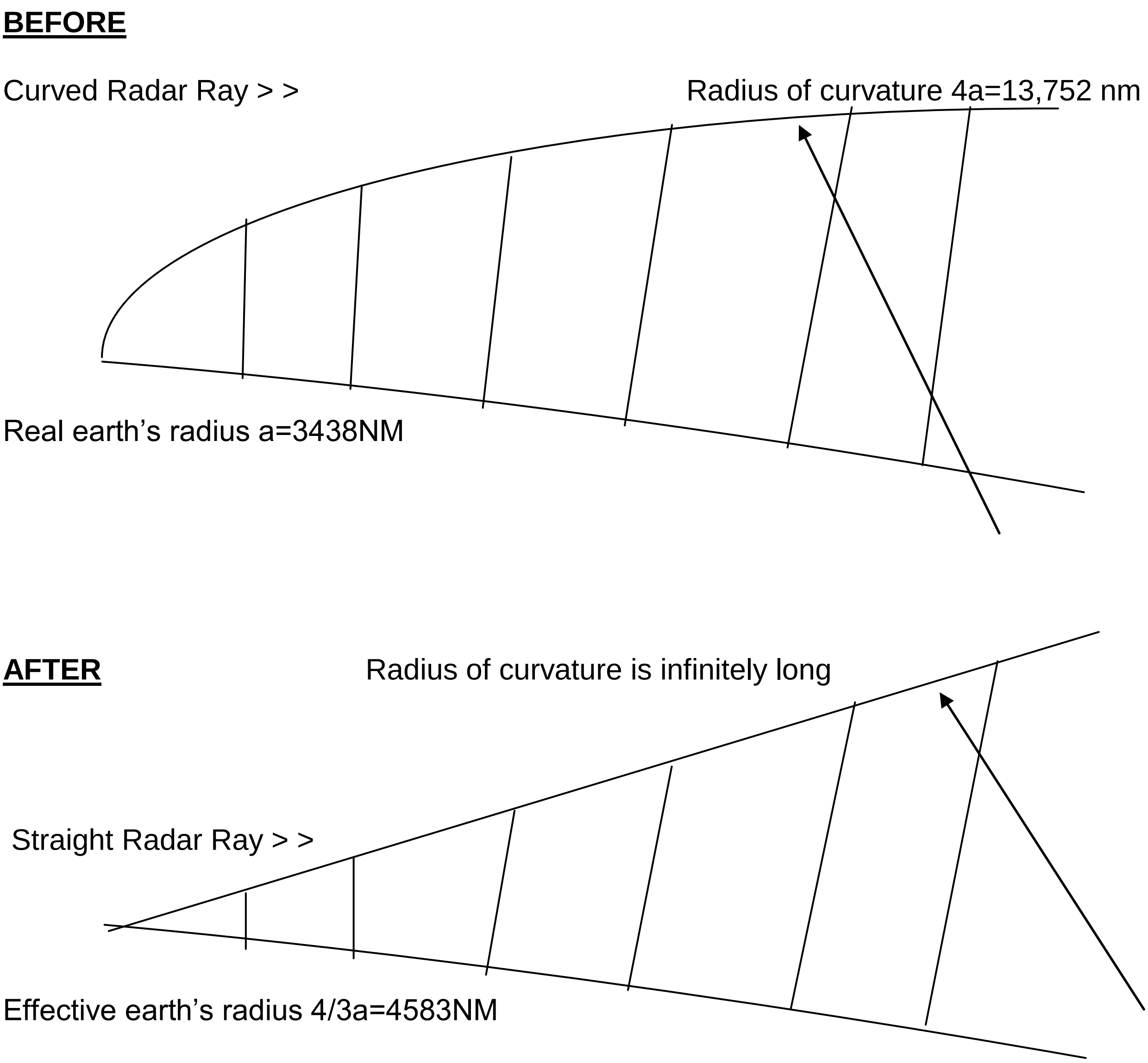


Fig 7.9: Before and After straightening of the radar ray

43. Notice that in distorting the diagram the only condition we had to meet was to keep points on the radar ray (a, b, c, d, e, f, g) at the same altitudes above the earth (A, B, C, D, E, F, G) and the same ranges from the ray source. As long as we do this our 2^{nd} diagram will give us just as accurate results in calculating the position of points on the ray as the 1^{st} diagram. The advantage of using straight rays, of course, is that they are drawn simply and accurately with a straight edge. It can be shown that for a change in index of refraction of 12 units per 1000 ft (standard atmosphere) the effective earth's radius is 4/3a. Remember that this rate of change of N is not accurate in the Polar Regions.

Radar Horizons

44. The farthest point of the earth illuminated by radar energy (under standard propagation conditions) at one azimuth. The radar horizon is the line joining all these points. The radar horizon, therefore, extends around 360^0. Below the diagram, of a radar tower ht 'h' on a smooth earth whose radius is 4/3a or 4/3 times the earth's radius, 'a'. Radar is shown coming from the top of the radar tower. This ray is tangent to the earth at point, 'T', and is the farthest point of illumination on the earth.

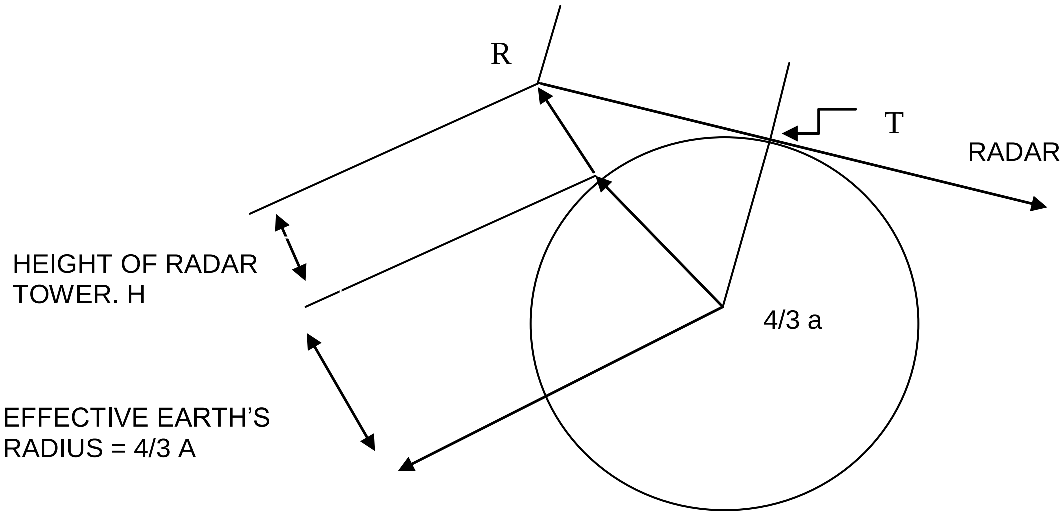


Fig 7.10: Radar Horizon

45. 'D' is the distance from the top of the tower to point 'T'. From plane geometry, we know that at point 'T' the ray is perpendicular to a radius of the earth; therefore, triangle RTO is a right triangle, with right angle T. From the Pythagorean Theorem,

$$\sqrt{OR^2} = \sqrt{RT^2} + \sqrt{TO^2}$$

$$\text{or, } (4/3a + h^2) = D^2 + (4/3a)^2$$

$$\text{or, } (4/3a)^2 + 8/3\,ah + h^2 = D^2 + (4/3a)^2$$

$$\text{or, } D^2 = 8/3ah + h^2$$

$$\text{or, } D^2 = h(8/3a + h)$$

46. We must make now a simplifying assumption. Notice that the term 8a/3 is about 9.168 NM (since a = 3438NM), while h, the height of the radar antenna, is rarely more than 100 ft, or about 0.02 NM. Obliviously,

$(8a/3 + h) = (8a/3)$ {with permissible error} therefore,

$D^2 = 8ah/3$ and

Equation (1) $D_{radar} = \sqrt{8ah/3}$

47. This formula, then, gives us the distance to the radar horizon. Calculate this distance for a tower height,

h= 100 ft. (therefore are 6080 ft in one NM)

$D = \sqrt{8/3\,(3438)\,(100/6080)}$

$= \sqrt{151}$

$= 12.3$ NM

48. At all points past 12.3 miles (the point of tangency) the ray will diverge from the earth's surface. Suppose radar rays were not refracted? What should be the horizon distance under that condition? To find this it is merely necessary to use the actual earth's radius instead of the effective earth's radius.

$$\text{Then, } (a+h)^2 = D^2 + A^2$$

$$a^2 + 2ah + h^2 = D^2 + A^2$$

$$h(2a+h) = D^2$$

But since (2a+h) is approximately equal to (2a)

$$D^2 = 2ah$$

And equation (2) $D_{Geometrical} = \sqrt{2ah}$

49. This distance is called the 'geometrical horizon'. In order to compare the radar horizon distance with the geometrical horizon distance it is merely necessary to take the ratio of one to the other:

$$D_{radar}/D_{Geometrical} = \sqrt{8ah/3} / \sqrt{2ah} = \sqrt{8ah/3 / 2ah} = \sqrt{4/3} = 1.15$$

50. This tells us that the radar horizon is always 1.15% of the geometrical horizon, in other words, 15% farther.

51. The above formulas are not useful when hills, buildings, trees, or other objects lie in the path of energy so that it cannot strike the point of tangency. We must devise other methods to find the horizon under those conditions. The same definition can be used, since we specified that a point on the horizon would be the point of 'farthest illumination'. The radar rays propagate in essentially straight lines, thus causing the mountain to cast a 'radar shadow' on the side opposite of the set. The question may rise, "how about point 'I', does not this similar hill also cast a shadow? This point is called an, 'intermediate horizon point'. The tall hill is called the 'primary screening object', while the short one is a 'secondary screening object'. Screening, then, is the blocking of radar energy. In the diagram below, area (A) is primary screening, while area (B) is secondary screening.

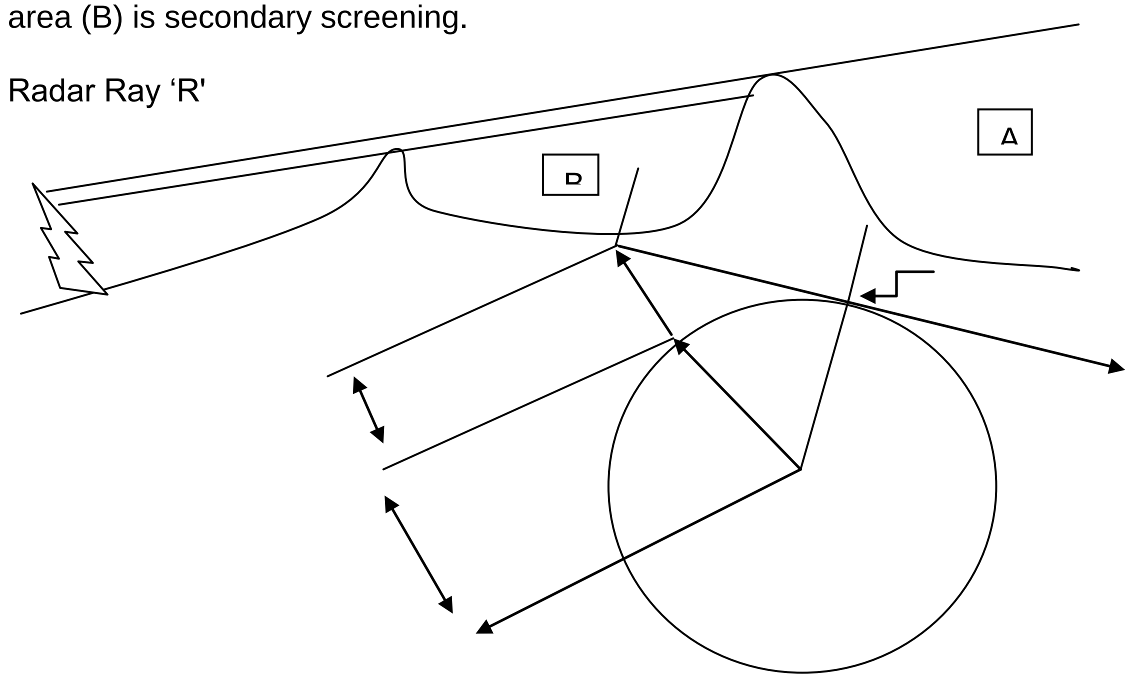


Fig 7.11: Radar ray 'R' is called the 'radar line of sight' or RLS. It is the ray which grazes the top of the primary screening object.

52. Thus we see that by intercepting the counter lines on a map we can draw a profile view of terrain at a particular azimuth (on a 4/3 earth graph) and from this profile view determine the horizon point at that azimuth. If we then plot these ranges on a polar graph which has coordinates of azimuth and range, we have a picture of the radar horizon.

53. We can't detect this aircraft until he reaches point C, the intersection of the RLS with the 5000 ft altitude contour. This point is known as the 'RLS cut off point' for that azimuth, and the range of it.

Screening

54. Within the range of a radar sot, there is an area in which a target may be present but remain undetected. This area is created by the screening effect of terrain features of the earth. When the earth is smooth, the curvature of the earth causes the area beyond the horizon to be invisible to the radar beam, as shown in figure 7.12 If there are hills or mountains in the radar path above the horizon, the screened area is increased and the radar coverage is reduced, as shown in figure 7.13.

55. The line from the radar antenna to the upper limit of the screening object, whether it is a hill or the horizon, is called the radar line-of-sight. The radar line-of-sight is considered a straight line when the radar energy travels through a standard atmosphere over a 4/3 earth's radius, as illustrated in figure 7.12 and 7.14. The radar line-of-sight establishes the maximum theoretical range at any given altitude and is used in the preparation of preliminary diagrams.

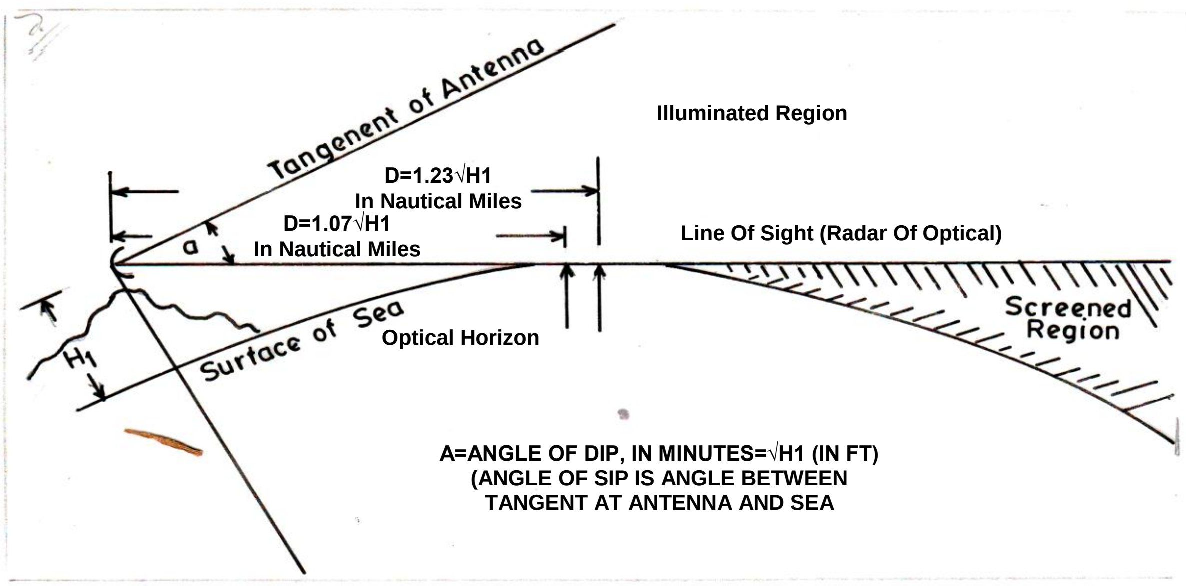


Fig 7.12: Curved Earth Screening

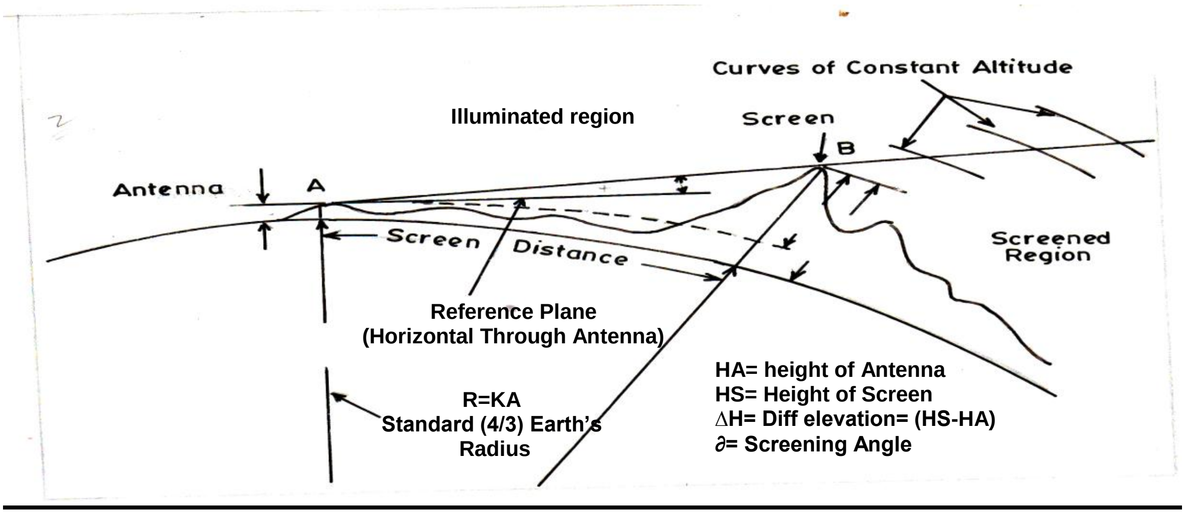


Fig 7.13: Obstacle Screening

56. **Screening Angle**. The amount of screening associated with the radar site depends upon the screening angle. Screening Angle is the angle of elevation of the radar line of sight. If the RLS lies below 0^0 then we call it a negative angle. This is the angle formed by the intersection of the radar line–of–sight and the horizontal plane at the r5adar antenna. The angle may be positive or negative depending on the elevation of the site, the effect of screening is expressed as a relationship between screening angle and radar range at a given altitude.

57. The effect of elevating the radar line-of-sight is shown graphically in figure 7.13. In figure 7.13, the antenna site is at sea level and the radar line-of- sight range for a screening angle of 0° at 10,000 feet is 123 nautical miles. If the radar line-of-sight is changed to give a screening angle of +1°, the line-of-sight limit for 10,000 feet is reduced to 67 nautical miles--a reduction in range of 56 nautical miles, or 46 percent.

58. If the maximum allowable redaction in range is now arbitrarily fixed at, for example, 15 percent at the altitude of interest (10,000 ft), the reduction in range is 18 nautical miles and the maximum range is 105 nautical miles (123 - 18). The corresponding screening angle is 0.25°, which is the maximum allowable-screening angle for the conditions stated.

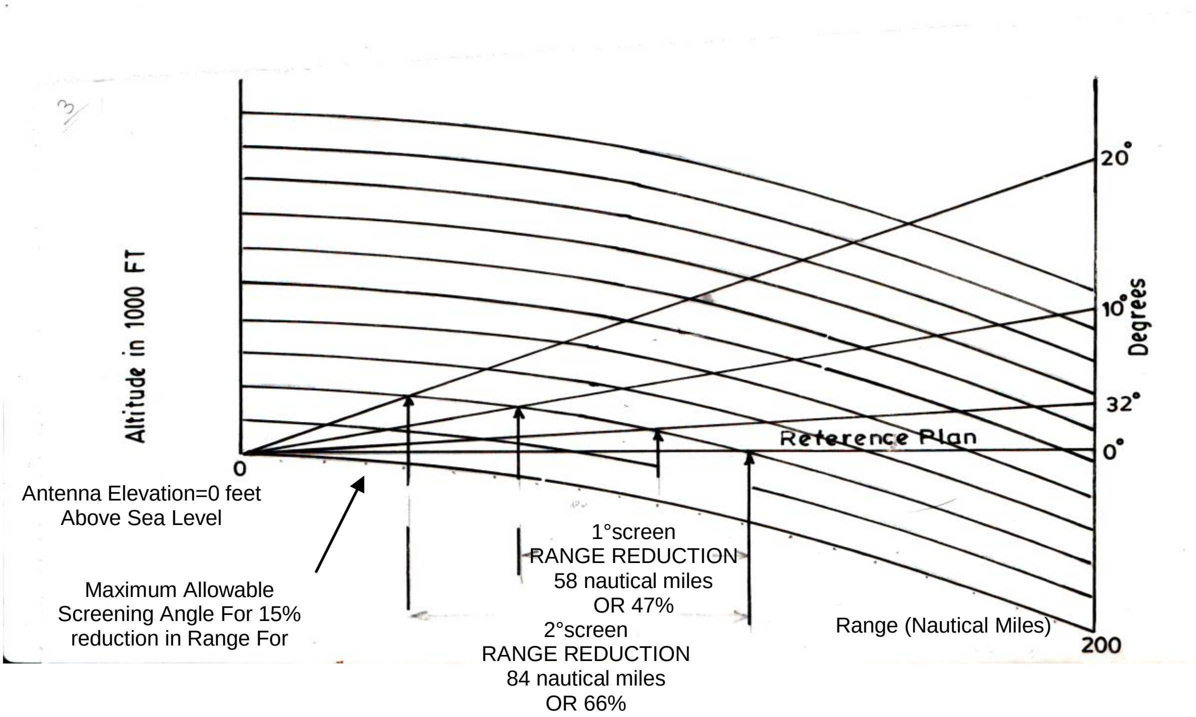


Fig 7.14: Screening Angle versus range

59. **Gaps**. The secondary screened area is usually called a 'terrain gap', and its depth is specified as being a certain number of 'feet over terrain'. Actually, we are specifying distance under the secondary line of sight.

60. **RLS cut offs (MSL contours)**. The most important problem we must face as a result of screening is due to the fact that an enemy aircraft can sneak into the radar station's range without being detected, by staying in the screened areas. We can determine the magnitude of the problem with the following analysis. Suppose an aircraft flying at 5000ft in the situation depicted below:

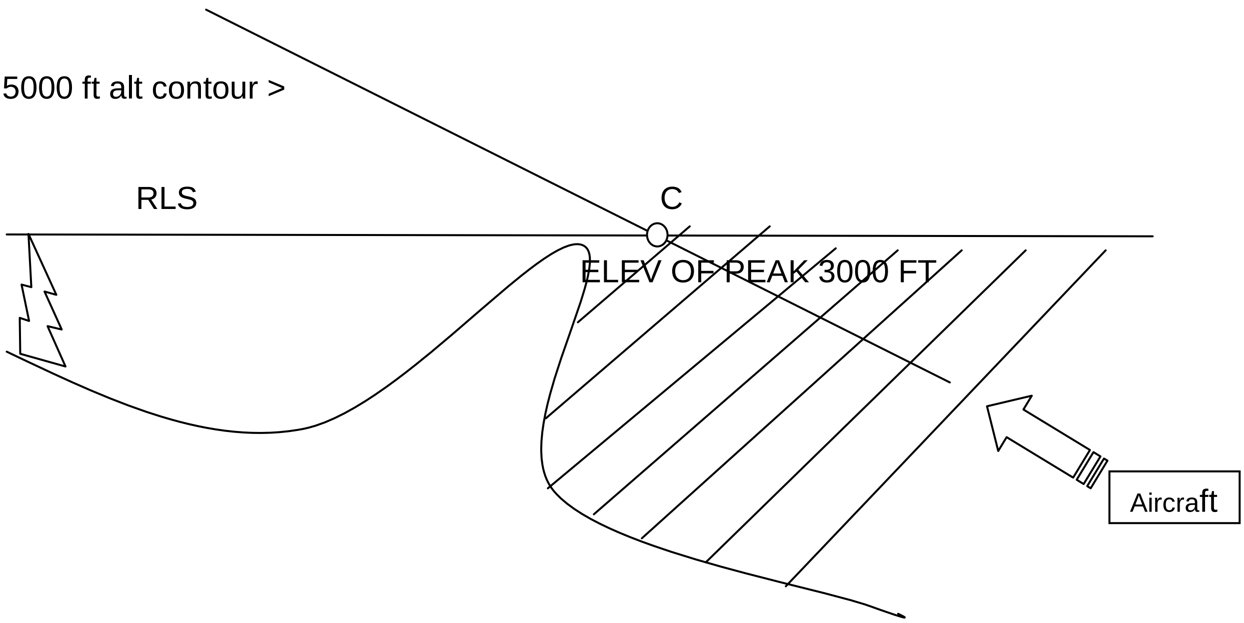
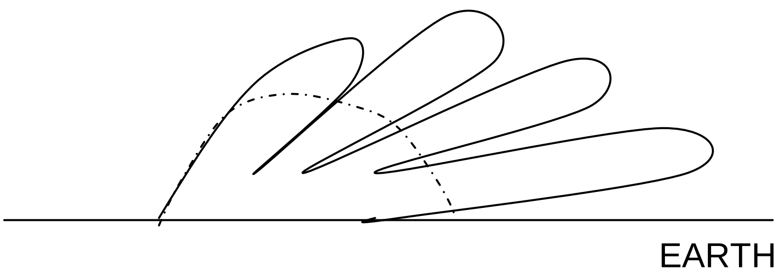


Fig 7.15: RLS Cut Offs

Ground Clutter

61. Clutter is the scope presentation of reflections from terrain features and buildings. Clutter can only extend as far as the radar horizon since objects on the ground past the horizon are screened. Thus the horizon gives us a useful indication of the probable extent of ground clutter.

62. **Ground Reflection**. Ground reflection occurs when the beam radiated from the antenna strikes the surface of the earth and bounces upward. The vertical coverage of radar can vary greatly because of ground reflections, as the reflected wave may arrive at the target in a manner that will either aid or oppose the direct wave. The reflected wave causes a decrease in the overall amount of power striking a target at certain altitudes and an increase In the amount of power striking the target at other altitudes. This effect of subtraction and addition between the reflected wave and the direct wave creates a "vertical pattern consisting of areas of minimum power, called nulls, and maximum power, called lobes, as shown in figure 7.16.



Legend

Dotted line: Free space pattern
Solid line: ground reflected pattern

Fig 7.16: Typical Vertical Radiation Pattern with Ground Reflection.

63. **Ground Reflector**. (Scattering) of the radar beam results, the radiation pattern is much less affected by ground reflection, and the factor of effective antenna height has much less significance. The radiation pattern at any azimuth position of the antenna is affected by the effective antenna height, the degree of ground reflection, the radar wave length, as well as the polarization of the radiated wave and the refractive index of the atmosphere along that azimuth.

Site Elevation

64. The effect of site elevation on the radiation pattern and coverage of the radar antenna may be, seen by comparing the diagrams in figures 7.17, 7.18, and 7.19. For ease of discussion, the range capability of a radar set is referred to as "long-Range'" and "short-range. A distinction is also made between high-sited or low-sited radar, referring to the difference of elevation between the radar antenna and the surrounding terrain.

65. A .comparison of radiation patterns between the high-sited radar, in, figure 7.17 and the low-sited radar in figure 7.18 shows that the high-sited radar has the greater low-angle coverage most useful for early warning purposes. However, the extent of clutter (signal return from near by land and sea surfaces) is increased and the high -altitude coverage is decreased.

66. The radiation patterns for both high-sited and low-sited short-range radars are illustrated in figure 7.19. The high-sited radar is designated "A"- and the low-sited radar is designated "B’’. A study of these radiation patterns shows the effects of elevation on the performance of this type of radar.

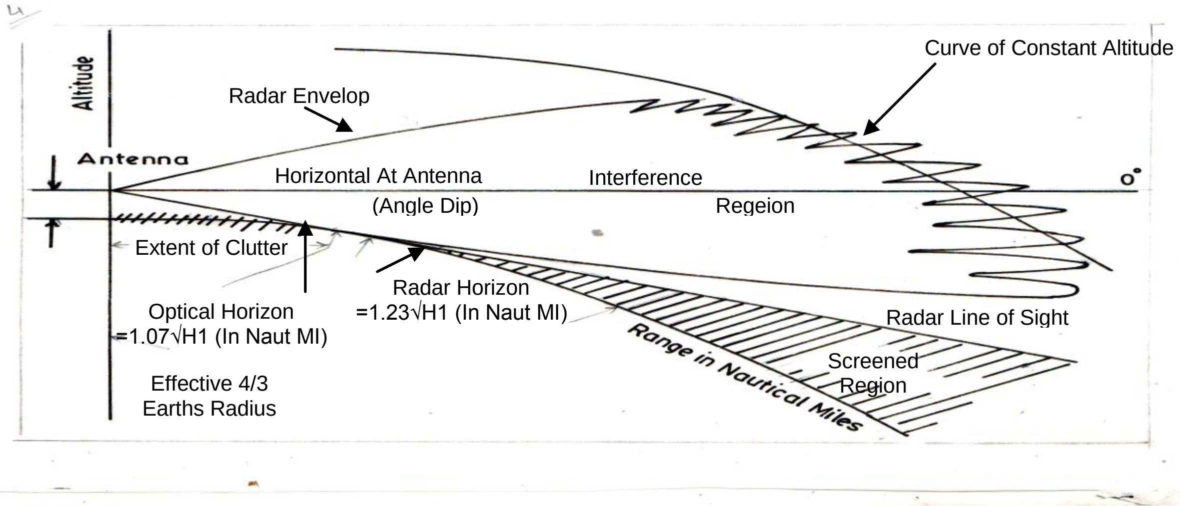


Fig 7.17: High-Sited, Long-Range Radar.

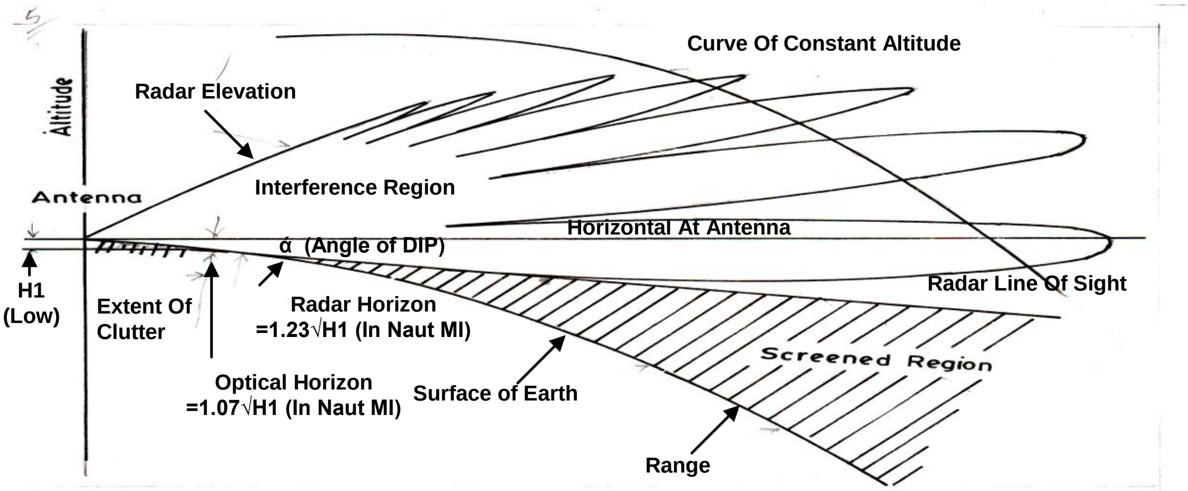


Fig 7.18: Low-Sited, Long-Range Radar.

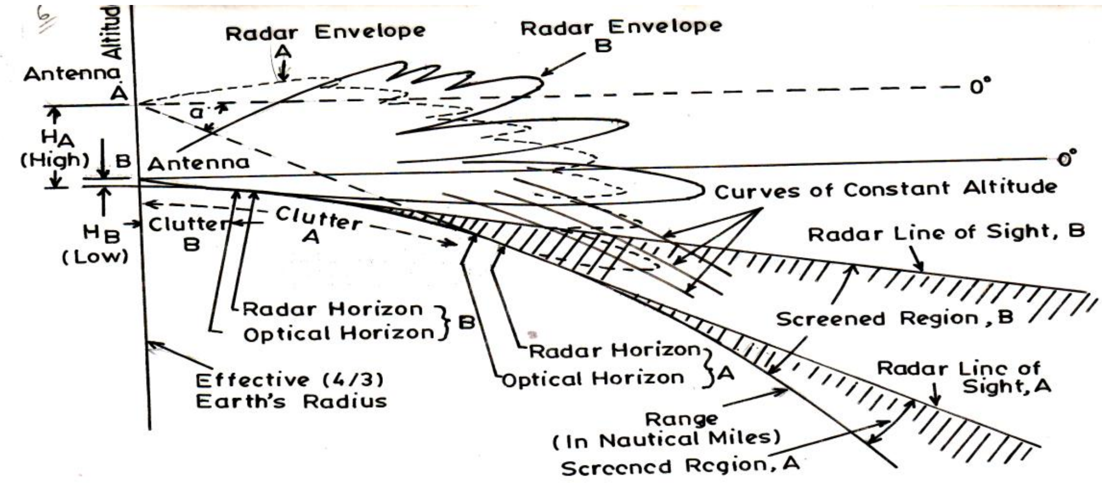


Fig 7.19: High-Sited, Low-Sited, Short-Range Radar.

67. **Effective Antenna Height**. The effective height of an antenna is a significant factor in calculating the effect of the earth on the radiation pattern. It may or may not correspond to the site elevation. The elevation of an antenna is fixed, once its location is fixed, and is given in feet above sea level. The effective height of an antenna-with, the earth regarded as a smooth reflector-is its' height above the local terrain or reflecting surface. Effective height can vary as the antenna rotates. This is especially true of a coastal eliff-sited antenna its effective height is equal to its elevation on an over-water azimuth but is much less when the antenna looks inland, as shown in figure 7.20.

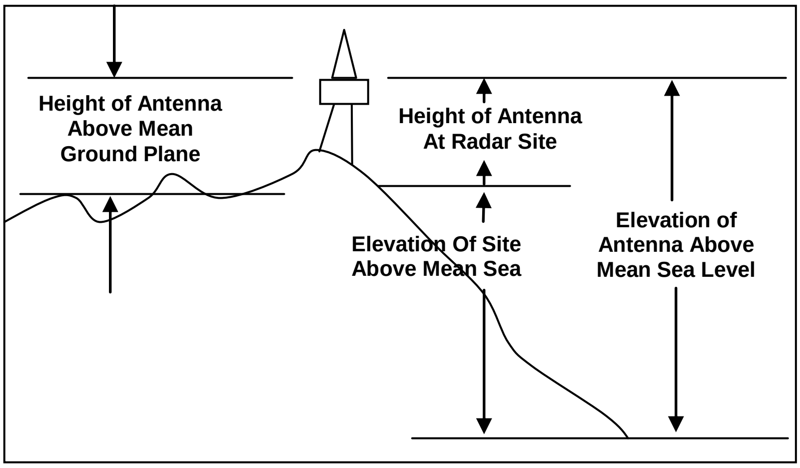


Fig 7.20: Effective Antenna Height versus Rotation

68. The factor of effective antenna height has significance only where reflection from the earth's surface materially affect the surface of the radiation pattern. Where the earth is sooth, relative to radar wavelength, ground reflections of the radar beam occur. Where the earth is rough diffuse reflection. (Scattering) of the radar beam results, the radiation pattern is much less affected by ground reflection and the factor of effective antenna height has much less significance.

69. The radiation pattern at any azimuth position of the antenna is affected by the effective antenna height, the degree of ground reflection, the radar wavelength, as well as the polarization of the radiated wave and the refractive index of the atmosphere along that azimuth.

70. **Terrain Variations**. In general, radar sights are divided into three geographic categories: coastal, flat-earth, and mountainous. Since the terrain varies considerably with locality, the discussion of each category is included as background information for guidance in specific site selection.

Coastal Sites

71. When the area of primary search overlooks the sea, the site should be located to obtain a wide, unobstructed panorama of the sea. Low angle long-range coverage is best obtained with the antenna site at the highest practical elevation.

72. Lowering the height of the antenna raises the radar line-of-sight and results in a reduction in range at lower altitudes. Therefore, if the detection of target aircraft at low angles is a criterion in meeting operational requirements, the sacrifice in low-angle coverage that results from decreasing the antenna height must be carefully considered.

73. The extent of sea clutter can be expected to diminish with decreased radar horizon distance as the elevation of the antenna is decreased. For the case of the long-range radar sited relatively low over the sea, the problem is one of intensity of clutter rather than of extent of clutter relative to the maximum range of the radar.

74. The radiation pattern for a lower antenna height, as shown in figure 14-15, is characterized by fewer lobes at higher elevation angles and greater spacing between the lobes. The consequent reduction in low-angle coverage is, in addition to that imposed by changing the radar line-of-sight. The reduction of low-angle coverage and the greater gaps in vertical coverage are perhaps the most important characteristics of the low-sited coastal radar.

75. For short-range radar, the elevation of the antenna above the sea is more critical. It will need to be, as for long-range radar, a compromise between the maximum range afforded by the radar and the extent of the sea return. Nothing is gained by locating the short-range search antenna at a high elevation if the extent of the sea return is comparable with the maximum range of the radar.

76. Radar range, as well as the extent of sea clutter, varies somewhat with the condition of the sea, that is, whether the sea is smooth or disturbed. When the sea is smooth, the clutter is reduced, and the vertical radiation pattern is characterized, in general, by a large number of closely spaced lobes in the pat tern. As an approximation, the number of lobes will be equal to the number of

half-wavelengths contained in the height of the antenna above the sea. Some ex tension of the radar range can be expected as a result of loving. This may be offset, however, by loss of tracking ability associate with the gaps of the interference pattern. Under condition, of a disturbed sea, may be expected that the clutter will increase in extend and intensity, and that the radiation pattern will tend toward, the free-space condition because of the effect of scattering. As a result, the radar coverage or tracking beyond the range of clutter may be expected, to be more "solid"; however, because of the great intensity of the sea return, cracking, within the range of clutter may be greatly diminished.

77. An estimate of the sea return can be made by assuming various antenna elevations and calculating the corresponding distances to the radar horizon. Under conditions of a disturbed sea, the sea return will tend to approach the radar horizon. Tracking at range less than the horizon distance may be largely handicapped by sea clutter.

78. If there is a choice between a site overlooking the open sea and one overlooking a large expanse of relatively protected water of comparable azimuth sweep, the latter is to be preferred. This is because of the reduced sea clutter and, to some extent, the more nearly stable effect on the radiation pattern. The guiding factors in any case should be; (1) maximum unobstructed azimuthal sweep of the antenna, and (2) sufficient antenna height for operational tie-in with adjacent installations.

Overland Sites

79. In overland azimuth sectors of search, particularly over rough terrain, ground clutter can be extensive up to the radar horizon.

80. In addition, the permanent echo returns from terrain features located beyond the radar horizon are visible on the radar indicator because of their height and large reflecting areas. The primary difference, then, between a site overlooking the sea and one overlooking land is the extent and intensity of the ground clutter. Land search imposes more severe clutter limitations on given radar.

81. Again the height of the antenna above the ground will have to be a compromise between the maximum useful ranges of radar, for given radar. Set target aircraft, and the amount of ground clutter that can reasonably be tolerated.

82. It is entirely possible, particularly in the case of short range radar, the ground clutter compare with, or even exceeds, practical maximum range of the radar. Tracking of targets in such a case may be extremely difficult, and the additional range gained by locating short range radar at a high elevation may be made useless by the increase of ground clutter.

Flat-Earth Sites

83. In situations where the terrain in the general locality of a proposed radar Site is relatively flat, particular regard should be given to the following:

a. the distant horizon should be visible from the antenna location over as great an azimuth sector as possible, particularly for the azimuth sector of interest for minimum screening.

b. the ground in the vicinity of the antenna should be flat and clear of obstructions such as trees, under growth buildings and towers, to assure a good reflecting surface for the radar beam. This also reduces the amount of ground clutter or permanent echoes resulting from these obstructions.

84. In heavily forested regions, or in the presence of natural or man-made obstructions to visibility, the radar antenna should be tower-mounted at a height sufficient to clear the obstruction's and permit visibility of the distant horizon.

85. If the range capability of a given radar set-target aircraft combination is comparable to the horizon distance, and therefore to that extent of clutter, it may be necessary to resort to some means of clutter reduction. This can usually be done only with some sacrifice of range capability.

86. Clutter may be reduced to some extent by adjusting the antenna tilt, by using moving target indicator (MTI) devices, or by incorporating an allowable amount of local screening. The first two clutter-control measures are associated with the radar' equipment. In the latter method, the screening obstacle may be a ridge, a succession of ridges, or a series of hills in the vicinity of the site. The location of the antenna with respect to the screening obstacle should be such that the clutter is reduced to allowable limits and that the elevation of the line-of-sight does not exceed operational limits. In an idealized case, the location of a radar antenna would be at the centre of a large, shallow, saucer-shaped depression. The clutter would then be limited largely to the periphery of the depression. However, such depressions are not commonly found.

Mountain Sites

87. In mountainous regions, the location of a search-radar antenna is determined, as a general rule, by the amount of screening that may be tolerated from adjacent mountain ranges or ridges, the extend and intensity of the clutter and permanent echo return, the accessibility of the site, and the -economic limitations imposed by special problems incident to the topography of a locality. With the relatively high elevation of an antenna site located on a mountaintop, the 'problem of clutter is correspondingly greater.

88. The principal factors to be considered in selecting a mountain-top location are: (1) the elevation of the tentative site in relation to that of adjacent screening terrain, (2) the distance between the site and the screening terrain, and (3) the range or performance capability of the radar compared with the extent of clutter. The first two combine to determine the angular elevation of the line-of-sight or screening angle. They should be such as to yield a maximum depression of the lint- of-sight \ the azimuth sectors of operational interest. The second, screen distance, affords or estimate of the

extent of clutter to be expected clutter generally extends to the visible sky line. The choice of a mountain- top location as a radar site thus involves a compromise between screening and clutter limitations and radar performance capability.

89. Mountain-lop sites often introduce special problems of access, installation operation, and maintenance. These concern access road construction, tramway construction, protection against wind, snow, and ice, the availability of water and local fuel, and the necessity of a split site. These are items of particular interest to the construction engineers in a siting party. They are items, too, whose costs may "rule out the use of otherwise desirable sites.

RADAR SITING

Training Objective. At the end of this chapter the students should be able to know procedures and various factors to consider while siting radar set.

Introduction

1. The phrase ‘siting of radar equipment’ means determination of the precise location of a radar station in order that it may best perform its function consistent with problems of installation and maintenance. The job of siting is assigned to a competent officer primarily concerned with the formulation of the tactical plans which will met the requirements of the immediate situation and which will work with the long range plans for a co-ordinated radar system. Radar siting is a comprehensive study of factors dealing with the selection of specific locations that will result in optimum operation of radar units, and all supporting equipment. No ground radar set operates independent of terrain conditions. The ground surface surrounding radar set, out to the horizon, must be considered to be as much a part of the transmitting and receiving equipment as the antenna itself. Siting a set, therefore, adds the last very important component to the equipment.

2. A site improperly chosen can almost completely nullify the usefulness of a radar set, and therefore, considerable time should be given to a thorough study of all proposed sites. However, it will often be found that the most desirable location, from a technical aspect, proves logistically unfeasible. Should this be the case, several alternate solutions must be developed; then from this source, the best plan can be selected. Extreme care, however, should be taken that a compromise for the sake of logistic support is not made at the expense of Radar performance, for the capability of any network is only as good as that of its individual stations.

Considerations for Radar Siting

3. **Station Spacing**

a. **Radar Network.** The basic requirements for any AC&W network generally are: (1) Early Warning time should be ample for our defence operations to go into action. (2) Tracking of enemy formations should be as continuous and positive as possible. These requirements dictate the extent of the radar network. The theatre commander must determine the percentage of detection probability that will be required. It has been found that it is impossible to detect all aircraft operating within the surveillance area of a radar station, and it is a realistic assumption that some will pass undetected to their targets. Consequently, the number and location of radar units in a defence area will determine the number and frequency with which unfriendly aircraft will pass undetected. The amount of coverage overlap between stations will directly affect the detection performance. Stations should be spaced so as to provide consistent detection probability and tracking capability throughout the network.

b. **Surveillance Stations**. Radars must be placed to cover the entire perimeter of the MLD. Radar placement will greatly depend on the number of sets available. Figure 7.21 shows how three surveillance sets have been placed to provide total coverage of a target’s MLD. Figure 7.22 shows the same sets being deployed too far away from the target with no consideration for MLD, and their effectiveness destroyed. Corridors exist through which aircraft could slip undetected. Another method of placing surveillance radar consists of deploying them in depth which is indicated in Figure 7.23. To place surveillance stations, first determine the MLD, then place the station to cover this line.

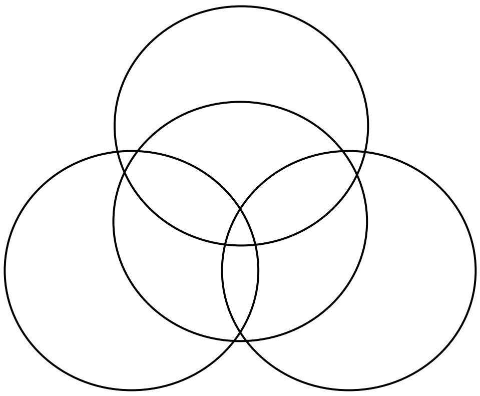


Fig 7.21

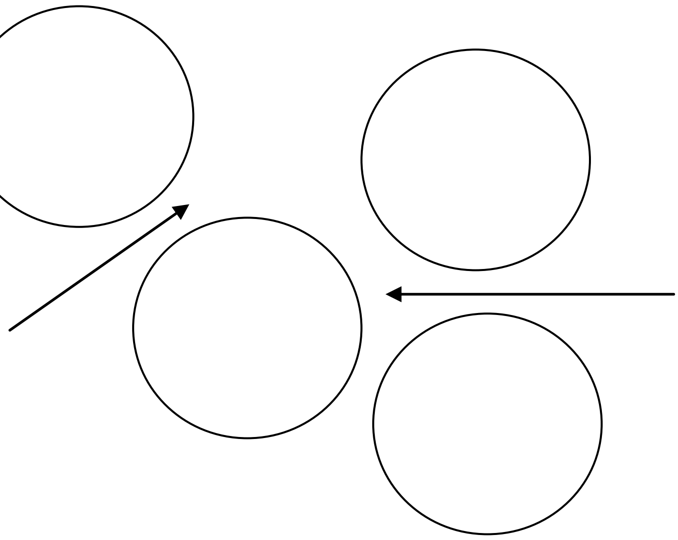


Fig 7.22

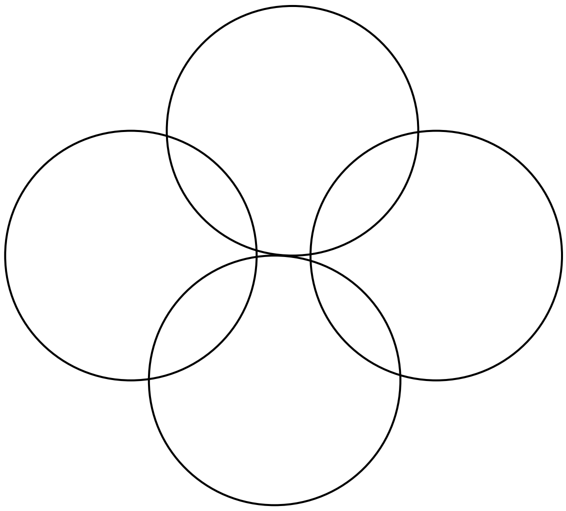


Fig 7.23

c. **Control Radar Stations**. These should cover CRC line instead of the MLD. Control radar should be carefully sited to ensure good coverage in the manoeuvre and combat areas. When radar units are deployed to cover targets and the approaches to the area, it is highly desirable that there be an overlapping of coverage between the stations, so that if one station is off the air, another can assume responsibility. The basic ideas concerning the deployment of a radar system: the computing of the minimum line of interception (MLI), control radar coverage (CRC) requirement line and the minimum line of detection (MLD). It must be realized that these lines are not always perfect circles around the target, but generally are distorted by airfield location, weather and so on. Radar deployment is a careful study of time, space and supply limitations.

4. **Tactical Requirement**. The most important tactical and technical considerations covering siting generally depend on the tactical requirement of the set. Some of the problems faced are:

a. The number and types of radar to be employed as GCIs, surveillance stations and gap filler types of radar.

b. The required performance of each radar in order that the desired system coverage be obtained.

c. The horizontal and vertical lobe coverage for each station.

d. The approximate location of each station within a determined area.

e. The pulse width of the radar so that the target resolution will be high.

f. The necessary logistical and engineering support that will be required to install and maintain the radar system.

5. **Operational Requirements**. Operational staffs are to state the operational requirements for:

a. Radar coverage requirements, area, range, high and low cover.

b. Special requirements regarding location of a station in a particular zone in order to fit into a broad plan to meet defence requirements.

c. Function of the station i.e. GCI, Early Warning etc.

d. Relative importance of various sectors around the station for early warning and fighter control.

6. **Technical Consideration**. The main points to be considered by the technical staff are:

a. Nature of ground configuration, contours, surroundings, obstructions in relation to the radar. Requirements in terms of the functions and location of the station and the equipment to be used.

b. Where several alternative sites are available, consideration should be given to the time and cost involved in the provision of the essential land line telecommunication circuits for the various sites.

c. The proximity of local power supply circuits should be considered when alternative sites are available. The performance of radar is most satisfactory when operated from a well regulated supply. Diesel sets should only be used as standby power supplies, if PDB supply is available.

7. **Logistics and Other Requirement**. Engineering support, transportation of materials and supplies, local defence and sanitation are also items of importance. Along with the technical aspects in the selection of a radar site, a good radar site fulfils the following requirements:

a. Available for immediate occupation.

b. Reasonably accessible.

c. Unobstructed in the desired radius of search.

d. Shielded or free from unwanted permanent echoes.

e. Sufficient reflection surface for vertical coverage.

f. Sited to provide for good low angle coverage.

g. Meet engineering and medical requirements for:

(1) A good Camps site.

(2) Water supply.

(3) Camouflage, etc.

Radar Siting Procedure

8. Siting operations will vary in scope and detail depending on the region of the world where these missions are undertaken; siting has been done in the arctic, the tropics, and deserts, and temperate zones. It is conceivable that additional siting will be done in the future with the increase in scope of military operations as well as with the constantly changing demands of new equipment. But the basic concepts of siting are universal and can apply to any part of the world. The procedure outlined below is generalized and should be only a guide. Local commands will no doubt have particular procedures, requirements, and channels to follow. Radar siting is usually done in a sequence of three phases which are discussed in subsequent paragraphs.

9. **Phase 1: Preliminary Office Studies**.

a. **Staff Sections Participating**.

(1) Communications and Electronics Staff section is charged with the responsibility of choosing the radar sites selected by the siting team personnel. The radar siting team is responsible directly to the Communication and Electronics Section, or sometimes the Operations Section.

(2) The Operations Staff section is initially concerned with the location of each site and the manner in which these sites will fit into the over-all system of defence. The Operations Staff section must indicate to the C&E section the over-all system coverage desired. The Operations section in conjunction with the Intelligence section should study the defence areas from a target viewpoint, estimate the enemy tactical capability and arrive at the most desirable system coverage that will be required.

(3) Air Installations is concerned in the physical construction and engineering of the site; therefore they should have a representative on the siting team to determine the feasibility of construction and installation on terrain selected by the Electronics Officers. if practicable, the Officer should submit a cost estimate.

(4) A Logistical Officer should be included in the siting studies since he is concerned with maintaining the radar station in continuous operation after initial construction.

b. **Criteria for Planning**.

(1) **Operational Coverage**. Operational coverage criterion is a responsibility of the Operations Staff section. These criteria should include the following:

(a) Selection of a number of possible sites to fulfil network coverage requirements.

(b) Selection of the sector or sectors most desirable to be covered by the site. This is important since in many situations it is impossible to obtain full 360^{o} coverage.

(c) Altitude coverage desired both low level and high level.

(2) **Cost of Installation**. The cost of installing a site should be indicated, and the importance of cost versus coverage should be considered carefully both by the siting team and staff section responsible for the Installations. Some of the considerations on cost estimates, are the following:

(a) Type of site i.e. EW, GCI or EW-GCI.

(b) The personnel strength contemplated for the site.

(c) Type of construction contemplated and period to be used i.e. 10 years or 20 years.

(d) Logistical support that will be required for operation.

(3) **Requirements for personnel and Equipment**. These requirements will depend on the extent of the mission and the region where it is taking place.

(a) **Personnel**.

i. A typical siting team may consist of the following personnel:

- ADWC Officer
- C & E Officer

- Engineering Officer
- Logistics Officer
- Draftsmen

ii. In addition to the above, the following should be available for consultation:

- Military Estate Office Representative
- Military Engineering Services Representative

(b) **Equipment**.

i. Surveying instruments, cameras, walkie-talkies, etc.

ii. The geographical location will determine the type Clothing to be used. Additional equipment, peculiar to the region, may be procured locally.

iii. Transportation to the proposed siting area is normally provided by the parent organization of the siting team.

iv. Vehicular transportation is normally available. If operations are in remote areas from military installations, a four-wheel drive vehicle should be provided (Jeep, Weasel, or Caterpillar).

v. A helicopter is invaluable for sites not readily accessible by roads. It has been found that vast areas of territory can be quickly and effectively surveyed for radar sites when the team has a helicopter available. Aircraft, such as C-47 and L-20 are most useful for reconnaissance and photo missions.

(4) **Preparations Prior to Siting**.

(a) Selection of Siting team personnel.

(b) Procurement of siting equipment.

(c) Briefing of Siting Team.

(d) Coordination between the siting team and all organizations that will be concerned with the siting mission.

(e) The field data to be obtained is normally determined by the Radar Officer. Requirements are brought out during the briefing and coordinating conferences attended by the Siting Officers.

(5) **Map Study and Aerial Reconnaissance**.

(a) Collection of maps and charts of siting area. Maps generally used are:

i. Aeronautical Charts

ii. Geodetic Survey Charts

iii. Official State Maps

iv. County Maps

v. Highway Maps

vi. Grazing Maps

vii. Aerial photos (Mosaics)

(b) After the operations section has indicated the sectors most desirable from an operational standpoint, a map study is made to determine the general characteristics of the terrain, locations of mountain ranges, highways and populated areas. A map study will generally indicate the most favourable areas for ground investigation parties. Horizontal RLS Coverage Diagrams (high altitude) and Terrain Gap (low altitude) Diagrams are prepared from the maps.

(c) Once the map study has been completed, an aerial, reconnaissance is made to obtain current information on access routes. The aerial survey may save many days and much effort by providing the ground team with information not obtainable from the maps. It may lead to elimination of a tentative site.

10. **<u>Phase 2: Field Work</u>**.

a. When the siting team has gathered all available information from the map study and aerial reconnaissance, a visit to the proposed site is made by the ground party. Having reached the site location, a general survey is made by the ground party to confirm data gained from the map study and the aerial reconnaissance. It will be a rare case where the first location visited will be the best. Normally many days are required to visit several possible sites. At each potential site, data is collected for a Skyline Chart, since it is from this chart that the Horizontal Coverage Chart is developed. Meteorological data for propagation studies is collected if needed.

b. The selection of acceptable sites is generally done by:

(1) Comparison of skyline charts and horizontal coverage charts, and propagation data.

(2) Comparison from a logistical support and engineering stand point. A site may have excellent coverage, but be impossible to construct or support.

(3) When a site selection has been finalized, the selected site should be revisited by the siting team for detailed study and additional

information, At this time a representative from the MES may be included for a study on accessibility to the site. This would include roads, air strips, docking facilities, etc.

(4) Once selection has been approved, the local telephone, power, water, housing and other agencies are visited by individuals of the team to collect specific data required.

11. **Final Office Work and Siting Report**. Upon return to base, data collected during Field Work is processed and presented on maps, photos, and diagrams. A formal report is prepared on each site visited. Final selection is made from these reports.

Preliminary Selection of Sites

12. The initial selection of a site is best made by careful study and examination of large contour maps of the region, where the radar station is required to be located for operational reasons. Several possible alternatives should be selected by reference to the maps. Due consideration must be given to:

a. The operational requirements.

b. Technical considerations in relation to the equipment available.

c. Topographical conditions.

d. Administrative problem for each site.

e. Defence problems and camouflage.

f. Performance or mobility of the station and accessibility.

g. Security and guarding of the station.

h. Telecommunication, land lines, standby radio and secure plotting system.

Technical aspect of radar siting

13. Satisfactory performance of radar equipment depends to a very great extent on the height above the ground at which the aerial is placed. Originally, it was thought that the best location for a radar station is on the highest point of land available; many stations which were so located found it almost impossible to detect targets because their indicators were cluttered with masses of permanent echoes. These PEs were so dense and existed at ranges extending out to nearly maximum range of detection, that echoes produced by aircraft were completely obscured other stations not necessarily located on high points of ground, performed unsatisfactorily, because the regions of the sky which they covered were avoided by hostile aircraft.

Provision of Maximum Low cover with Minimum P.Es.

14. The siting of inland early warning stations always present special problems. In all early warning system, the most important feature is the provision of 'Maximum Low Cover' and if this can be made available by finding a good site, then the extent of high cover and low range detection will depend on the type of equipment used. However, there is an optimum value of the low cover to be obtained from any inland station, since at the same time the station is required to present a good operational performance i.e. to have a minimum of long range ground response in order to facilitate long range raid reporting. In practice for early warning stations, the ideal is to find a site which is as high as possible, and at the same time sensibly flat in all directions over a distance of 800 yards. All around such a site it is desirable that there should be rising ground which subtends from the centre of the site a maximum angle of one degree above the horizon. The selection of inland early warning sites, substantially in conformity with these principles, will provide good low cover, maximum screening of distant ground responses and long range detection of aircraft.

Selection of Most Favourable Site

15. The foregoing considerations will determine the efficiency of the station from operational and technical stand-points. The preferred site will usually be a compromise between the operational requirements and the technical possibilities. However, the selection of the best site must be made on the spot with regards to the other points noted earlier. Having selected several sites, a small siting party should be constituted, including two technical officers, one operational officer, one administration officer and one ground defence officer. This siting party should proceed to each site to conduct preliminary investigations with a view to rule out unsatisfactory locations. The remaining sites should then be surveyed bearing in mind the requirements quoted above. In practice it is unusual to obtain the ideal conditions and one has to accept a site, which offers the best conditions when 'looking' towards the most important operational sectors.

16. Proper deployment and siting as discussed above are essential to good radar operation, but their effectiveness may diminish if the testing and calibration procedures covered in the following are not applied to each set. Often the site of a radar is relative in value and extensive testing may prove that the site has become poor and a new site is needed. This may be especially true around areas where a new construction multiplies permanent echoes until they clutter up the scope.

17. Radar factors such as radiated power and obsolete receiver sensitivity can only be accurately measured in the field by radar calibrating. The first few flights of a performance test provide the only certain method for determining weather or not the equipment is operating at optimum performance levels. The calibration is an extremely specialized test requiring close cooperation between ground and airborne sections. It should normally be performed by radar calibration flights.

Azimuth, Range and Height Accuracy Tests

18. Accurate knowledge of range, azimuth and height correctness is a prerequisite to good performance tests.

a. **Azimuth Accuracy**. Azimuth accuracy is determined by a series of tests. Orientation of the antenna by means of compass provides a reference point for the azimuth dial setting. Permanent echoes or fixed targets that may be located accurately on a reference map may be used for an orientation check. However, the best check is by means of a pre-arranged flight where the azimuth of the aircraft is known or controlled. This should be accomplished throughout the stations area of responsibility and at least at every 10^o in azimuth.

b. **Range Accuracy**. Range accuracy may be checked by using the PEs or known fixed targets and by accurately locating points on a reference map. Generally speaking, radar sets measure range more accurately than any other factor. Aircraft flights during performance tests may serve as a further check.

c. **Height Accuracy**. Height accuracy can be checked by using a single aircraft flying at different heights. Flights can be carried out at every 5000 ft. If the site is considered to be bad, flights at every 1000 ft may be tried. Should the flights at different bearings show discrepancies at a given height, the results are to be smoothed out to give the best mean heights the error is to be corrected on the scope.

Conclusion

19. It must be remembered that the existence of an AC&W system does not necessarily mean that the defence net is fool-proof or completed. Changes and modification must be constantly carried out. Characteristics of newer equipment and new methods of operation modify the extent and effectiveness of present or proposed radar networks.