ANALYSIS OF THE POSITION OF DECOY FOR THE FUNCTIONAL DECEPTION OF MISSILE RADAR

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In partial fulfillment of the requirements for the award of Degree of

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IN

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(AUTONOMOUS)

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

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CERTIFICATE

This is to certify that the project report entitled **"ANALYSIS OF THE POSITION OF DECOY FOR THE FUNCTIONAL DECEPTION OF MISSLE RADAR"** is the bonafied work done by **K.V. Midhun Chakravarthi (20711A0460), B. Chandra Kumar (20711A0415), C.Rohit Venkata Naga Eswar (20711A0426) and G. Maria Jaswanth Kumar (20711A0448)** in the partial fulfillment of the requirements for the award of Degree of **BACHELOR OF TECHNOLOGY** in **ELECTRONICS & COMMUNICATION ENGINEERING** during the academic year **2023-2024.**

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NARAYANA ENGINEERING COLLEGE::NELLORE

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Mission of the Institute:

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PEO_3	Gain reputation by functioning effectively to address social and ethical responsibilities.

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1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
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10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
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the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

    Program Specific Outcomes (PSOs):

    A graduate of the Electronics & Communication Engineering Program will be able to :

13. **PSO2: Domain Specific Knowledge:** Implement electronic systems related to Electronics Devices &Circuits, VLSI, Signal processing, Microcomputers, Embedded and Communication Systems to fulfill the solutions to real world challenges
14. **PS01: Hardware Product Development:** Apply the software and hardware tools in Analog and Digital Electronic circuit design to address complex Electronics and Communication engineering problems

ABSTRACT

In a battle engagement scenario, while missile interception and hard kill options can be exercised, soft kill options are less expensive and elegant. In this project, optimum positioning of an active decoy which is fired in the form of a cartridge from the platform of the target is reported. Various radar and jammer parameters for effective luring away of the missile are exercised. Computer simulations are carried out and it is shown that miss distances of the order of half a kilometer or more can be obtained for typical monopulse radars. Missile threats are the most dangerous ones and valuable platforms like ships and land based installation have become most vulnerable targets. To counter multiple or singular missile attacks, with radar terminal phase horming both hard kill in the form of anti missiles and soft kill in the form of decoys have been used with increasing success rate for protecting the vital installations and platforms. In this pa per, active decoy deployment for most effective luring away of missiles from the installations and platforms is analyzed and discussed. Miss distance of the missiles from the vital targets is computed with various parametric studies and is analyzed. It is shown that maxi- mum miss distance is obtained, when the active decoy is positioned around 1100 from the reference axis of the target platform. Optimum angular deployment positions for various J/S ratios have been analyzed .

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1ELECTRONIC WARFARE

Electronic Warfare (EW) is not strictly 'electronic', i.e., it is not conducted using electrons; rather it is electromagnetic, and uses the entire range of the electromagnetic spectrum, as shown in Fig.l.1. Because of this, some people also call it Electromagnetic Warfare. During World War II, Sir Winston Churchill coined the words 'wizard war' and 'battle of beams'. However, the most accepted term for this field of applied science is 'Electronic Warfare'. Electronic circuits are, of course, used in EW equipment.

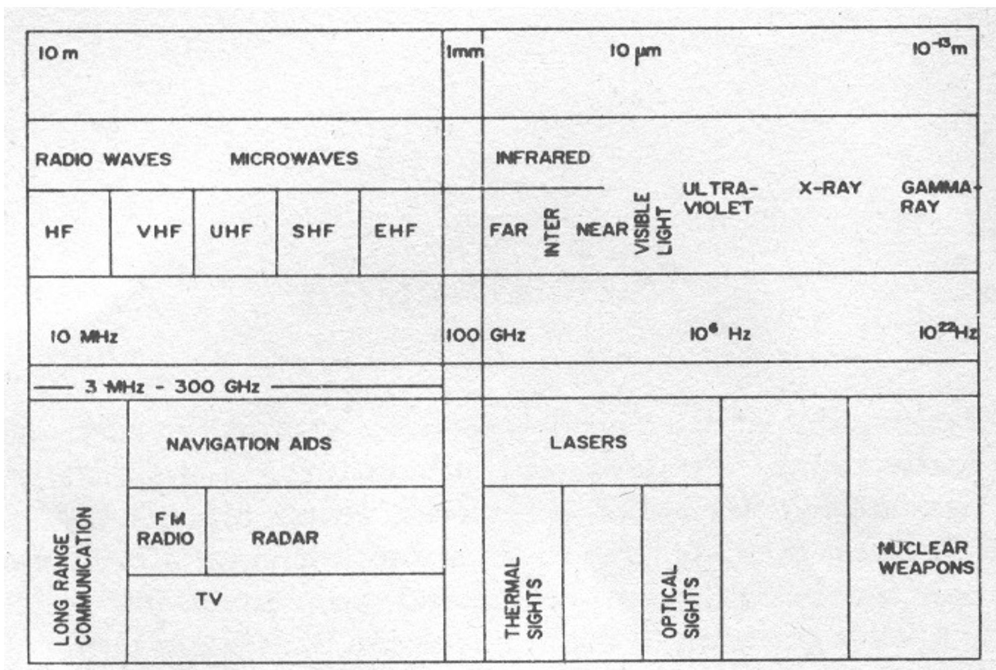

Fig 1.1 Electronic Warfare Spectrum

Warfare (EW) is a critical aspect of modern military strategy, focusing on the use and control of the electromagnetic spectrum to gain a tactical advantage. By employing various techniques to detect, disrupt, deceive, or protect against enemy electronic systems, EW plays a pivotal role in ensuring the success and security of military operations. Its importance has grown alongside the increasing reliance on technology and the electromagnetic spectrum in contemporary warfare.One of the primary functions of EW is to intercept and analyze enemy signals, providing valuable intelligence that informs military decisions and actions. This capability enhances situational awareness, allowing forces to anticipate and counter enemy movements and strategies effectively. Additionally, EW can disrupt enemy communications and radar systems, creating confusion and hindering their ability to coordinate and execute operations.

The basic concept of EW is to exploit the enemy's electromagnetic emissions in all parts of the electromagnetic spectrum in order to provide intelligence on the enemy's order of battle, intentions and capabilities and to use countermeasures to deny effective use of communications and weapons systems while protecting one's own effective use of the same spectrum

Technological advancements have significantly enhanced EW capabilities. Modern EW systems incorporate sophisticated sensors and signal processing technologies that enable real-time analysis and rapid response. The integration of artificial intelligence and machine learning further improves the efficiency of these systems, automating complex tasks and enhancing the ability to detect and counter threats swiftly. Directed energy weapons represent another technological leap, offering precise methods for disabling enemy electronics with minimal collateral damage.

Despite its advantages, EW faces several challenges, including the congestion of the electromagnetic spectrum and the need for continuous innovation to keep pace with emerging technologies. Ensuring interoperability among various military branches and allied nations is also crucial for coordinated operations. Additionally, ethical and legal considerations must be addressed, particularly regarding the use of advanced technologies like directed energy weapons and their potential impact on civilian infrastructure

1.2 EM SPECTRUM

The electromagnetic spectrum is the full range of electromagnetic radiation, organized by frequency or wavelength. The spectrum is divided into separate bands, with different names for the electromagnetic waves within each band. From low to high frequency these are: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays. The electromagnetic waves in each of these bands have different characteristics, such as how they are produced, how they interact with matter, and their practical applications.

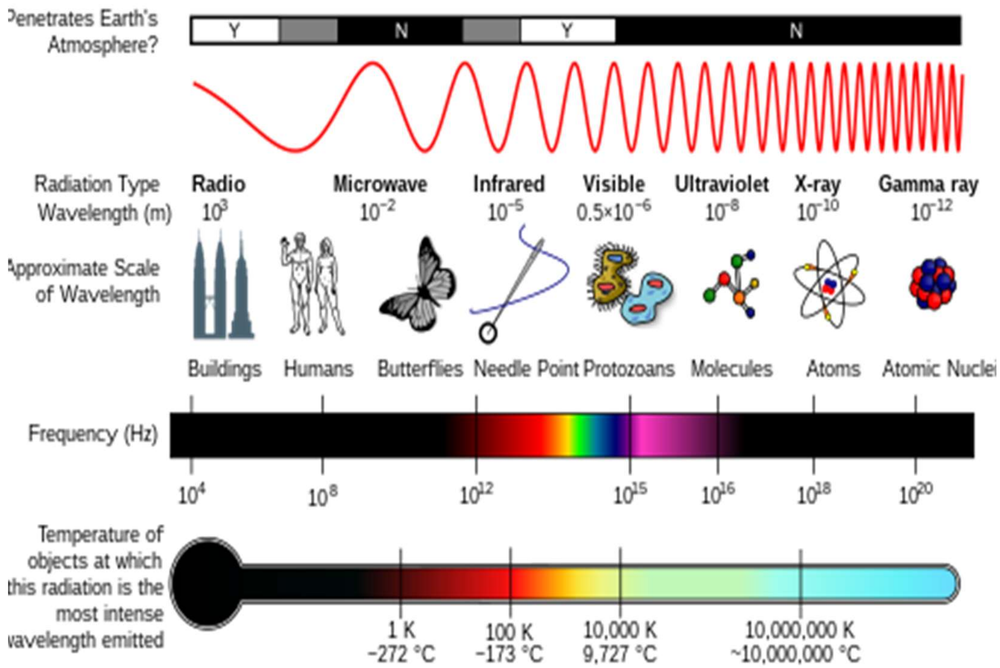

Fig 1.2 EM SPECTRUM

Radio waves, at the low-frequency end of the spectrum, have the lowest photon energy and the longest wavelengths—thousands of kilometers, or more. They can be emitted and received by antennas, and pass through the atmosphere, foliage, and most building materials.

Gamma rays, at the high-frequency end of the spectrum, have the highest photon energies and the shortest wavelengths—much smaller than an atomic nucleus. Gamma rays, X-rays, and extreme ultraviolet rays are called ionizing radiation because their high photon energy is able to ionize atoms, causing chemical reactions. Longer-wavelength radiation such as visible light is nonionizing; the photons do not have sufficient energy to ionize atoms.

Throughout most of the electromagnetic spectrum, spectroscopy can be used to separate waves of different frequencies, so that the intensity of the radiation can be measured as a function of frequency or wavelength. Spectroscopy is used to study the interactions of electromagnetic waves with matter.

1.2.1Range

Electromagnetic waves are typically described by any of the following three physical properties: the frequency f, wavelength λ, or photon energy E. Frequencies observed in astronomy range from 2.4×10^{23} Hz (1 GeV gamma rays) down to the local plasma frequency of the ionized interstellar medium (~1 kHz).Wavelength is inversely proportional to the wave frequency, so gamma rays have very short wavelengths that are fractions of the size of atoms, whereas wavelengths on the opposite end of the spectrum can be indefinitely long. Photon energy is directly proportional to the wave frequency, so gamma ray photons have the highest energy (around a billion electron volts), while radio wave photons have very low energy (around a femtoelectronvolt). These relations are illustrated by the following equations:

where

- c = 299792458 m/s is the speed of light in vacuum
- $h = 6.62607015\times10^{-34}$ J·s $= 4.13566733(10)\times10^{-15}$ eV·s is the Planck constant.

Whenever electromagnetic waves travel in a medium with matter, their wavelength is decreased. Wavelengths of electromagnetic radiation, whatever medium they are traveling through, are usually quoted in terms of the *vacuum wavelength*, although this is not always explicitly stated.

Generally, electromagnetic radiation is classified by wavelength into radio wave, microwave, infrared, visible light, ultraviolet, X-rays and gamma rays. The behavior of EM radiation depends on its wavelength. When EM radiation interacts with single atoms and molecules, its behavior also depends on the amount of energy per quantum (photon) it carries.Spectroscopy can detect a much wider region of the EM spectrum than the visible wavelength range of 400 nm to 700 nm in a vacuum. A common laboratory spectroscope can detect wavelengths from 2 nm to 2500 nm. Detailed information about the physical properties of objects, gases, or even stars can be obtained from this type of device. Spectroscopes are widely used in astrophysics. For example, many hydrogen atoms emit a radio wave photon that has a wavelength of 21.12 cm. Also, frequencies of 30 Hz and below can be produced by and are important in the study of certain stellar nebulae and frequencies as high as 2.9×10^{27} Hz have been detected from astrophysical sources

1.3RADAR FREQUENCY BANDS

Radar systems use a specific range of frequencies within the electromagnetic spectrum. This choice of frequency impacts how well the radar performs and what it's suited for. Here's a breakdown of radar frequency bands:

Table 1.1 Frequency Band Designations

#	**Band Designation**	**Frequency Range**
1	HF	3-30 MHz
2	VHF	30-300 MHz
3	UHF	300-3000 MHz
4	L	1-2 GHz
5	S	2-4 GHz
6	C	4-8 GHz
7	X	8-12 GHz
8	Ku	12-18 GHz
9	K	18-27 GHz
10	Ka	27-40 GHz
11	V	40-75 GHz
12	W	75-110 GHz
13	mm	110-300 GHz

Radar devices operate in different frequency and wave ranges, which have different physical properties and each cover specific areas of application.In the frequency range of several hundred megahertz (MHz), radar systems achieve long detection ranges and good penetration of obstacles. Radars for air surveillance and air defense, for example, operate in the VHF band (30 to 300 MHz). Modern air surveillance radars with a long detection range even operate in the frequency range of up to two gigahertz (GHz). The C-band (4 to 8 GHz) is used for weather radar and monitoring the sea surface. Radio waves in the X-band (8 to 12 GHz) offer high resolution and can penetrate thin walls. They are therefore suitable for precision applications and simple industrial applications.

As the transmission frequency increases, the detection range decreases due to attenuation in the atmosphere, while a higher range resolution becomes possible. In the K-band (18 to 27 GHz), for example, the airfield surveillance radar is operated, which can already detect the contours of aircraft and vehicles. Radars in the V-band (60 GHz) and above only achieve detection ranges of a few tens of meters, but the resolution is getting better and better. Like radars in the W-band, typical MIMO (multiple input multiple output) radars are imaging radars, i.e., 3-D radar systems with several emitting and receiving antennas. They are therefore used for more complex tasks such as environmental monitoring and object detection. Radars in the W-band (75 to 77 GHz) are frequently used in the automotive industry, for example as parking aids, brake assistants, and for automatic accident avoidance. There is also a frequency range around 80 GHz in the W-band, which is used for more complex and high-resolution tasks in level measurement in closed containers or tanks. The N-band (122 GHz), on the other hand, is preferred in measurement technology: radar modules in this frequency range can penetrate dry, non-conductive materials well and are applied, for example, as body scanners or for scanning packaged objects.

The fundamental parameter is the radar operating frequency: as seen, radars radiate electromagnetic energy which, when reflected, allows us to detect and locate targets. Radars operating at different wavelengths (or energy bands, where the association between frequency ranges and energy bands is reported) have different purposes: for instance, a C-band radar can penetrate through clouds and dust particles on the surface of the Earth, while an L-band radar can measure the GPS and soil moisture. X and Ku bands are commonly used for satellite communications. For certain applications, multiple energy bands have been explored: Toan et al. analyzed radar backscatter intensity from forest and they found the greatest intensity at P-band; the intensity would then decrease with the increase of frequency . Different tree elements (leaves, branches, stems, etc.) using different frequency bands were studied by Picard. A plant crowded with a large number of leaves and twigs can be investigated with higher frequency than what can happen for wilted plants.Radar incident angle is also a parameter which affects remote-sensing applications: it is defined as the angle between the direction of the incident radiation and the perpendicular to the target surface.Attema et al. studied the back-scattering produced by different kinds of plants in case of both dry soil and moist content. In particular, they observed plants on soil with different moisture employing radar at X and Ku bands, and, more specifically, frequencies between 8 and 18 GHz. They concluded that, in the case of a smooth surface, the backscatter was very sensitiveto a near nadir incident angle, while in the case of rough surfaces, the backscatter was almost independent of the incident angle.

1.4 BRANCHES OF ELECTRONIC WARFARE

According to this, the field of EW is most commonly sub- divided into three categories: Electronic Support This Measure,Electronic Counter Measure and Electronic Counter-CounterMeasures.This classifies the usage according to the following Figure:

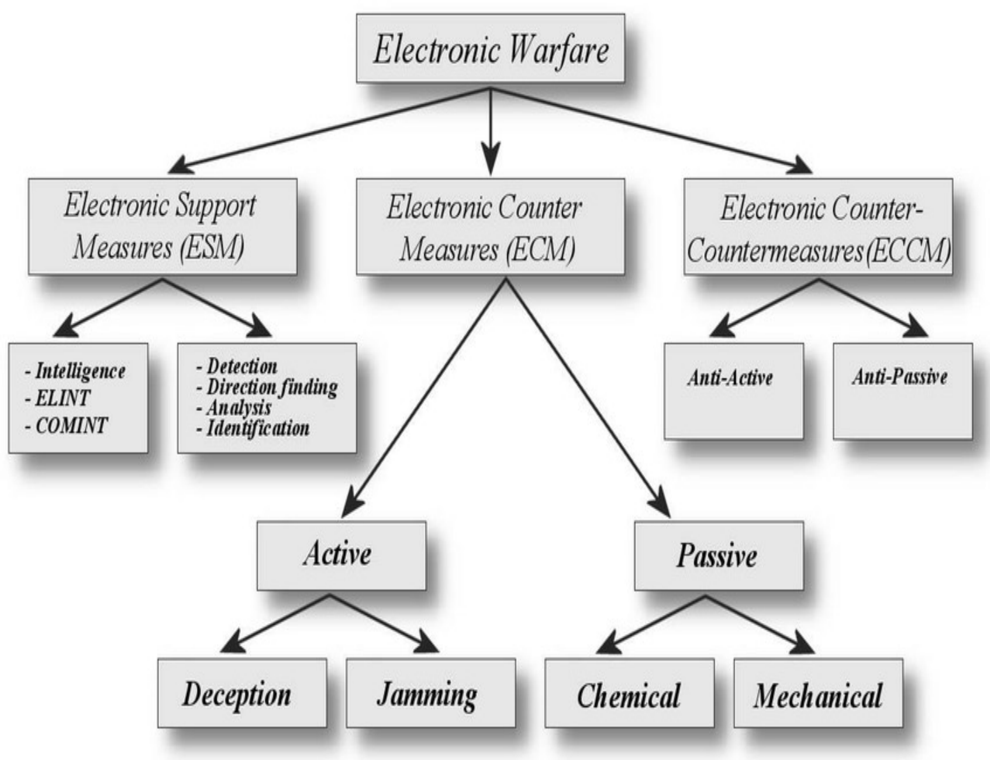

Fig 1.3 Branches of Electronic Warefare

1.4.1 Electronic Support Measures

In military telecommunications, electronic support measures (ESM) gather intelligence through passive "listening" to electromagnetic radiations of military interest. They are an aspect of electronic warfare involving actions taken under direct control of an operational commander to detect, intercept, identify, locate, record, and/or analyze sources of radiated electromagnetic energy for the purposes of immediate threat recognition (such as warning that fire control radar has locked on a combat vehicle, ship, or aircraft) or longer-term operational planning.[1] Thus, electronic support provides a source of information required for decisions involving electronic protection (EP), electronic attack (EA), avoidance, targeting, and other tactical employment of forces. Electronic support data can be used to produce signals intelligence (SIGINT), communications intelligence (COMINT) and electronics intelligence (ELINT).

Electronic support measures can provide initial detection or knowledge of foreign systems, a library of technical and operational data on foreign systems, and tactical combat information utilizing that library. ESM collection platforms can remain electronically silent and detect and analyze RADAR transmissions beyond the RADAR detection range because of the greater power of the transmitted electromagnetic pulse with respect to a reflected echo of that pulse. United States airborne ESM receivers are designated in the AN/ALR series.

Desirable characteristics for electromagnetic surveillance and collection equipment include (1) wide-spectrum or bandwidth capability because foreign frequencies are initially unknown, wide dynamic range because the signal strength is initially unknown, narrow bandpass to discriminate the signal of interest from other electromagnetic radiation on nearby frequencies, and good angle-of arrival measurement for bearings to locate the transmitter. The frequency spectrum of interest ranges from 30 MHz to 50 GHz. Multiple receivers are typically required for surveillance of the entire spectrum,but tactical receivers may be functional within a specific signal strength threshold of a smaller frequency range.

1.4.2 Electronic Counter Measures

An electronic countermeasure (ECM) is an electrical or electronic device designed to trick or deceive radar, sonar, or other detection systems, like infrared (IR) or lasers. It may be used both offensively and defensively to deny targeting information to an enemy. The system may make many separate targets appear to the enemy, or make the real target appear to disappear or move about randomly. It is used effectively to protect aircraft from guided missiles. Most air forces use ECM to protect their aircraft from attack. It has also been deployed by military ships and recently on some advanced tanks to fool laser/IR guided missiles. It is frequently coupled with stealth advances so that the ECM systems have an easier job. Offensive ECM often takes the form of jamming. Self-protecting (defensive) ECM includes using blip enhancement and jamming of missile terminal homers.

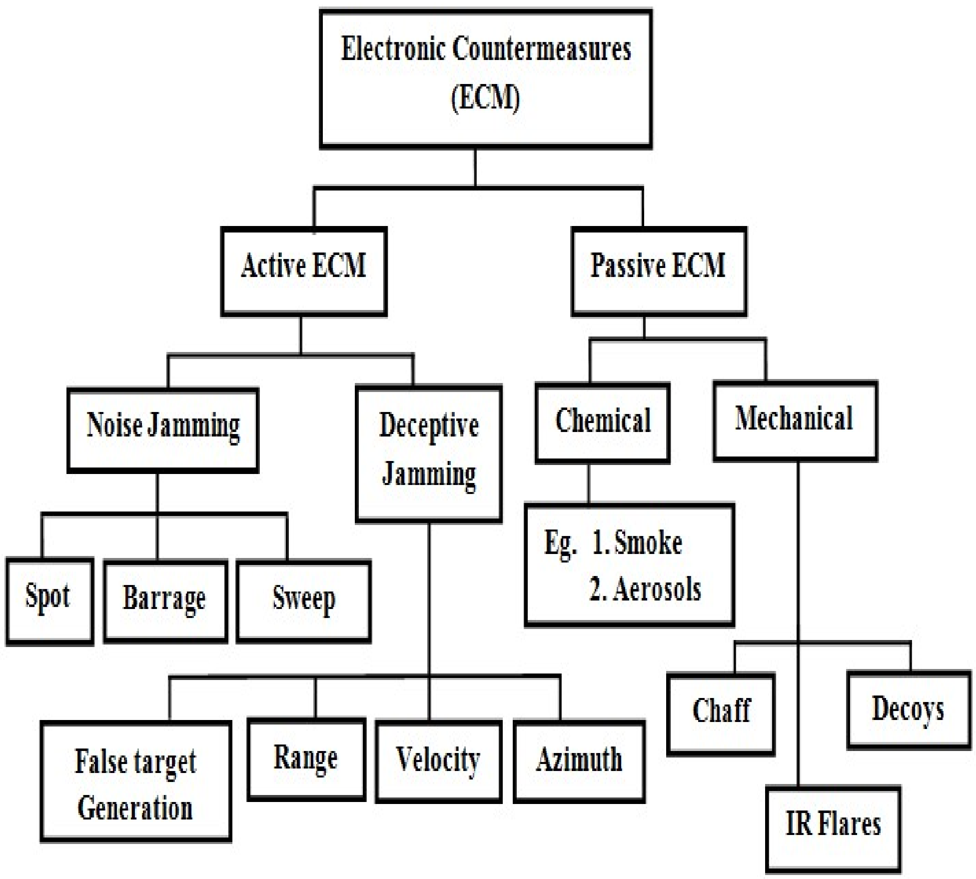

Fig 1.4 Classification of ECM

ECM is the active part of EW and is intended to disrupt the surveillance systems of the enemy, whether by radar or radio communications, and also to counter any of his weapons which use electromagnetic, infrared or laser systems for guidance or aiming. There are two main methods of achieving this: by jamming, or by the use of decoys, both of which are effective when used properly. Many modern ECM equipment, particularly in the naval scenario, employ both methods in an integrated system.Noise jamming is the use of transmissions to disrupt the enemy's communications channels or to saturate his radar to obscure its target. Although this denies the enemy his information channels it also means that the jamming source cannot read the signals for intelligence purposes. Apart from this, modern frequency-agile communication systems are no longer easy to jam effectively.Simple noise jamming is still in widespread use in the land warfare scenario, one important application being in remotely operated expendable jammers. These can be hand-emplaced, artillery-delivered, dropped from aircraft or used in unmanned aerial vehicles, and serve as short term jammers for a particular operation.The second method of ECM is the use of decoys, either chaff in the case of electromagnetic threats or flares to combat infrared devices. The use of chaff goes back over 50 years to the Second World War, and the material itself has changed very little. What has changed has been the method of dispersal and this varies according to the type of platform. For infrared countermeasures flare cartridges are ejected from the dispensers and most dispensers have a dual role of carrying both chaff and flares.

1.4.3 Electronic Counter-CounterMeasures

Electronic Counter-CounterMeasures (ECCM) is the method by which you endeavor to combat the ECM systems of the enemy by either making your equipment ECM-resistant or by using techniques to nullify his jamming and/or decoy systems. It is an extremely sensitive area in that any disclosure of ECCM measures designed into a system is likely to inform the enemy of its vulnerability to ECM.Against jamming systems, the most commonly used method is frequency agility, whereby the transmissions are made to "hop" over a large frequency band in a random fashion. This means that either the jammer has to spread its power over the entire band with the inevitable loss of strength on any particular frequency, or it must attempt to follow the signal as it hops randomly.The latest technique is the use of "stealth" techniques to combat the radar system. This is beginning to be employed in aircraft and consists of several methods to reduce the radar cross section of the aim. The main techniques employed are to design the airframe itself to avoid sharp corners and flat surfaces which act as radar reflectors, and the use of radar-absorbent material which minimizes the amount of energy reflected back to the radar.At the aircraft, the most important parts of the fuselage can be covered in radar-absorbent material to make it extremely difficult to detect.Many anti-radiation missiles have been developed. The missile is passive in operation so that it cannot be picked up by ESM systems, and normally locks on to the sidelobes of the radar transmission. The main countermeasures against this type of missile are low sidelobes, frequency agility, and the use of decoy transmitters which must be positioned close enough to the surveillance radar to “seduce” the missile but not so close as to endanger the main system.

1.5 MONOPULSE TECHNIQUES

Monopulse radar techniques are a sophisticated method used in radar systems to accurately determine the direction of a target. Unlike traditional radar systems, which may require multiple pulses and extensive signal processing to locate a target, monopulse radar can achieve this with a single pulse, enhancing accuracy and reliability. This technology is particularly valuable in both military and civilian applications, such as air traffic control, missile guidance, and surveillance systems.

1.5.1 Principles of Monopulse Techniques

Monopulse radar operates by comparing the received signals from multiple, closely spaced antennas simultaneously. The key principle involves splitting the radar beam into two or more overlapping sub-beams, typically arranged in sum and difference patterns. When a target reflects these beams back to the radar, the system measures the difference in amplitude or phase between the signals received by the different antennas. This difference provides precise information about the target's angle relative to the radar. There are primarily two types of monopulse techniques: amplitude comparison and phase comparison.

1.5.2 Amplitude Comparison Monopulse

In this method, the radar system uses two or more overlapping beams and compares the amplitude of the signals received in each beam. The difference in amplitude helps determine the angular position of the target. For instance, if a target is off-center, one beam will receive a stronger signal than the other. The radar processes these differences to accurately calculate the direction. Amplitude comparison monopulse radar is a technique used to determine the angle of a target by comparing the strength of signals received by multiple antennas. This method involves splitting a single radar pulse into two or more overlapping beams, each covering slightly different directions. Upon the return of these beams after bouncing off a target, their signal strengths are compared to ascertain the target's direction. The radar system calculates the difference in signal strength and translates it into an exact angular position. This method offers high accuracy, fast response times, and robustness against interference, making it valuable for applications such as missile guidance, air traffic control, and surveillance systems.

1.5.3 Phase Comparison Monopulse

Phase comparison monopulse radar determines the direction of a target by comparing the phase of signals received by multiple antennas. Unlike amplitude comparison, which relies on signal strength, phase comparison utilizes the phase differences resulting from the target's position relative to the radar antennas. This method involves multiple antennas positioned at specific distances apart, forming an array. As the radar pulse is transmitted and reflections from the target are received by these antennas, phase differences between the signals are measured. The radar system then calculates the angular information using known relationships between phase shifts and angles. Phase comparison monopulse offers high precision, especially at higher frequencies, and performs well in cluttered environments. It finds applications in military targeting systems, astronomy, and remote sensing for its ability to provide accurate directional information in various scenarios.

1.6 EW SYSTEMS

Electronic warfare (EW) systems are designed to detect, intercept, and counteract threats posed by electromagnetic emissions from adversaries. These systems play a crucial role in modern military operations by disrupting or denying the enemy's ability to use electronic devices, such as radar, communications systems, and guided missiles. Electronic warfare encompasses a broad range of capabilities and techniques, including electronic support, electronic attack, and electronic protection. Electronic Warfare (EW) systems are essentially military tools that utilize the electromagnetic spectrum (EMS) to control the battlefield in the electronic realm. Imagine a battlefield where radio waves, microwaves, and even lasers are used to disrupt, deceive, and exploit the enemy's electronic systems.Some of the examples of Electronic Warfare Systems are mentioning below as they work in various aspects as follows

Fig 1.5 Mobile Electronic Warfare System

The Large vehicles house extensive EW equipment, providing comprehensive electronic warfare capabilities on the ground.

EW systems come in three main flavors:

- **ESM:** These are the scouts, eavesdropping on enemy radio chatter or radar emissions to gather intelligence on their movements and equipment.

Fig 1.6 A soldier using Electronic Support Measures (ESM) equipment

- **ECM:** This is where things get aggressive. ECM actively disrupts enemy electronics with jamming signals, like a radio station turned up to drown out others, making it hard for enemies to communicate or use radar.

Fig 1.7 Jamming System using ECM

- **ECCM:** Just like every move has a counter, ECCM protects friendly forces from enemy jamming. These systems can detect and defeat jamming attempts, keeping communication lines open and radars functioning.EW systems are used for defense (protecting your own communication networks), offense (jamming enemy communications or spoofing radars), and intelligence gathering (analyzing enemy signals to understand their plans). As technology advances, so does EW, making it a constantly evolving and crucial part of the modern battlefield. In military contexts, ECCM techniques are crucial for ensuring that electronic systems remain effective in the face of attempts to jam or interfere with their operation. ECCM can include a variety of methods such as frequency hopping, spread spectrum techniques, signal modulation, adaptive filtering, and more sophisticated algorithms to detect and mitigate jamming signals. To achieve these objectives, ECCM employs a variety of techniques. Frequency hopping involves rapidly changing transmission frequencies to avoid jamming on any single frequency. Spread spectrum techniques spread the signal over a wide range of frequencies, making it harder to detect and jam. Adaptive filtering uses dynamic filters that adjust to changing conditions to isolate and remove jamming signals. Advanced signal processing algorithms can distinguish between legitimate signals and interference, ensuring that communications remain clear. Directional antennas focus the signal in specific directions to minimize the impact of jamming from other directions. Power control adjusts transmission power to ensure signals are strong enough to overcome jamming without being easily detected. Redundant systems provide multiple pathways for critical communications, ensuring continuity even if one path is compromised.

Fig 1.8 Miltary Radar Systems using ECCM

ECCM systems are the shield against the sword of ECM. They work to protect friendly forces from enemy jamming attempts.Think of ECCM as advanced filters that can separate the jamming noise from the actual signal, ensuring your own communication and radar systems function properly.

CHAPTER 2
LITERATURE REVIEW

- **Liu et al. (2012), He et al. (2022):** the trade-offs in Phasor Measurement Unit (PMU) deployment for state estimation in active distribution grids. Although this study does not directly relate to active decoy deployment, it underscores the importance of understanding the implications of deploying active elements in complex systems. Future research could explore similar trade-offs in the context of active decoy deployment and radar deception.Liu et al. highlight that deploying PMUs requires balancing cost, accuracy, and coverage. Similar considerations could apply to the deployment of active decoys, where optimizing the number and placement of decoys can maximize their effectiveness while minimizing costs and operational complexity[2]. He et al. (2022) explore the coexistence of reconfigurable intelligent surfaces (RIS) with communication radar systems. While this study does not directly focus on active decoy deployment, it provides valuable insights into the integration of intelligent surface technologies with radar systems. Future research could investigate the potential use of RIS to enhance the deployment and effectiveness of active decoys in radar deception scenarios.He et al. discuss how RIS can be used to dynamically alter the electromagnetic environment, potentially improving the ability of decoys to mimic real targets and deceive missile radar systems[5].

- **Lv et al. (2022) Salem and Stolfo (2011):** present a novel approach for radar deception jamming recognition based on a weighted ensemble convolutional neural network with transfer learning. This highlights the potential integration of machine learning and artificial intelligence techniques in developing effective active decoy deployment strategies. Future research could focus on leveraging advanced computational methods to optimize the deployment of active decoys for radar deception. Lv et al. demonstrate that machine learning techniques can significantly enhance the ability to recognize and counter radar deception jamming. This suggests that similar techniques could be applied to improve the effectiveness of decoy deployment strategies[3].Salem and Stolfo (2011) discuss decoy document deployment for effective masquerade attack detection. Although this study does not pertain to radar systems, it offers insights into the deployment of decoy elements for effective deception. Future research could draw parallels from these findings to optimize the deployment of active decoys in missile radar deception scenarios.Salem and Stolfo’s work on deploying decoys in cybersecurity provides a framework for understanding how to strategically position decoys to mislead and confuse attackers, which can be applied to radar decoy deployment[6].

- **Zhao et al. (2017)** address the discrimination between radar targets and deception jamming in distributed multiple-radar architectures. Understanding the challenges associated with distinguishing between real radar targets and decoys is crucial for effective active decoy deployment. Future research should investigate the development of advanced discrimination techniques to enhance the effectiveness of active decoys in deceiving missile radars. Zhao et al. emphasize the importance of sophisticated algorithms and signal processing techniques to differentiate between actual targets and deceptive signals. This is critical for ensuring that decoys can effectively mislead enemy radar systems without being easily identified[4].

CHAPTER 3
DECOYS

Decoy is a deceptive device used to draw an enemy away from a more important target. Active decoys are the principal method of self-defense for military aircraft and intercontinental ballistic missiles (ICBMs).

3.1 DECOY LAUNCHING SYSTEM MARKET:

The "Decoy Launching System Market" is combining an array of fixed and fast maneuvering stabilized rocket launchers, the system responds simultaneously to multiple threats from numerous directions by delivering various payloads at accurate time intervals, according to specified anti-missile doctrines and guidelines.

Fig 3.1 Decoy Launching System Market

The "Decoy Launching System Market" is carefully researched in the report while largely concentrating on top players and their business tactics, geographical expansion, market segments, competitive landscape, manufacturing, and pricing and cost structures. Each section of the research study is specially prepared to explore key aspects of the Market. For instance, The market dynamics section digs deep into the drivers, restraints, trends, and opportunities of the Market. With qualitative and quantitative analysis, we help you with thorough and comprehensive research on the

Market. We have also focused on SWOT, PESTLE, and Porter's Five Forces analyses of the Decoy Launching System Market.

Leading players of the Decoy Launching System Market are analyzed taking into account their market share, recent developments, new product launches, partnerships, mergers or acquisitions, and markets served. We also provide an exhaustive analysis of their product portfolios to explore the products and applications they concentrate on when operating in the Market. Furthermore, the report offers two separate market forecasts - one for the production side and another for the consumption side of the Market. It also provides useful recommendations for new as well as established players in the Market.

3.2 HARPOON ANTI-SHIP MISSILE:

The Harpoon (RGM-84/UGM-84/AGM-84) **i**s a U.S.-designed subsonic antiship cruise missile that has been in service since 1977. Numerous variants have been produced since its inception, including air-, ship-, and sub-launched versions. The Harpoon has also undergone multiple upgrades to improve its range and guidance. Variants of the Harpoon have been exported to 32 countries.

Fig 3.2 Harpoon Anti-Ship Missile

In 1965 the U.S. Navy began developing an antiship missile designed to target surfaced submarines. Because the missile would target "whales"—naval slang for submarines—the missile was designated the Harpoon. Following the sinking of the Israeli destroyer Eilat in 1967 by Soviet-made Styx antiship cruise missiles, the U.S. Navy recognized a widening gap in their capabilities and contracted McDonnell-Douglas to begin the Harpoon missile program.

By 1977, the Navy had deployed the Harpoon as its basic antiship missile for fleet-wide use. An air-launched variant followed soon after, first equipped on the Navy's P-3 Orion in 1979, and later on F/A-18 Hornet and B-52H Bomber, among other aircraft.

3.3 MALD DECOY:

The MALD-J decoy is the jammer variant of the basic decoy and the first ever stand-in jammer to enter production. The unmanned system can operate alone or in pairs, and moves much closer to the victim radar than conventional electronic warfare when jamming electronics. It's able to loiter in the target area, allowing plenty of time to complete the mission.

Fig 3.3 Mald Decoy

Operators send a formation of the MALD decoys into hostile airspace. The flexible, modular systems fly a preprogrammed mission that protects allied aircraft while confusing enemy integrated air defense systems. Each craft weighs less than 300 pounds and has a range of around 500 nautical miles.

3.4 Naval Decoy:

Naval Decoy IDS300 (Inflatable Decoy System) is a passive, off board, octahedral, corner reflector decoy of the Royal Navy's Type 45 destroyer and the US Navy's Arleigh Burke-class destroyer, forming part of a layered defence to counter anti-ship missiles. Unlike chaff, the decoy is persistent and will float for up to three hours in sea state.

e

Figure 3.4 Naval Decoy

The decoy is launched out of a deck-mounted tube and self-inflates on the sea surface before being released to free-float past the stern to mimic a ship's radar and radio signatures. The deployment and inflation process takes seconds and the decoy is completely independent, requiring no further input from the ship. Typical ship fitment is four launchers, fitted using eight bolts and an electrical feed. The system is most effective in littoral waters with a calm sea state.

3.5 SEA UNVEILS TRAINABLE DECOY LAUNCHER:

A Trainable Decoy Launcher system designed to protect surface platforms from missile and torpedo threats has been revealed by SEA in partnership with Chess Dynamics and MASS, its fellow Cohort subsidiaries.

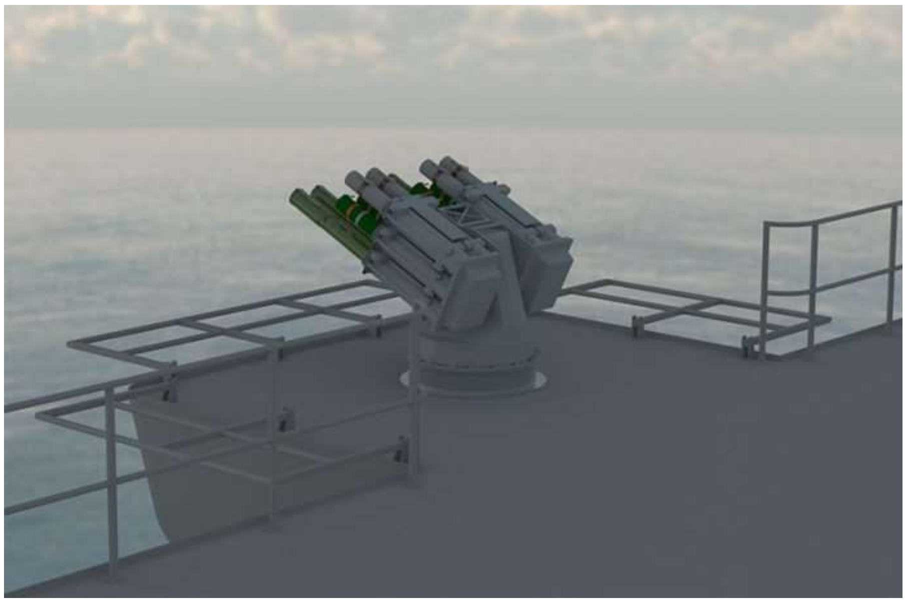

Fig 3.5 SEA unveils Trainable Decoy Launcher

The system is capable of a wide range of movement, rapidly delivering complex patterns of mixed decoys around platforms. It offers a sophisticated threat processing engine, which can recommend and enact responses to a wide range of threats much more quickly than traditional systems, minimising the need to manoeuvre the ship, improving its effectiveness. The gyro stabilised launcher has a wide range of movement, so that the system can offer countermeasure coverage to both sea skimming and ballistic trajectory threats.

CHAPTER -4

CLASSIFICATION OF MISSILES

Missiles are sophisticated, self-propelled projectiles designed to deliver a payload to a specific target. They are characterized by their ability to navigate through the air under their own power, guided by onboard systems that control their trajectory and ensure precision targeting. Unlike unguided munitions such as artillery shells or rockets, missiles incorporate advanced propulsion, guidance, and control systems to achieve high levels of accuracy and effectiveness in engaging targets.

Missiles serve a diverse range of tactical and strategic purposes across various domains of warfare. Their primary function is to project firepower over long distances with speed, precision, and lethality. Missiles are employed for offensive and defensive operations, including air defense, anti-ship warfare, ground attack, precision strikes, and strategic deterrence. They provide military forces with the capability to engage and neutralize enemy targets across different theaters of operation, enabling commanders to achieve their objectives with minimal risk to personnel and resources.

Missiles play a crucial role in modern warfare, providing military forces with the ability to project force, deter aggression, and achieve strategic objectives. They offer commanders flexible and responsive options for engaging enemy targets across a wide range of scenarios, from localized conflicts to global confrontations. The strategic importance of missiles is underscored by their role in shaping military doctrine, defense policies, and international security dynamics.

A missile is most often guided by a guidance system though there are missiles that are unguided during some phases of flight. Missile guidance refers to methods of guiding a missile to its intended target. Effective guidance is important because reaching the target position accurately and precisely is a critical factor for its effectiveness. The missile guidance system accomplishes this by four steps: tracking the target, computing the directions using tracking information, directing the computed inputs to steering control and steering the missile by directing inputs to motors or flight control surfaces. The guidance system consists of three sections: launch, mid-course and terminal with same or different systems employed across sections

4.1 TYPES OF MISSILES

Missiles can be classified into categories by various parameters such as type, launch platform and target, range, propulsion and guidance system. Missiles are generally categorized into strategic or tactical missile systems. Tactical missile systems are short-range systems used to carry out a limited strike in a smaller area and might carry conventional or nuclear warheads. Strategic missiles are long-range weapons used to target beyond the immediate vicinity and are mostly designed to carry nuclear warheads though other warheads can also be fitted.

4.1.1 Strategic

Strategic weapons are often classified into cruise and ballistic missiles. Ballistic missiles are powered by rockets during launch and follow a trajectory that arches upwards before descending to reach its intended target while cruise missiles are continuously powered by jet engines and travel at a flatter trajectory.

4.1.1.1Ballistic Missile

A ballistic missile is powered by single or multiple rockets in stages initially before following an unpowered trajectory that arches upwards before descending to reach its intended target. It can carry both nuclear and conventional warheads A ballistic missile might reach supersonic or hypersonic speed and often travel out of the earth's atmosphere before re-entry. It usually has three stages of flight:

- Boost phase: First phase at launch when one or more stages of rocket engine(s) fire propelling the missile
- Mid-course phase: Second phase when the rocket engines stop firing and the missile continues ascending upwards on the given trajectory
- Terminal phase: Final phase when the warhead(s) detach and descend towards the target

Fig 4.1 Ballistic missile

4.1.1.2Cruise Missile

A cruise missile is a guided missile that remains in the atmosphere and flies the major portion of its flight at a constant speed. It is designed to deliver a large warhead over long distances with high precision and are propelled by jet engines. A cruise missile can be launched from multiple platforms and is often self-guided. It flies at lower speeds (often subsonic or supersonic) and close to the surface of the Earth, which expends more fuel but makes it difficult to detect.

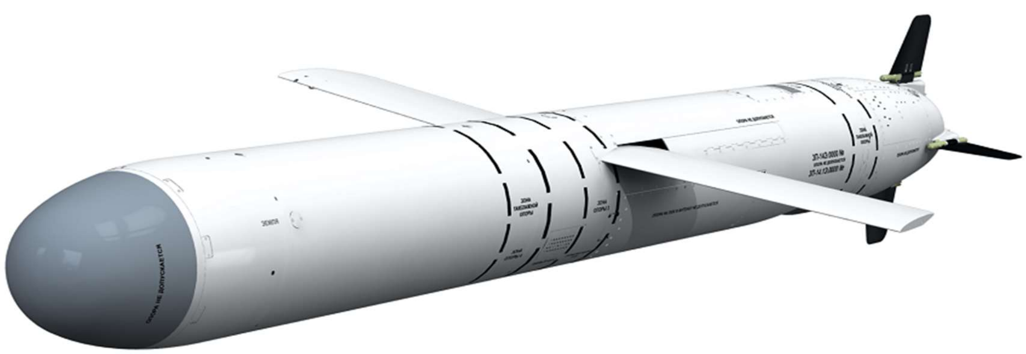

Fig 4.2 Cruise Missile

4.1.2 Tactical

Missiles might be also be classified basis launch platform and target into surface-to-air, surface-to-surface, air-to-air, air-to-surface, anti-ship and anti-t

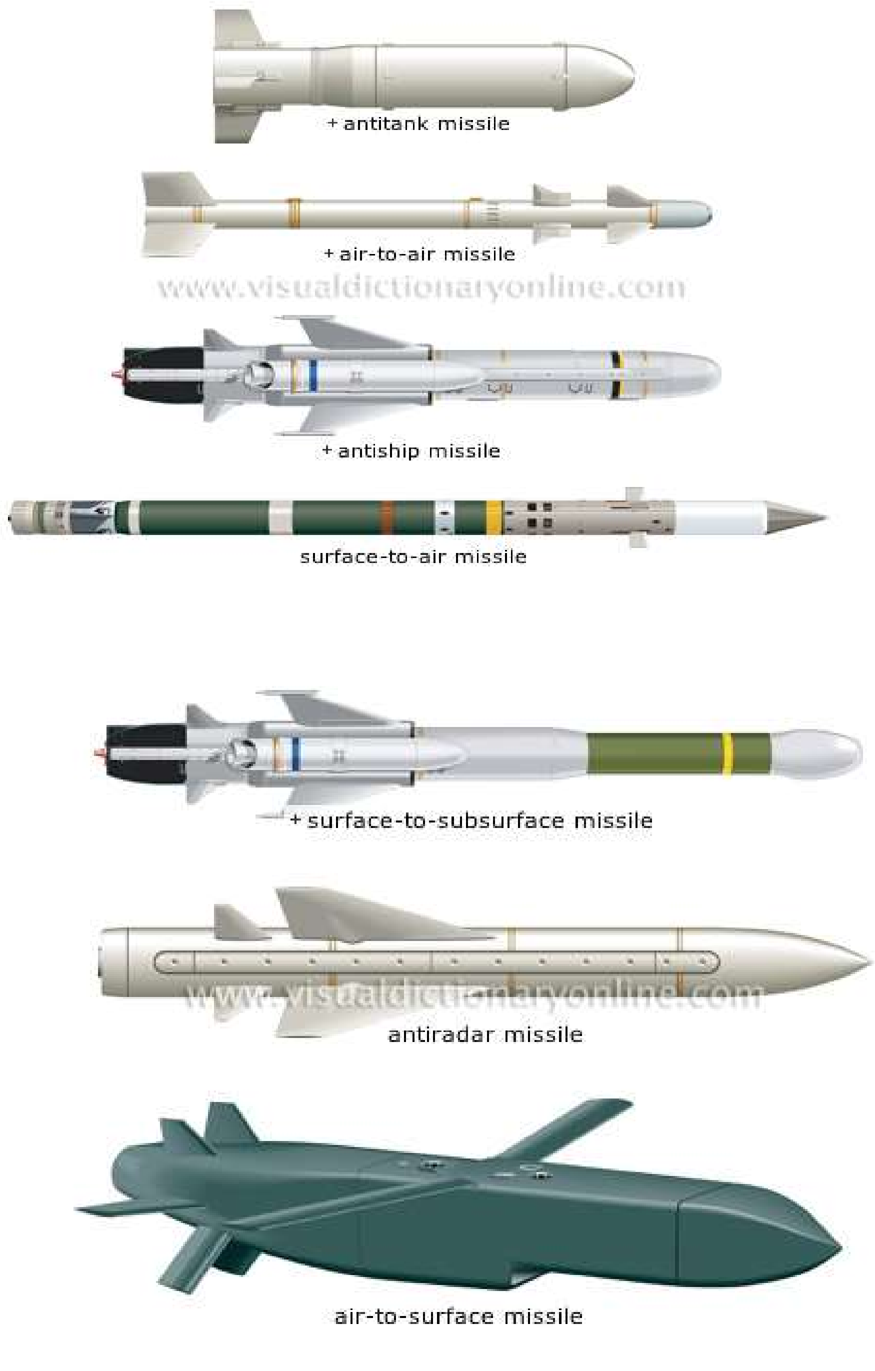

Fig 4.3 Different types of Tactical Missiles

- **Anti-tank**

An anti-tank guided missile (ATGM) is a guided missile primarily designed to hit and destroy heavily armored military vehicles. ATGMs range in size from shoulder-launched weapons, which can be transported by a single soldier, to larger tripod-mounted or vehicle and aircraft mounted missile systems. Earlier man-portable anti-tank weapons like anti-tank rifles and magnetic anti-tank mines had a short range but sophisticated antitank missiles can be directed to a longer target by several different guidance systems, including laser guiding, television camera, or wire guiding.

- **Air-to-air**

An air-to-air missile (AAM) is a missile fired from a fighter aircraft for the purpose of destroying another aircraft. AAMs are typically powered by one or more rocket motors, usually solid fueled but sometimes liquid fueled. A radar or heat emission based homing system is generally used and sometimes can use a combination. Short range missiles used to engage opposing aircraft at ranges of less than 16 km often use infrared guidance while long range missiles mostly rely upon radar guidance.

- **Anti-ship**

An anti-ship missile (AShM) is designed for use against large boats and ships such as destroyers and aircraft carriers. Most anti-ship missiles are of the sea skimming variety, and many use a combination of inertial guidance and active radar homing. A large number of other anti-ship missiles use infrared homing to follow the heat that is emitted by a ship; it is also possible for anti-ship missiles to be guided by radio command all the way. Many anti-ship missiles can be launched from a variety of weapons systems including surface warships, submarines, fighter aircraft, patrol planes, helicopters, shore batteries, land vehicles and by infantry. Anti-submarine missile is a standoff anti-submarine weapon variant of anti-ship missiles used to deliver an explosive warhead aimed directly at a submarine, a depth charge, or a homing torpedo.

- **Surface-to-air**

A surface-to-air missile (SAM) is a missile designed to be launched from the ground to destroy aircraft, other missiles or flying objects. It is a type of anti-aircraft system and missiles have replaced most other forms of anti-aircraft weapons due to the increased range and accuracy. Anti-aircraft guns are being used only for specialized close-in firing roles. Missiles can be mounted in clusters on vehicles or towed on trailers and can be hand operated by infantry. SAMs frequently use solid-propellants and may be guided by radar or infrared sensors or by a human operator using optical tracking.

- **Surface-to-surface**

A surface-to-surface missile (SSM) is a missile designed to be launched from the ground or the sea and strike targets on land. They may be fired from hand-held or vehicle mounted devices, from fixed installations or from a ship. They are often powered by a rocket engine or sometimes fired by an explosive charge, since the launching platform is typically stationary or moving slowly. They usually have fins and/or wings for lift and stability, although hyper-velocity or short-ranged missiles may use body lift or fly a ballistic trajectory. Most anti-tank and anti-ship missiles are part of surface-to-surface missile systems.

- **Anti-satellite**

An anti-satellite weapon (ASAT) is a space weapon designed to incapacitate or destroy satellites for strategic or tactical purposes. Although no ASAT system has yet been utilized in warfare, a few countries have successfully shot down their own satellites to demonstrate their ASAT capabilities in a show of force. ASATs have also been used to remove decommissioned satellites. ASAT roles include defensive measures against an adversary's space-based and nuclear weapons, a force multiplier for a nuclear first strike, a countermeasure against an adversary's anti-ballistic missile defense (ABM), an asymmetric counter to a technologically superior adversary, and a counter-value weapon.

- **Air-to-surface**

An air-to-surface missile (ASM) is a missile fired from a fighter aircraft or a attack helicopter for the purpose of destroying land based targets. Missiles are typically guided and unguided glide bombs not considered missiles. The most common propulsion systems are rocket motor for short range and jet engines for long-range but ramjets are also used. Missile guidance is typically via laser, infrared homing, optical or satellite. Air-to-surface missiles for ground attack by aircraft provide a higher standoff distance engaging targets from far away and out of range of low range air defenses.

4.2 MISSILE GUIDANCE SYSTEMS

4.2.1 Inertial Guidance

Inertial guidance systems rely on accelerometers and gyroscopes to measure a missile's acceleration and rotation, respectively. By continuously integrating these measurements, the system can determine the missile's position and velocity relative to its initial starting point.

- **Principles of Operation:**
  - Inertial guidance systems operate independently of external references, making them resistant to jamming and GPS denial.
  - However, they are subject to drift over time, requiring periodic updates from other navigation sources or ground-based stations.
- **Accuracy and Reliability:**
  - Inertial guidance systems offer high accuracy over short to medium ranges, making them suitable for applications where GPS signals may be disrupted or unavailable.
  - They are commonly used in cruise missiles, tactical ballistic missiles, and precision-guided munitions.

4.2.2 Global Positioning System (GPS)

GPS guidance systems utilize signals from a network of satellites to determine the missile's position, velocity, and time. By triangulating signals from multiple satellites, the system can calculate the missile's precise location on the Earth's surface.

- **Principles of Operation:**
  - GPS-guided missiles rely on receivers onboard the missile to acquire and track signals from GPS satellites.
  - The receivers use the timing and location information from the satellites to calculate the missile's position in real-time.
- **Accuracy and Reliability:**
  - GPS guidance systems offer high accuracy over long ranges, allowing missiles to navigate with precision to their intended targets.

- However, they are susceptible to jamming or spoofing attacks, which can degrade or disrupt the GPS signal.

4.2.3 Radar Guidance

Radar guidance systems use radar signals to detect and track targets, providing guidance commands to direct the missile towards its objective. Radar-guided missiles can operate in all weather conditions and are capable of engaging moving targets.

- **Principles of Operation:**
  - Radar-guided missiles emit radar signals towards the target and receive reflections to determine the target's position and velocity.
  - The missile's onboard computer processes the radar data to generate guidance commands, adjusting the missile's trajectory to intercept the target.
- **Applications:**
  - Radar guidance systems are commonly used in air-to-air missiles, surface-to-air missiles, and anti-ship missiles.
  - They offer robust performance against electronic countermeasures and can engage targets beyond the line of sight.

4.2.4 Infrared Guidance

Infrared guidance systems detect the heat emitted by a target, such as an aircraft engine or exhaust plume, using infrared sensors mounted on the missile. By tracking the infrared signature, the missile can home in on the target with precision.

- **Principles of Operation:**
  - Infrared-guided missiles scan the surrounding airspace for heat sources, such as enemy aircraft or missiles.
  - The missile's guidance system locks onto the infrared signature of the target and guides the missile towards it using thrust vectoring or control surfaces.
- **Applications:**
  - Infrared guidance systems are widely used in air-to-air missiles, surface-to-air missiles, and anti-tank missiles.
  - They offer high accuracy and are particularly effective against targets with high infrared signatures, such as aircraft engines or armored vehicles.

4.2.5 Monopulse Radar Guidance

Monopulse radar guidance systems compare the received signals from multiple antenna beams to determine the target's direction relative to the radar antenna. This technique offers high accuracy and resistance to jamming.

- **Principles of Operation:**
  - Monopulse radar systems simultaneously compare the amplitude or phase of signals received from multiple antenna beams within a single radar pulse.
  - By analyzing the differences between signals, the system calculates the target's angular position and provides guidance commands to direct the missile towards the target.
- **Applications:**
  - Monopulse radar guidance systems are utilized in missile defense systems, precision-guided munitions, and air-to-air missiles.
  - They offer rapid target tracking and high accuracy, making them ideal for engagements where precise target localization is critical.

CHAPTER 5

ACTIVE DECOY DEPLOYMENT

5.1 PROBLEM DEFINATION

The aim is to protect the target within the available reaction time by deploying an active decoy that is fired in the form of a cartridge from the target platform. In a combat engagement scenario, soft-kill options are less expensive and more elegant than hard-kill options. The hard-kill measures usually refer to measures considered in the so-called “final-game” shortly before a missile/warhead hits its target. Generally, the hard-kill (destructive measures) physically damages the incoming warheads through explosive action and/or fragment action. Soft-kill counter measures are divided into expendable and on-board countermeasures. While the on-board measurements are fixed on the platform to be protected, expendable measures are ejected from the platform. The problem of luring away of the missile during terminal phase is dealt in this chapter. In a typical sea skimming missile engagement scenario in the terminal phase against a ship, the reaction time available for defensive action is 90 seconds. With this reaction time, the option of soft-kill with an active cartridge fired decoy has been considered. Various parameters that influence the deployment and effective luring away of the missiles are considered. It is shown that the skip distance of about 0.5km to 1km is easily possible.

5.2 DECOY DEPLOYMENT GEOMETRY:

The monopulse system transmits a sinusoidal pulse with additive noise. This signal travels a distance Rt from the monopulse antenna and is back scattered from the target and travels a distance Rt back to the monopulse antenna. Active decoys are a military's shield against radar-guided missiles and require clever positioning to be truly effective. This positioning is all about creating a deceptive geometry that fools the incoming threat. Here's a breakdown of how geometry plays a vital role in decoy deployment.The first step involves understanding the battlefield. Imagine a game of cat and mouse,where the cat is the missile and the mouse is your target. You need to know the missile's direction and speed (think of the cat's path and how fast it's chasing). This intel, usually from radar, helps decide the ideal launch point for your decoy

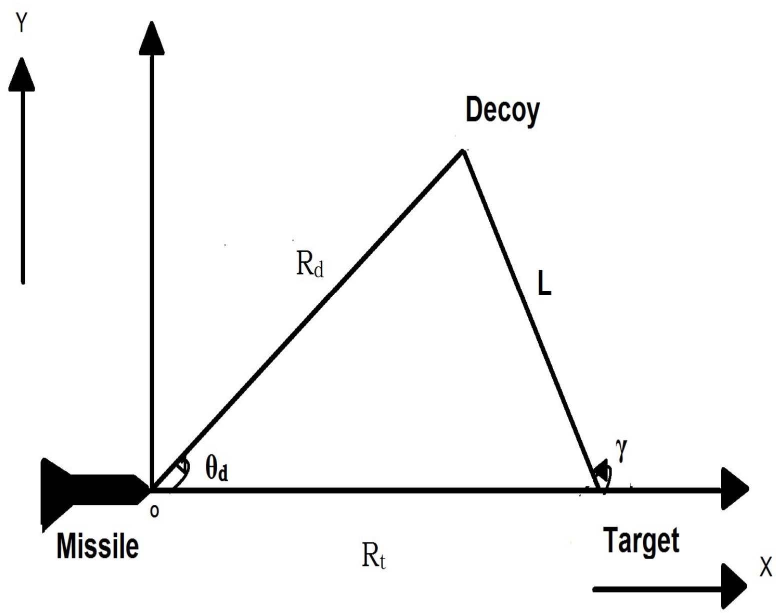

Fig 5.1: Geometry of deployment of Decoy, Ship (target) and missile

Depending on their deployment characteristics, active decoys can be categorized into fixed, towed, buoyed, parachuted, hovered decoys, and drones. In land-based anti-missile operations, active decoys are primarily used to jam anti-radiation missiles and are typically deployed around protected radar stations. To achieve a better jamming effect, active decoys and protected platforms generally form a "triangle" or "diamond" shape.

Most air platforms carry towed or launched decoys. Towed decoys have a towline between 90 m and 120 m. When the missile is traveling at 0.8 Mach, the aircraft has a survival probability of 80% after launching the decoys 2 km from the missile and then turning to maneuver. In maritime anti-missile operations, active decoys are mostly floating, hovering, and parachuting ones. The “triangle” jamming formation of the decoy, ship and missile was quantitatively described in analogy with the chaff [9]. Using "Nulka" as an example, the jamming process of OAD can be typically divided into four stages, i.e., the ship being targeted, the angle deviated, the range gate captured and the ship escaping.

The angle of the decoy is measured using the mathematical equations where it isexecuted using the Matlab Software to generate the results

Fig 5.2 "Nulka" hovering OAD

From an energy perspective, the jamming-to-signal ratio (JSR) should be above 5 dB. If the direction of arrival (DOA) is 0°, the decoy should be deployed at 70°–110° from the ship bow, and the distance should be maintained at 500 m . The forwarding delay of the jammer was further considered, and a forward-out deployment distance for the decoy was proposed. The monopulse system transmits a sinusoidal pulse with additive noise. This signal travels a distance Rtfrom the monopulse antenna and is back scattered from the target and travels a distance Rt back to the monopulse antenna. Atmospheric noise as well as amplitude and phase noise due to target motion is added to the signal as the additive noise and individual noise phenomena follow the Gaussian distribution. Due to the central limit theorem, the addition of this noise in turn follows the Gaussian distribution. Hence, it is assumed that the amplitude of the noise has a Gaussian distribution and phase of the noise has a uniform distribution. In addition, there is a sea clutter, which has not been taken into account in the present formulation. The reason for this is that sea clutter is attenuated by the way of MTI processing to a level of 50 to 60dB and therefore it is assumed that this is not the case to impact on the tracking. This assumption is valid because the monopulse system requires at least 10 to 15 pulses for processing and integration, which is essential for MTI processing.

5.3 MATHEMATICAL FORMULATION:

The voltage output of horns namely V_1 and V_2 are given by

$$V_{10t} = sqrt(S*G_0*exp(-2.776*\{(\theta_t - \theta_0)/\theta_B\}^2))+A_B \quad (5.1)$$

$$V_{lt} = V_{10t} * \sin(\omega*t + \Delta*\phi) \quad (5.2)$$

$$V_{20t} = sqrt(S*G_0*exp(-2.776* \{(\theta_t +\theta_0)/\theta_B\}^2))+A_n \quad (5.3)$$

$$V_{2t} = V_{20t} * \sin(\omega*t + \Delta*\phi) \quad (5.4)$$

$$V_{10d} = sqrt(J*G_0*exp(-2.776*\{(\theta_d - \theta_0)/\theta_B\}^2))+A_B \quad (5.5)$$

$$V_{ld} = V_{10d} * \sin(\omega*t + \Delta*\phi) \quad (5.6)$$

$$V_{20t} = sqrt(J*G_0*exp(-2.776* \{(\theta_t +\theta_0)/\theta_B\}^2))+A_n \quad (5.7)$$

$$V_{2d} = V_{20d} * \sin(\omega*t + \Delta*\phi) \quad (5.8)$$

The error voltage related to angular tracking error is

$$V_{error}(f,\theta,t)=real(v_{diff}/v_{sum}) \quad (5.9)$$

CHAPTER-6

RESULTS AND DISCUSSION

In this project we used two types of results that is with noise and without noise to compare the miss distance of the gamma angle ranging from 10° to 120°,where the miss distance and J/S ratio is mentioned on every gamma angle as follows.The graph represents the miss distance between the target and the decoy .

6.1 WITH NOISE(SNR 5dB)

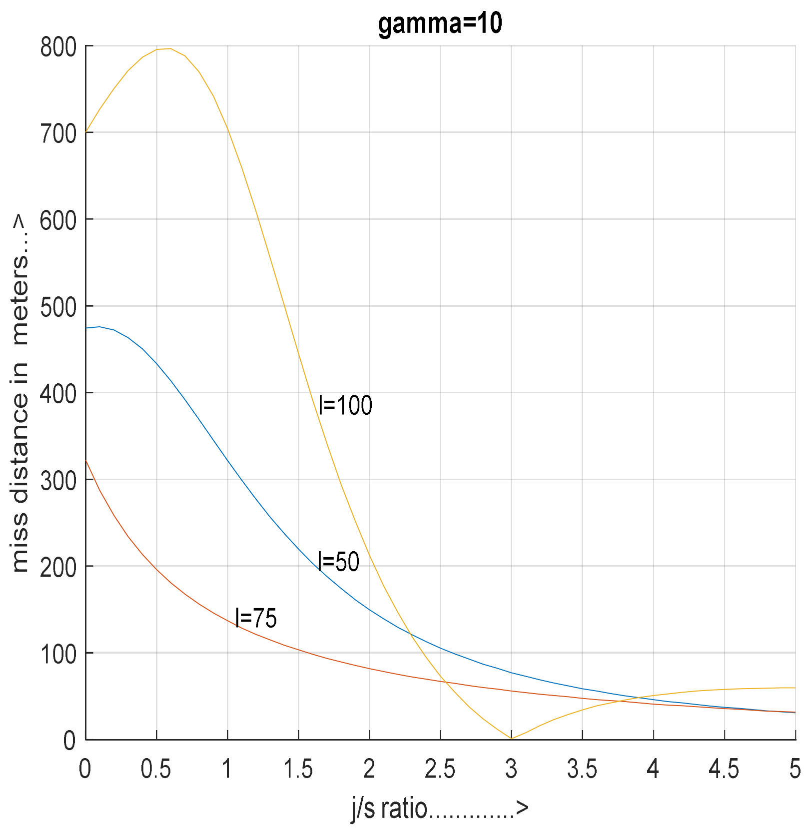

Fig6.1 Graph at gamma 10° with Snr 5dB

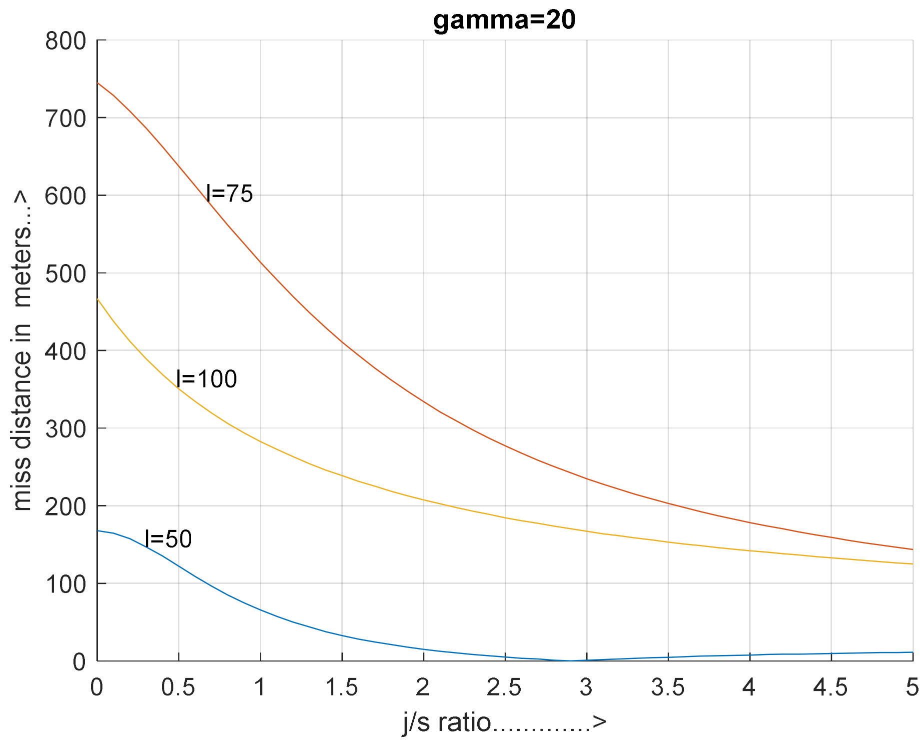

Fig6.2 Graph at gamma 20° with snr 5dB

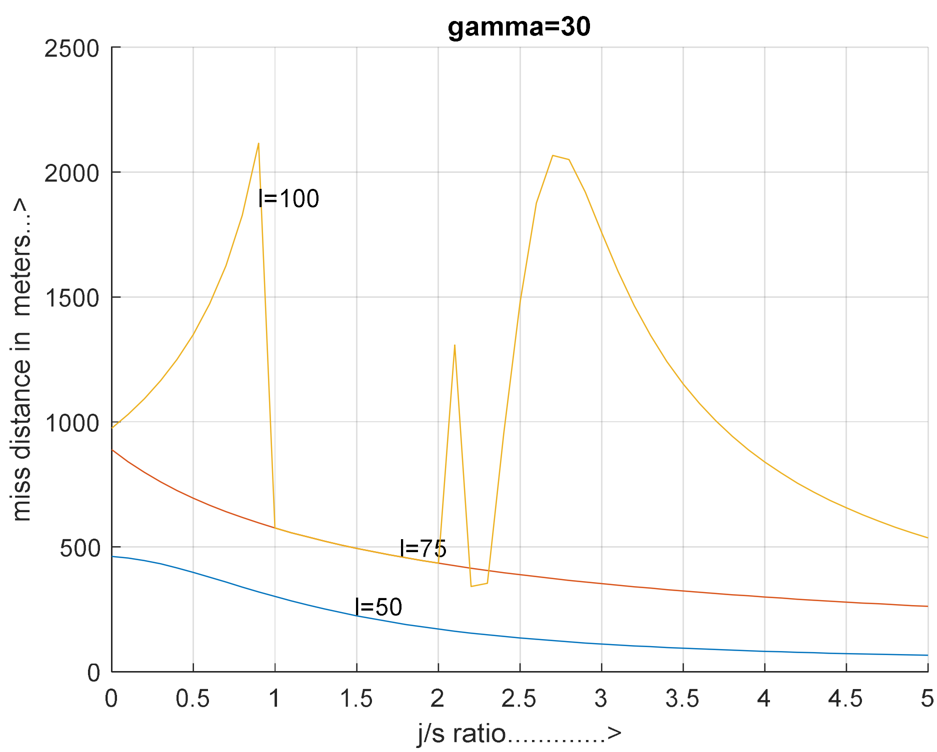

Fig6.3 Graph at gamma 30° with snr 5dB

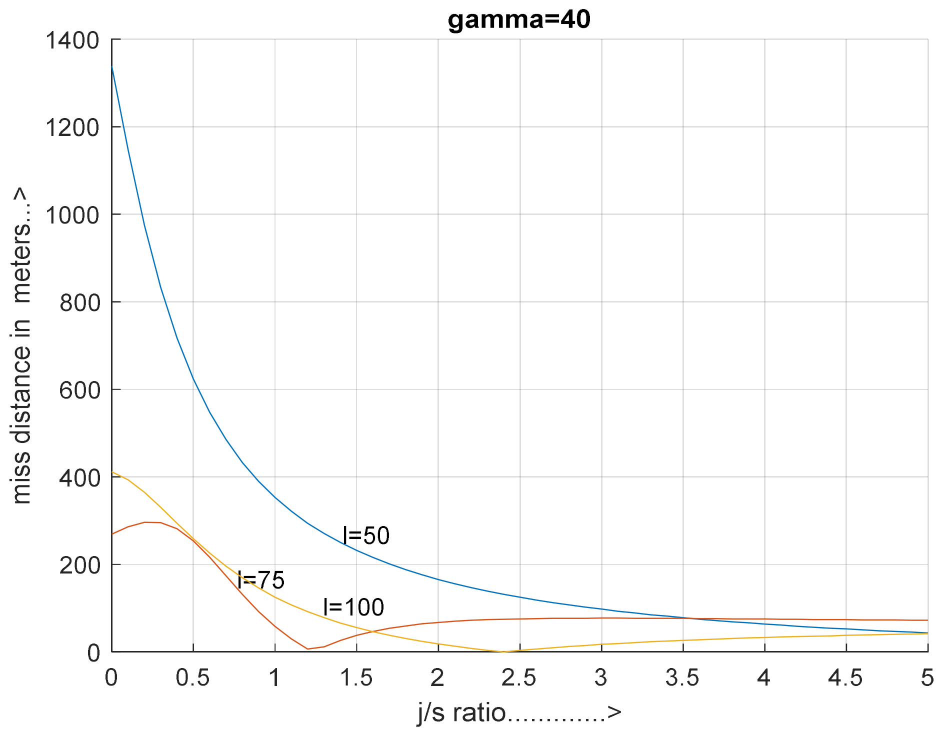

Fig6.4 Graph at gamma 40° with snr 5dB

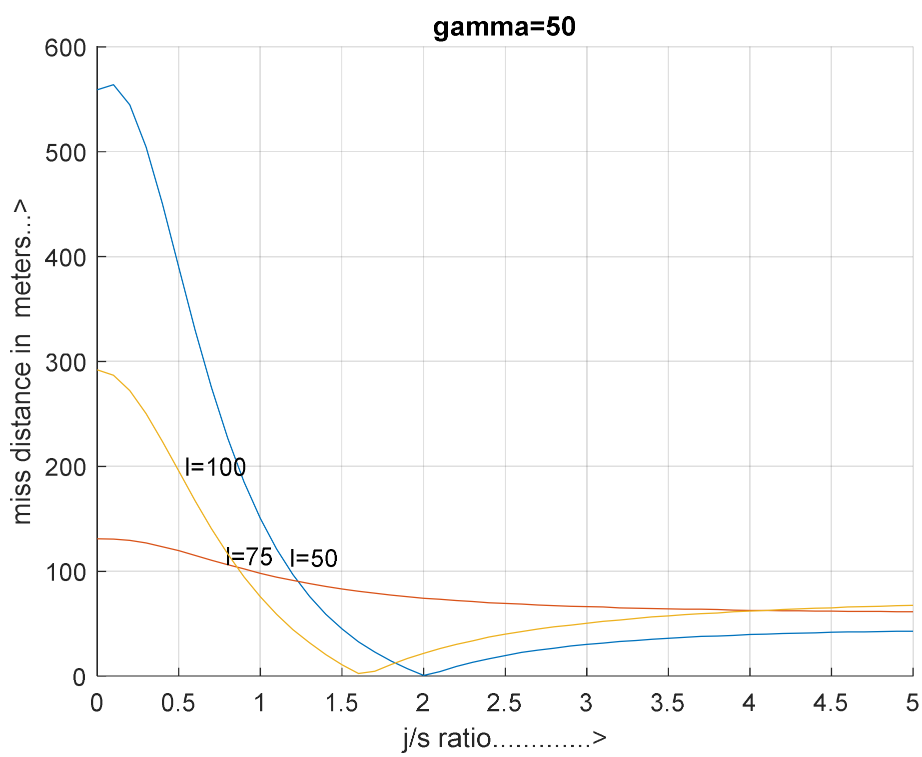

Fig6.5 Graph at gamma 50° with snr 5dB

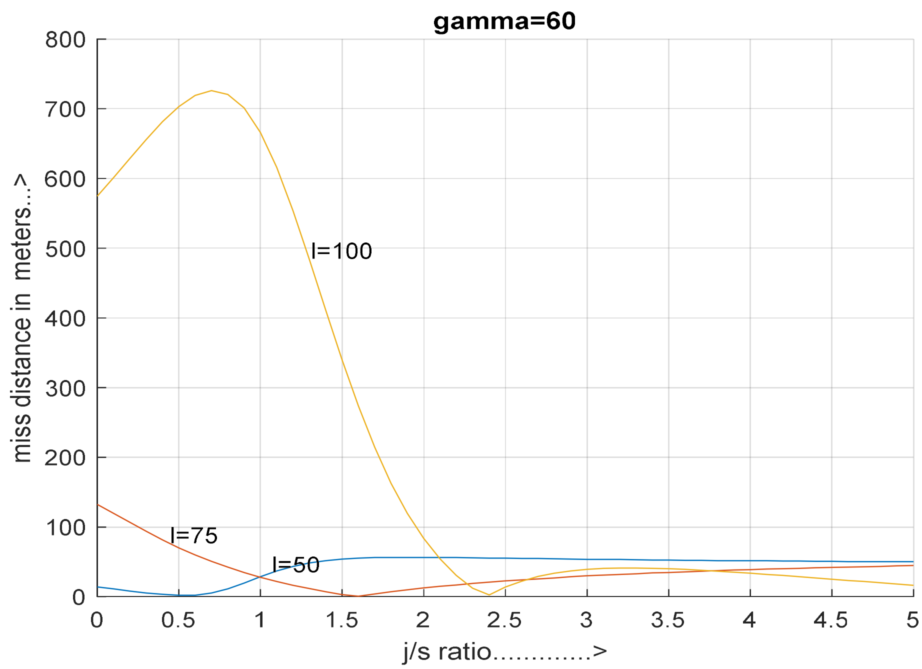

Fig6.6 Graph at gamma 60° with snr 5dB

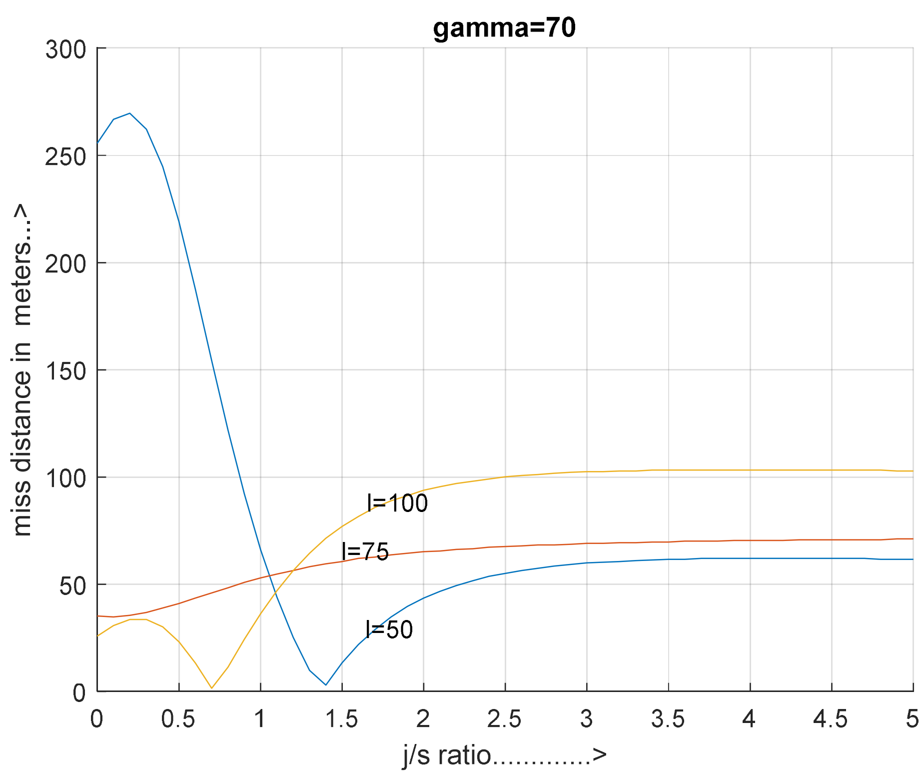

Fig6.7 Graph at gamma 70° with snr 5dB

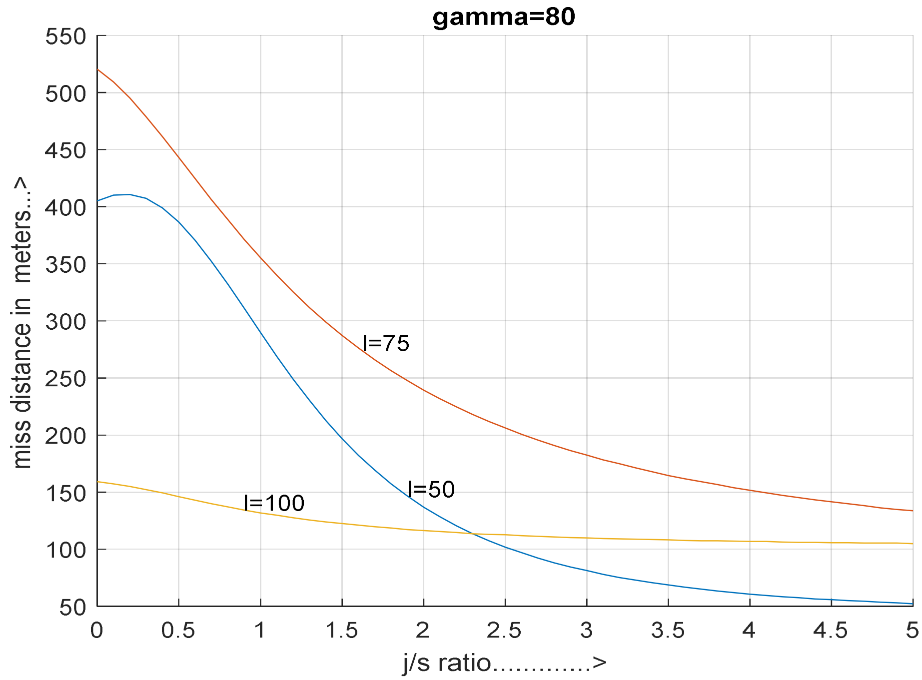

Fig6.8 Graph at gamma 80° with snr 5dB

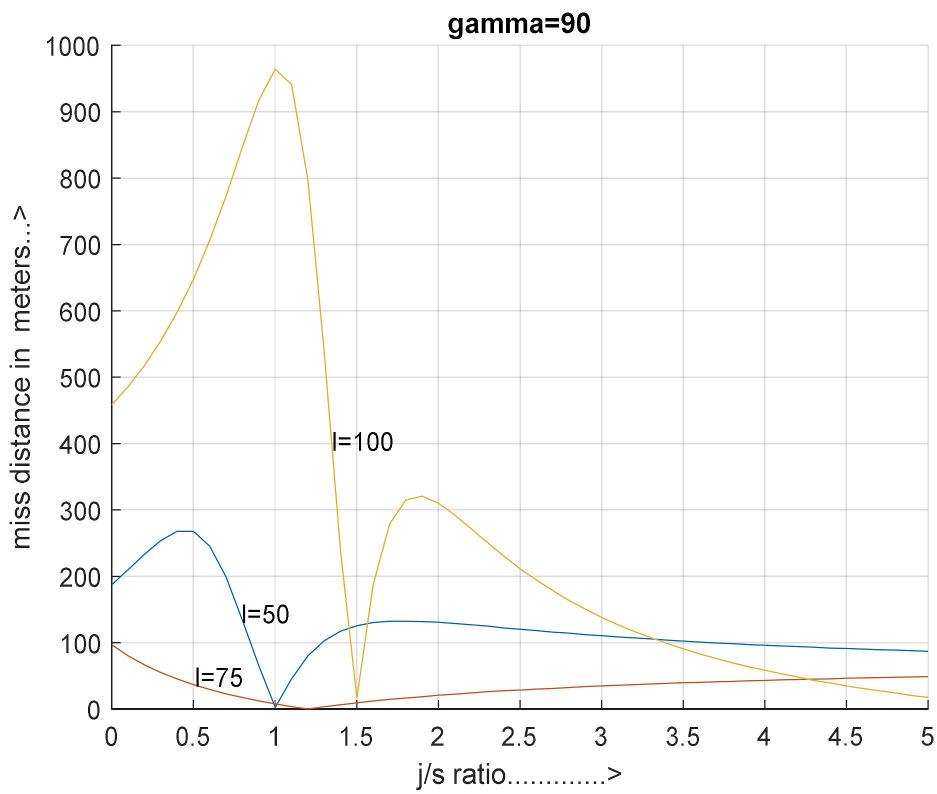

Fig6.9 Graph at gamma 90° with snr 5dB

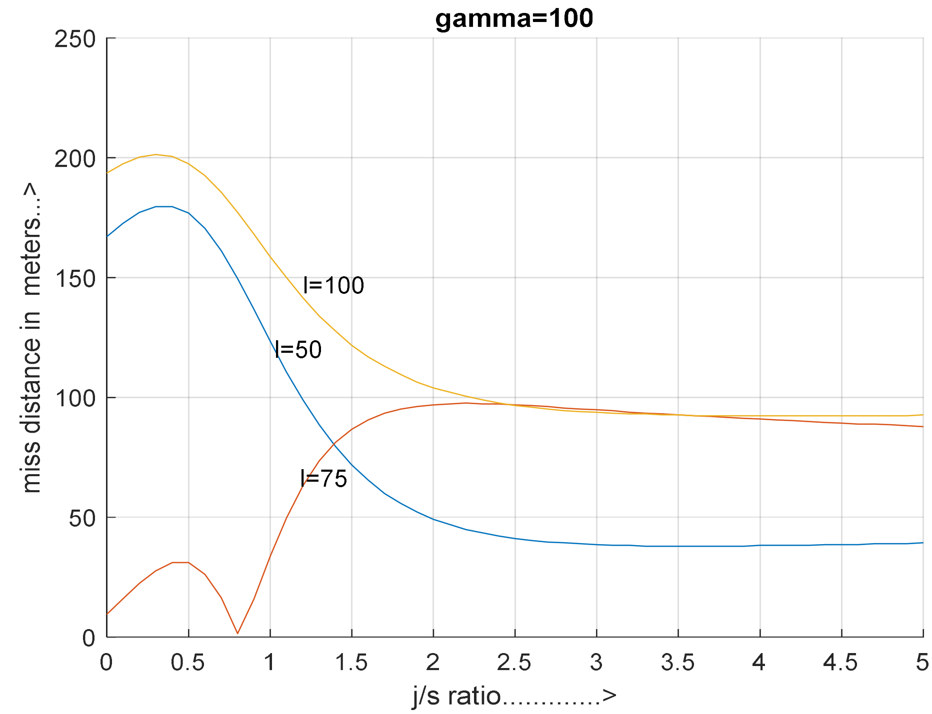

Fig6.10 Graph at gamma 100° with snr 5dB

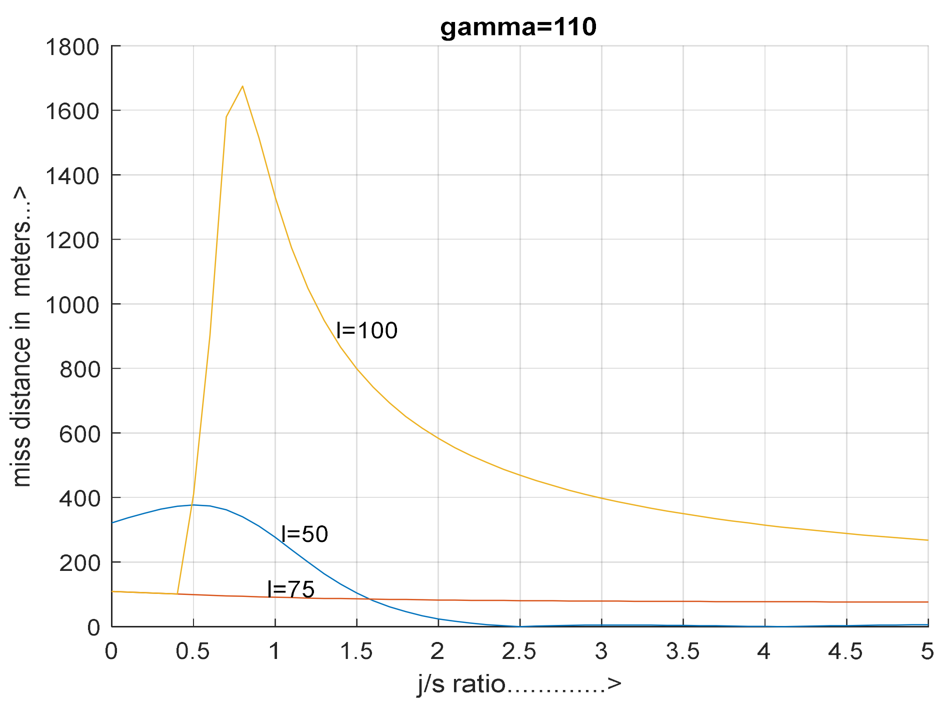

Fig6.11 Graph at gamma 110° with snr 5dB

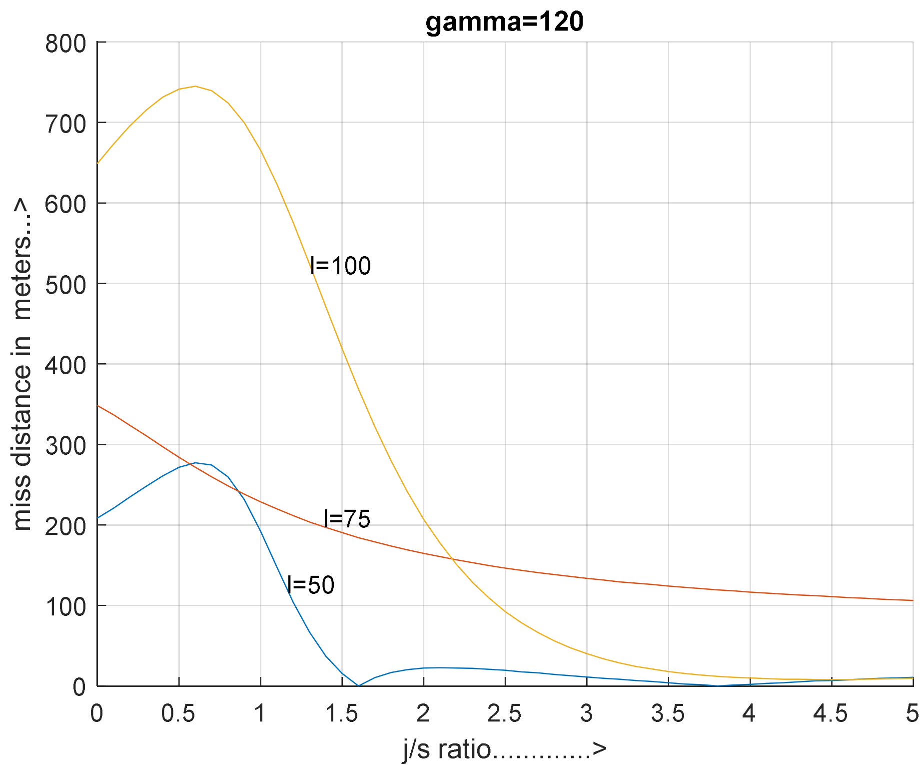

Fig6.12 Graph at gamma 120° with snr 5dB

- In the above figures we observed that the maximum miss distance takes place at γ =110° where the mis distance is approximately 1700
- The miss distance at γ =90° is also equal to 1000 it is due to perpendicular angle at which the missile can target the original signal.
- It is observed that when skip distance required is nearly equal to the decoy distance, γ values to be chosen are between 60° and 110°,for J/S ratio of 1 or more
- γ values of 60° to 110° give almost monotonically increasing curves with respect to J/S
- Hence in view of this, γ value of 110° maximum miss distance which is employed

6.2 WITHOUT NOISE(SNR 0dB)

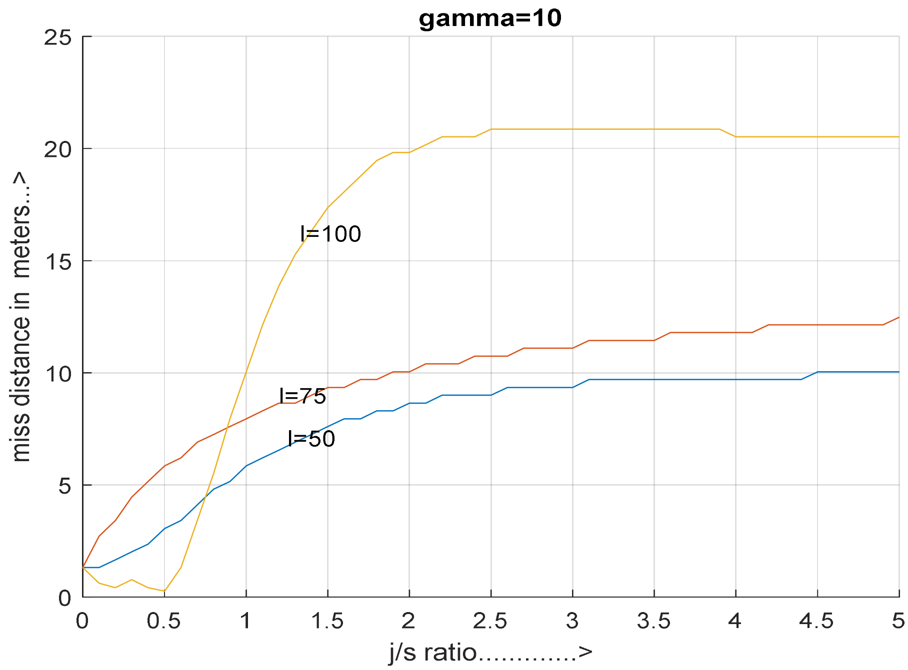

Fig6.13 Graph at gamma 10° without snr 0dB

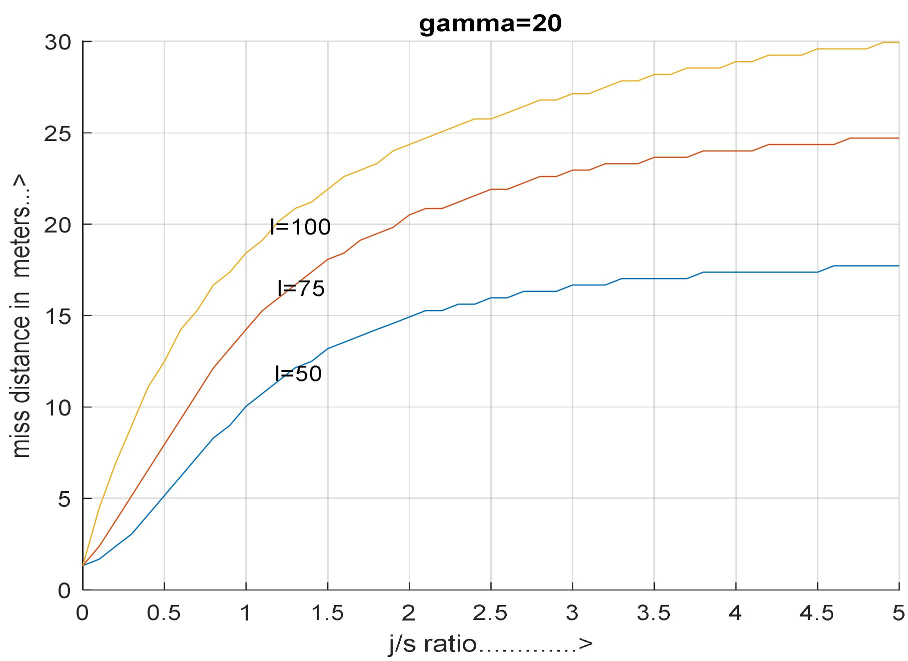

Fig6.14 Graph at gamma 20° without snr 0dB

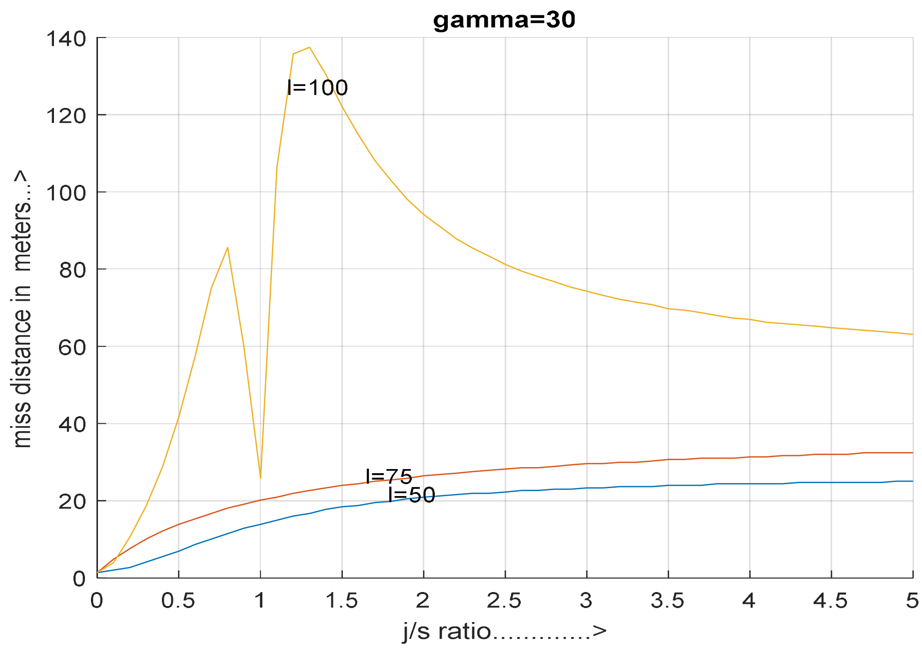

Fig6.15 Graph at gamma 30° without snr 0dB

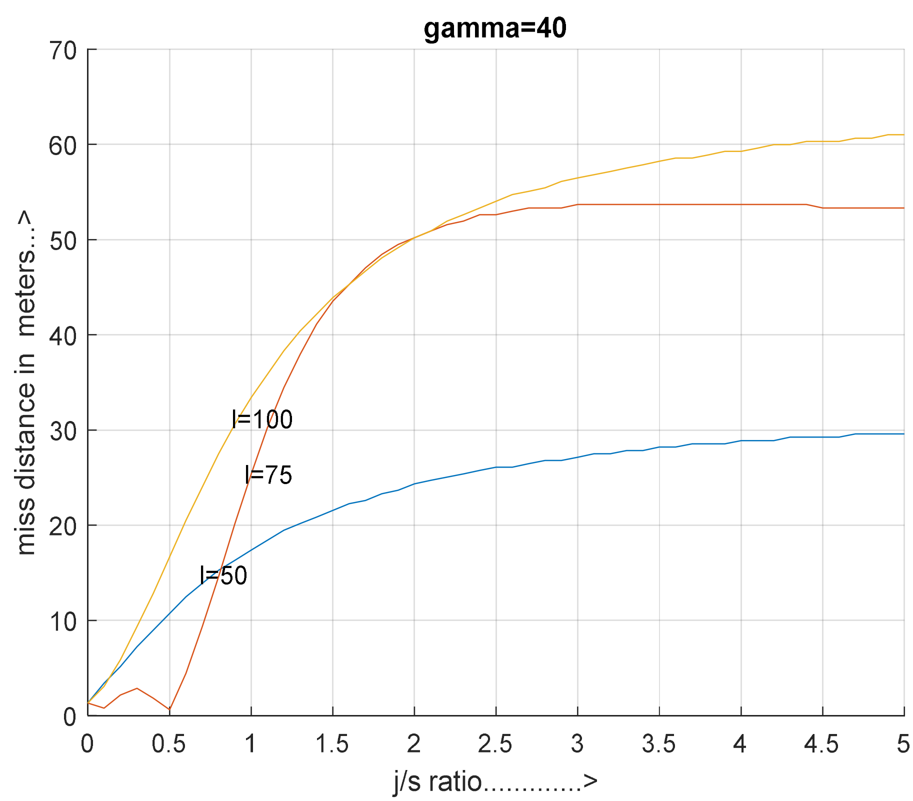

Fig6.16 Graph at gamma 40° without snr 0dB

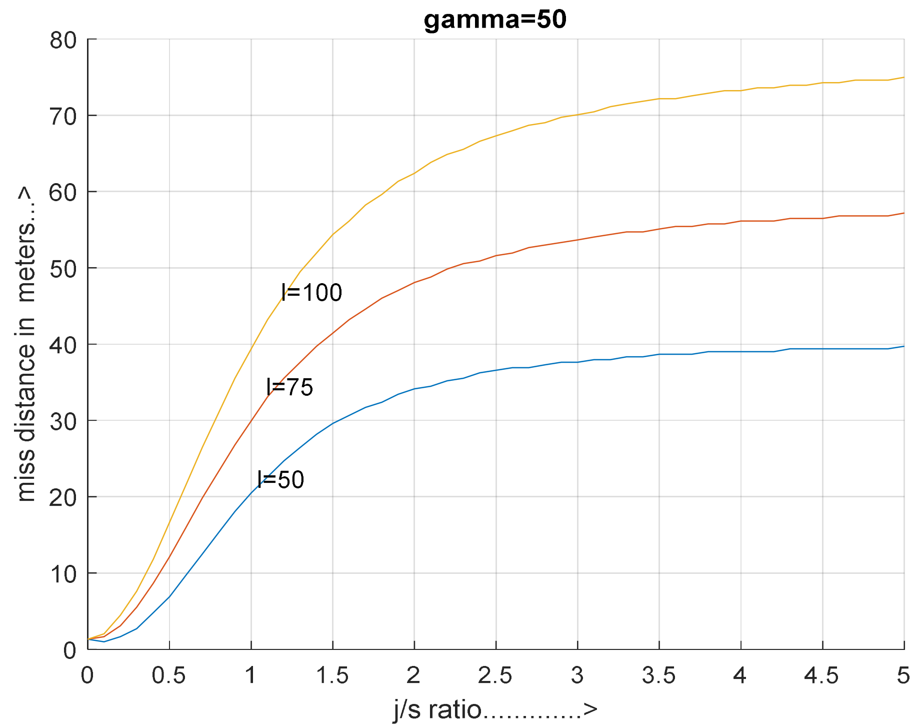

Fig6.17 Graph at gamma 50° without snr 0dB

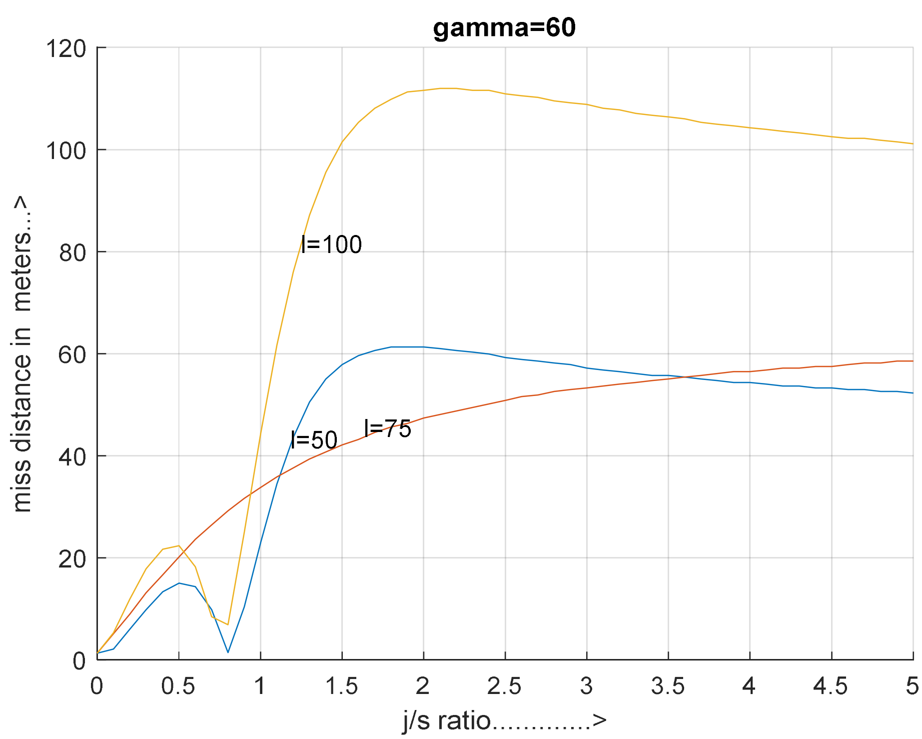

Fig6.18 Graph at gamma 30° without snr 0dB

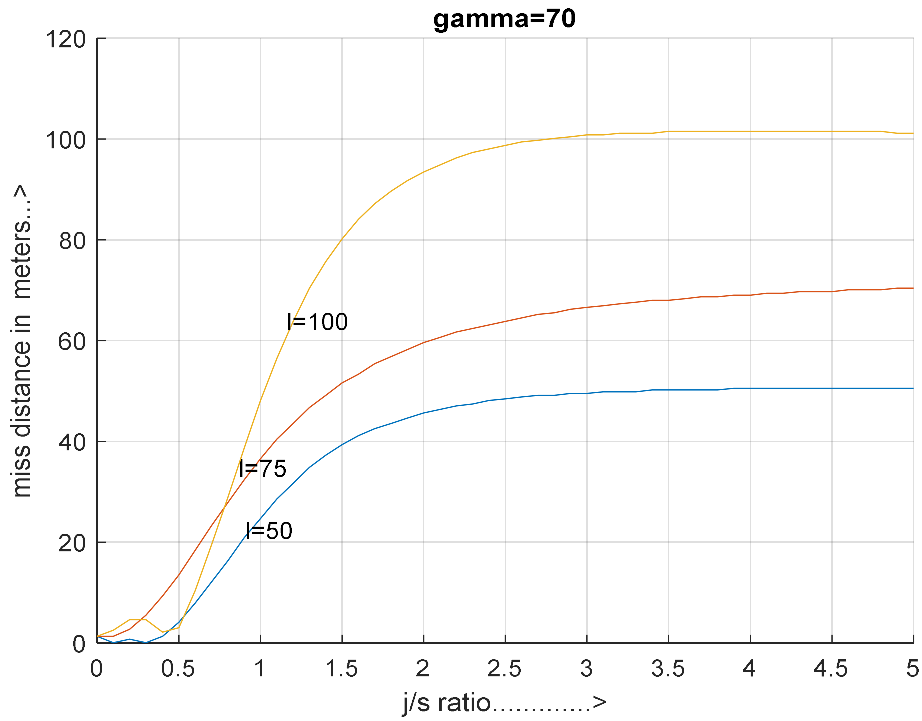

Fig6.19 Graph at gamma 70° without snr 0dB

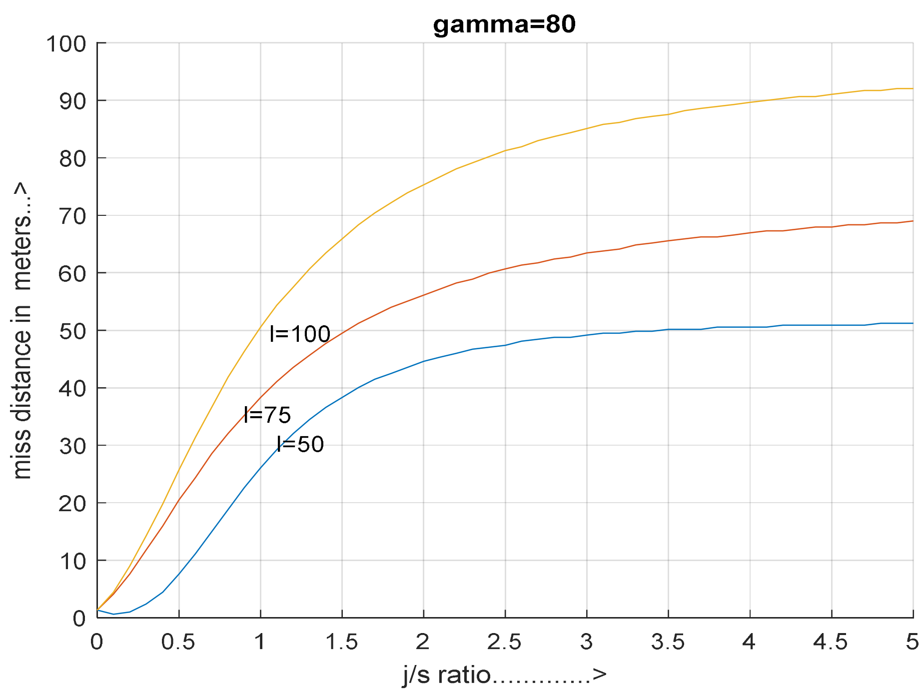

Fig6.20 Graph at gamma 80° without snr 0dB

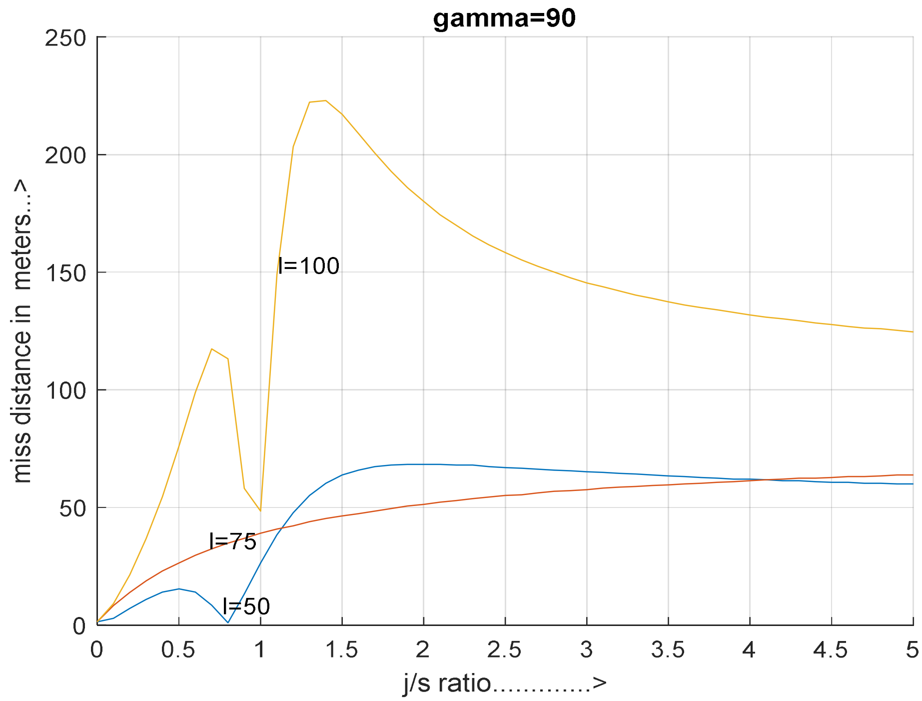

Fig6.21 Graph at gamma 90° without snr 0dB

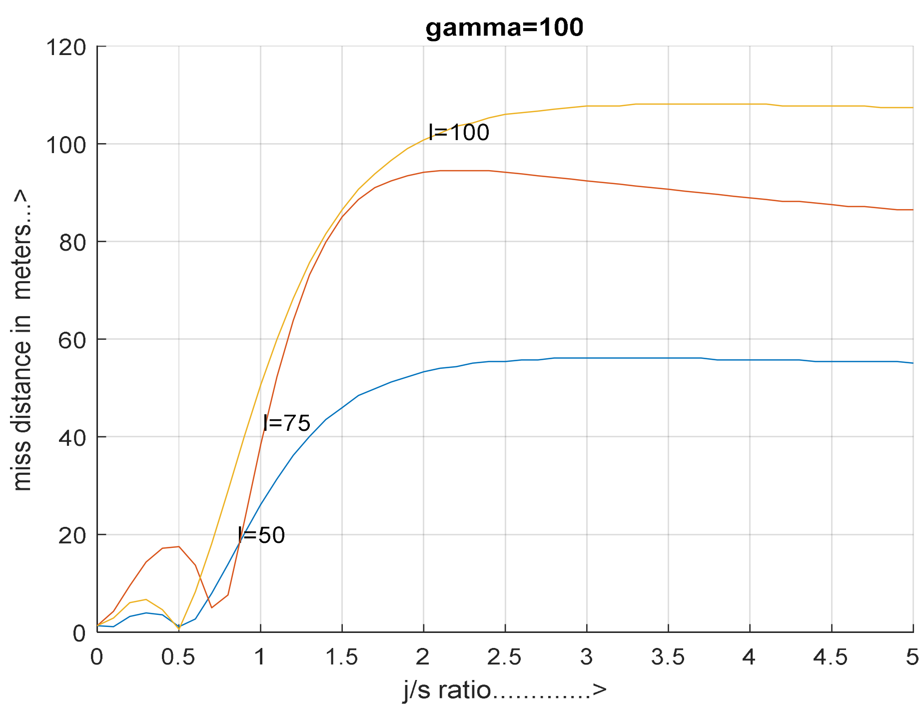

Fig6.22 Graph at gamma 100° without snr 0dB

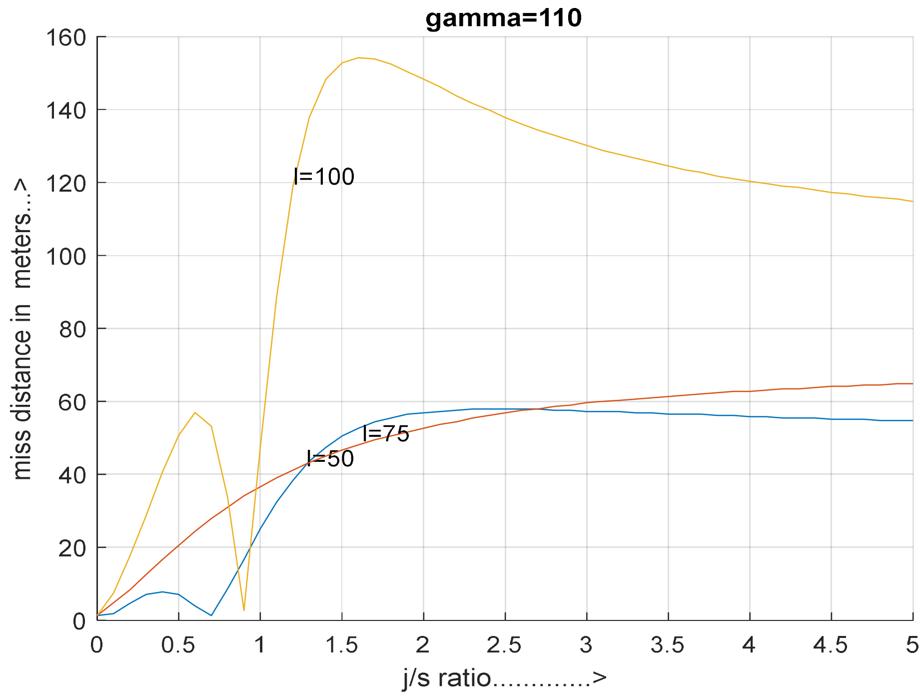

Fig6.23 Graph at gamma 110° without snr 0dB

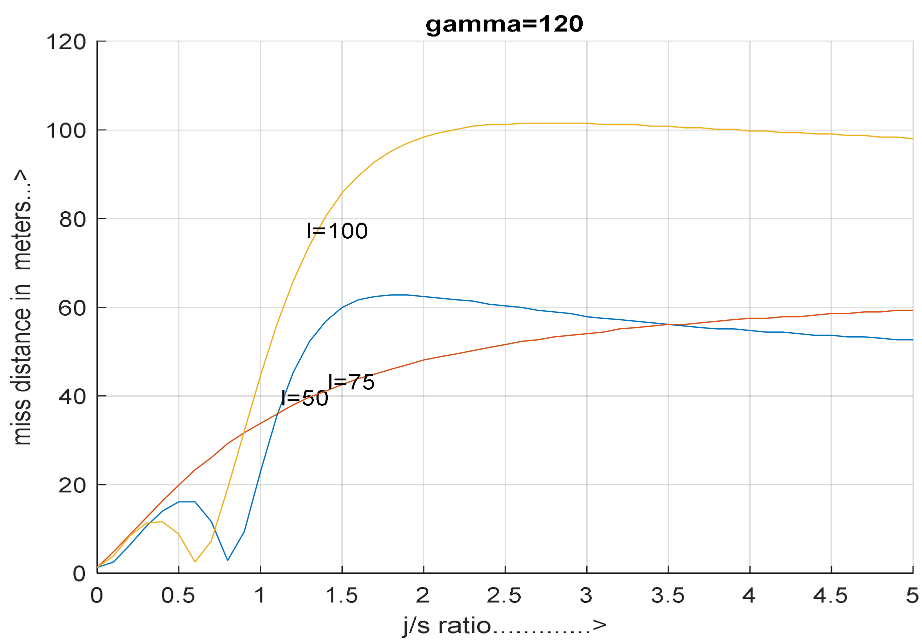

Fig6.24 Graph at gamma 120° without snr 0dB

- In this case the maximum miss distance is 200meters where it is without noise so that the miss distance is less than with noise.
- The Graphs Without Noise has less mis distance than With Noise

CHAPTER 7
SOURCE CODE

7.1 CODE

```
clf;

clear all;

clear workspace;

clc;

f=9;

lamb=30/f;

rt=20000;

gama=110;

D=30;

g0=1;

G0=1;

s=1;

gamar=gama*pi/180;

delgo=0;

hpbw=65*lamb/D;

hpbwr=hpbw*(pi/180);

teta0=hpbw*0.283;

tetar0=teta0*pi/180;

tetat=0;

tmin=-hpbw;
```

```
tmax=hpbw;
tinc=.001;
teta=[tmin:tinc:tmax];
tetar=teta*pi/180;
steps=((tmax-tmin)/tinc)+1;
dh=4;
for k=1:steps
   v1(k)=(s*G0*exp((-2.776)*((teta(k)-teta0)/hpbw).^2));
   v2(k)=(s*(G0+delgo)*exp((-2.776)*((teta(k)+teta0)/hpbw).^2));
   vsum(k)=v1(k)+v2(k);
   vdiff(k)=v1(k)-v2(k);
 %  dbvsum(k)=20*log10(v1(k)+v2(k));
  % dbvdiff(k)=20*log10(v1(k)-v2(k));
   ve(k)=real(vdiff(k)/vsum(k));
end
ve1=round(ve*10);
ve2=ve1/10;
lmin=50;
linc=25;
lmax=100;
lsteps=(lmax-lmin)/linc+1;
l=[lmin:linc:lmax];
for l1=1:lsteps
```

```
    if gamar==90*pi/180
        gamar=89.98*pi/180;
    elseif gamar==140*pi/180
       gamar=139.98*pi/180;
    elseif gamar==30*pi/180
       gamar=29.98*pi/180;
   else gamar=gamar;
   end
    rd(l1)=sqrt(rt*rt+l(l1)*l(l1)-2*rt*l(l1)*cos(pi-gamar));
    temp(l1)=(l(l1)/rd(l1))*sin(pi-gamar);
    tetadr(l1)=asin(temp(l1));
    tetad(l1)=tetadr(l1)*180/pi;
end
s=1;
Jmin=0;
Jmax=5;
Jinc=0.1;
J=[Jmin:Jinc:Jmax];
Jsteps=(Jmax-Jmin)/Jinc+1;
n=Jsteps;
randn('seed');
na=randn(1,n);
snrdb=0;
```

```
snr=10^(snrdb/20);

for l1=1:lsteps

    for m=1:Jsteps

        path(l1)=rt-rd(l1);

        psi(l1)=2*pi*path(l1)/(lamb/100);

        %v1s(m,l1)=sqrt(s*g0*exp((-2.776)*((tetat-teta0)/hpbw)^2))+na(l1)/snr;

        v1s(m,l1)=(s*g0*exp((-2.776)*((tetat-teta0)/hpbw)^2));

        v1j(m,l1)=(J(m)*g0*exp((-2.776)*((tetad(l1)-
teta0)/hpbw)^2))*exp(j*psi(l1));

        v1(m,l1)=v1s(m,l1)+v1j(m,l1);

        v2S(m,l1)=(s*g0*exp((-2.776)*((tetat+teta0)/hpbw)^2));

        v2j(m,l1)=(J(m)*g0*exp((-
2.776)*((tetad(l1)+teta0)/hpbw)^2))*exp(j*psi(l1));

        v2(m,l1)=v2S(m,l1)+v2j(m,l1);

        vsum(m,l1)=v1(m,l1)+v2(m,l1);

        vdiff(m,l1)=v1(m,l1)-v2(m,l1);

        volerr(m,l1)=real(vdiff(m,l1)/vsum(m,l1));

    end

end

volerr1=round(volerr*10);

volerr2=volerr1/10;

for l1=1:lsteps

    for m=1:Jsteps

        for k=1:steps
```

```
          if(abs(volerr(m,l1)-ve(k)))<=0.001
              angerr(m)=teta(k);
           else
           end
       end
 md(m)=abs(rt*angerr(m)*(pi/180));
   end
   hold on;
   figure(1);
   plot(J,md);
   xlabel('j/s ratio............>');
   ylabel('miss distance in  meters...>');
   title('gamma=120');
   if l1==1
       gtext('l=50');
   elseif l1==2
       gtext('l=75');
   elseif l1==3
       gtext('l=100');
%    elseif l1==4
 %   gtext('l=500');
   else
   end
```

```
    hold off;

    grid on;

end
```

CHAPTER 8

CONCLUSION AND FUTURE SCOPE

8.1 CONCLUSION

Decoys with repeated jammers have been studied. In this project ,the optimum angle of fire γ for maximum miss distance has been computed. The computations are based upon, missile borne Monopulse receiver outputs at the IF stage. Both the radar echo signal and the repeated jammer signal are compared at the IF output. For various fire angles γ of cartridges containing repeater jammer, miss distances have been obtained with J/S ratios varying from 0 to 30. Also the cases of signal plus additive noise with SNRs of 5dB, 10dB with no additive noise have been analyzed. In all the above cases, the miss distance of the missile from the target is much less than the target to decoy distance. Also, in order to be effective J/S ratios of the order of 4 or more have to be employed. For γ=90° the decoy is vertically above the target plat-form, and hence, should not be the choice. γ=110° is found to be most optimum yielding maximum miss distance. This analysis is useful in EW applications in protecting valuable assets.

8.2 FUTURE SCOPE

The future scope of optimum active decoy deployment for effective deception of missile radars encompasses several promising and innovative directions. Here are some key areas that hold potential for future research and development:

1. **Advanced Decoy Technology**
    - **Stealth and Low Observable Technologies:** Developments in materials and design to create decoys with reduced radar cross-section (RCS) and enhanced stealth capabilities, making them more convincing as targets.
    - **Adaptive Decoys**: Decoys that can change their electromagnetic signature in real-time to match the characteristics of different targets, increasing their effectiveness against a variety of missile radar systems.
2. **Artificial Intelligence and Machine Learning**

- **AI-driven Decoy Control**: Use of AI to control decoy behavior and deployment strategies, making them more unpredictable and effective against advanced missile guidance systems.
- **Pattern Recognition:** Machine learning algorithms to analyze and predict missile radar behavior, allowing decoys to better mimic legitimate targets and improve evasion tactics.

3. **Swarm Technology**
    - **Swarm Decoys**: Deployment of multiple decoys working in coordination, mimicking the appearance of larger and more complex targets, overwhelming missile radar systems, and increasing the probability of successful deception.
    - **Autonomous Swarming**: Autonomous control systems that allow decoys to operate without direct human intervention, adapting to the threat environment in real-time.
4. **Electronic Warfare Integration**
    - **Jamming and Spoofing:** Integration of decoy systems with electronic jamming and spoofing technologies to create a multi-layered defense against missile radar systems.
    - **Cyber Decoys:** Development of cyber-physical systems that can deceive not only the radar but also the data processing systems of the missile, introducing false information at multiple levels.
5. **Simulation and Testing**
    - **Advanced Simulation Models:** Creation of high-fidelity simulation environments to test and refine decoy deployment strategies against various missile radar systems.
    - **Field Testing:** Extensive real-world testing of decoy systems in different operational environments to validate their effectiveness and improve their deployment tactics.
6. **Integration with Defense Networks**
    - **Networked Defense Systems:** Integration of decoy systems with broader defense networks, allowing for coordinated responses and information sharing across multiple platforms and sensors.

- **Interoperability:** Ensuring that decoy systems can work seamlessly with various other defense assets, such as drones, aircraft, and naval vessels.

7. **Cost-Effective Solutions**
   - **Economical Manufacturing:** Research into cost-effective manufacturing techniques for decoys, making them more accessible for widespread use.
   - **Reusable Decoys:** Development of decoys that can be recovered and reused, reducing the overall cost and improving the sustainability of defense operations.

8. **Regulatory and Ethical Considerations**
   - **International Regulations:** Exploration of international regulatory frameworks governing the use of decoy technologies in military operations.
   - **Ethical Implications:** Consideration of the ethical implications of deploying deceptive technologies in warfare and the potential impact on civilian populations and conflict escalation.

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