International Journal of Engineering & Technology, 7 (4) (2018) 4814-4818

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.17689
Research paper

Analysis of active decoy deploymentagainst anti-radiation missiles

E.Vijayalakshmi[1]*, Dr. N.N. Sastry[2], Dr. B. Prabhakar Rao[3]

[1]*Associate Professor, Jagan's Engineering College, Nellore, India*
[2]*Professor, Departmentof ECE, V. R. Siddhartha Engineering college, Vijayawada, India*
[3]*Professor, Department of ECE, JNTU, Kakinada, India*
**Corresponding author E-mail:edurivijaya@gmail.com*

Abstract

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 homing 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 paper, 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 maximum 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 and results presented.

Keywords: *Radar; Electronic Warfare; Decoy; Monopulse.*

1. Introduction

In a typical sea skimming missile engagement scenario in the terminal phase against a ship the reaction time available for defensive actions is typically 90 seconds. With this reaction time, soft kill option with an active cartridge fired decoy for luring away the missile during the terminal phase which is dealt with in this paper. Various parameters affecting deployment and effective luring away of the missile are considered. Decoys have been used widely to protect valuable platforms from incoming missiles. With the development of anti radiation missile (ARM) technology, serious threats have come into vogue, which are to be dealt with effectively. Similarly, the stealth platforms are also a serious threat to valuable assets. To counter these threats antimissile missile technologies have been developed for destroying the incoming missiles in mid air. While this is a hard kill option, there are soft kill options such as deploying of passive and active decoys, and other jamming techniques.

In this paper, we are concerned with active decoy deployment and effective jamming. The countermeasure techniques against ARM have been studied in recent times [1-7]. An anti ARM technique using random phase and amplitude active decoys has been reported [8]. In this paper, the optimum distance between decoys and radar was derived. In another paper, multi active source decoy system, using deceptive effect of blinking decoys against ARM have been discussed [9]. Performance evaluation of radar and decoy system against anti radiation missiles has also been reported [10]. In this paper, the effects of quadrangular topology for distribution of three decoys have been described [11]. In the radar terminal guidance, discriminating the target and decoy using frequency profile modeling has been studied [12]. An impact of multipath reflections from the sea surface on active decoy jamming has been analyzed [13].

In this paper section II describes deployment geometry, section III mathematical formulations, section IV simulations, results and analysis, section V conclusions. The reference paper for this analysis is the paper published by the author earlier [14].

2. Deployment model

The deployment model is shown in Fig. 1. The various parameters in the figure are as follows. Missile is located at the origin of the X – Y co-ordinate system .Target is assumed to be tracking the target in its terminal phase making near zero angles. Decoy is located at a length L from the target making an angle γ with respect to Missile to Target axis. θ_d – Angle between target and decoy as seen from the missile; R_d- Range between missile and the decoy in meters; R_t- Range between missile and target in meters.

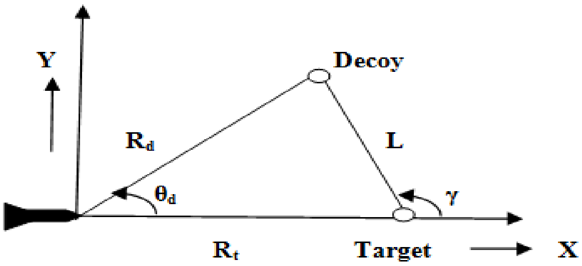

Fig. 1: Deployment Model of Target, Decoy and Missile.

The monopulse system transmits a sinusoidal pulse with additive noise. The signal traverses a distance R_t from the monopulse antenna and gets scattered back from the target and traverses a distance of R_t back to the monopulse antenna. Atmospheric noise as well as amplitude and phase noise due to target movement is added to the signal as additive noise and is assumed to be Gaussian. The phase noise is assumed to have uniform distribution as every value of phase is equally probable.

3. Mathematical formulation

The radar echo signal enters the two horn monopulse radar system whose block diagram is shown in Fig. 2. Each horn is assumed to have a Gaussian power pattern which is a valid approximation to horn patterns, down to 10 dB level measured from the peak of the pattern. The voltage output of horn1 and horn 2 are down converted with a local oscillator and filter. The IF output is passed for getting azimuth angle tracking errors. In this formulation, coherent monopulse processing is assumed as this gives better SNR performance.
The voltage output of horns namely V_1 and V_2 are given by [1-2].

$$V_{10t} = \sqrt{(S * G_0 * \exp(-2.776 * ((\theta_t - \theta_0)/\theta_b)^2 + A_n} \quad (1)$$

$$V_{1t} = V_{10t} * \sin(\omega t + \Delta\varphi) \quad (2)$$

$$V_{20t} = \sqrt{(S * G_0 * \exp(-2.776 * ((\theta_t + \theta_0)/\theta_b)^2 + A_n} \quad (3)$$

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

$$V_{10d} = \sqrt{(J * G_0 * \exp(-2.776 * ((\theta_d - \theta_0)/\theta_b)^2 + A_n} \quad (5)$$

$$V_{20d} = \sqrt{(J * G_0 * \exp(-2.776 * ((\theta_d + \theta_0)/\theta_b)^2 + A_n} \quad (6)$$

$$V_{1d} = V_{10d} * \sin(\omega t + \Delta\varphi) \quad (7)$$

$$V_{2d} = V_{20d} * \sin(\omega t + \Delta\varphi) \quad (8)$$

$$V_1 = V_{1t} + V_{1d} \quad (9)$$

$$V_2 = V_{2t} + V_{2d} \quad (10)$$

Where
V_1- Time domain signal voltage at IF output
V_2- Time domain signal voltage at IF output
V_{10t}-Amplitude of the target echo signal at horn1
V_{20t}-Amplitude of the target echo signal at horn2
V_{10d}-Amplitude of the decoy signal at the output of horn1
V_{20d}-Amplitude of the decoy signal at the output of horn2
S-signal power
J-Decoy repeater power
$\Delta\phi$-Random phase of additive noise
G_0-Gainof receiving antennas1 and 2, assumed to be equal
θ_t- Angle between missile and target=0
θ_0- Squint angle of the horns from missile-target axis
θ_B- Half power beam width
ω- Radian frequency at r. f.
A_n-Additive noise amplitude

The horn outputs are summed in a hybrid and the output is amplified, down converted to IF and passes through an AGC amplifier and then given to a PLL as in Fig. 2. Similarly, the difference of voltage outputs of the two horns is amplified down converted to IF and passes through an AGC amplifier. This is mixed with PLL corrected VCO output and passes through LPF and given to azimuth tracking servo system [3-4].This output is normalized with respect to the sum channel output. The sum and difference outputs are given by,

$$V_{sum}(f, \theta, t) = V_1 + V_2 \quad (11)$$

$$V_{diff}(f, \theta, t) = V_1 - V_2 \quad (12)$$

The error voltage related to angular tracking error of radar is given by,

$$V_{error}(f, \theta, t) = \text{real}(V_{diff}/V_{sum}) \quad (13)$$

Where, θ- Angle off bore sight axis of the monopulse antenna system T=n==Number of snap shots.

The VCO is locked to the incoming IF frequency in its steady state.

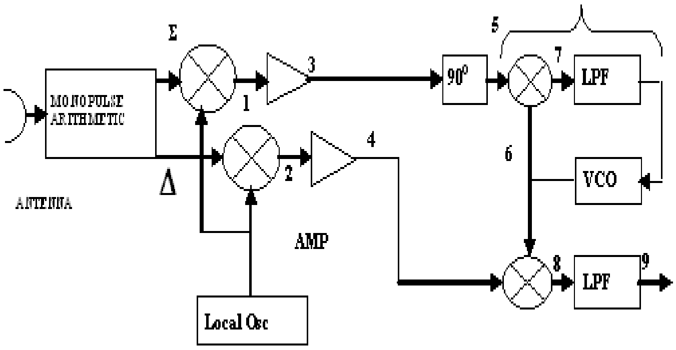

Fig. 2: Block Diagram of Two Horn Monopulse System.

Computer simulations have been carried out for studying variation of voltage error V_{err} for various values of active decoy jammer power to radar echo signal ratio J/S (as measured at receiver SUM channel R. F. output) against γ and L. Miss Distance D_m is the distance between target and the missile nearest to the target in the presence of decoy. Miss distance is computed as follows.
R_d is obtained from the trigonometrical relation,

$$R_d^2 = R_t^2 + L^2 - 2.R_t.L.\cos(180-\gamma) \quad (14)$$

$$D_m = R_d \times \theta_{err}$$

Where, θ_{err} is the error in tracking angle introduced by the decoy's repeater jammer.
Missdistance is obtained from V_{error} (f, θ, t) at eqn. (13) and computing the corresponding angle off boresight from the monopulse difference voltage to sum voltage ratios obtained for various angles off boresight at the IF output in the presence of missile radar echo signal only.

4. Simulations, results and analysis

The ranges of the parameters which are used in computer simulations are given below, and miss distance D_m versus J/S is computed.

J/S - 0 to 30
γ - 10^0 to 170^0
L - 100 to 600meters
R_t - 10 Km

The above have been repeated with typical r. f. SNRs of 5dB, 10dB and without noise. From the voltage error, the angular error produced by the monopulse system which is used for tracking with a single target has been computed and miss distance in meters is plotted. Two cases are analyzed for miss distance namely, one without noise and the other with noise. The plots of J/S versus Miss Distance are presented in Fig. 3-5.
Case (i) without additive noise, and $\gamma=60^0,70^0,90^0, 110^0, 120^0$ and L=100 to 600 meters.

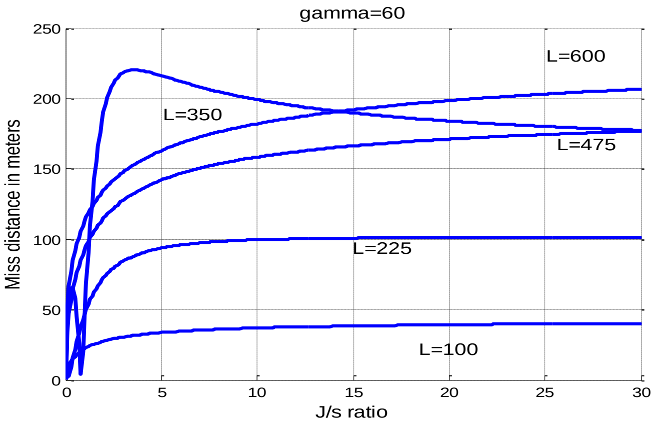

Fig. 3: A) Miss Distance Variation with J/S and L, $\Gamma=60^0$.

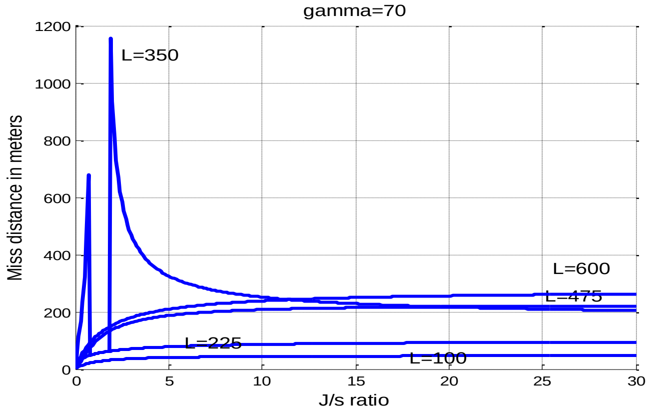

Fig. 3: B) Miss Distance Variation with J/S and L, $\Gamma=70^0$.

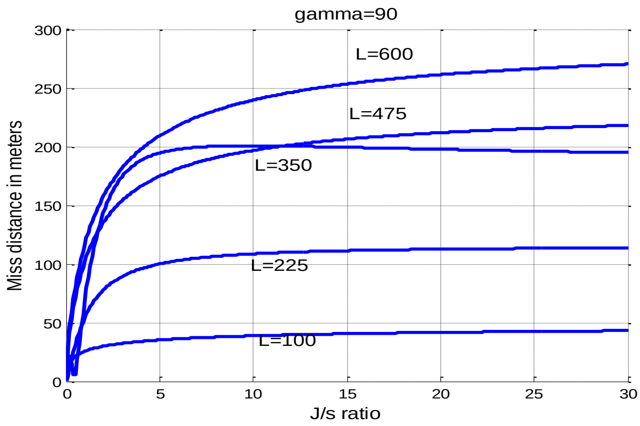

Fig. 3: C) Miss Distance Variation with J/S and L, $\Gamma=90^0$.

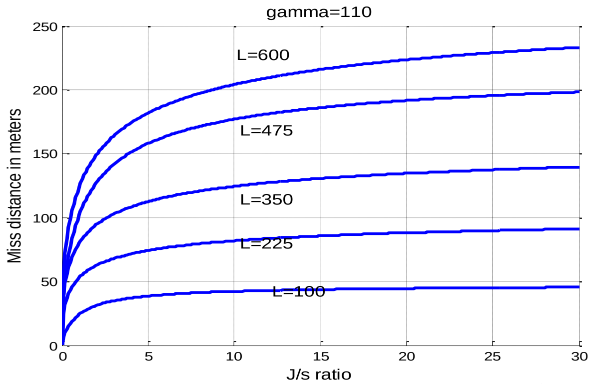

Fig. 3: D) Miss Distance Variation with J/S and L, $\Gamma=110^0$.

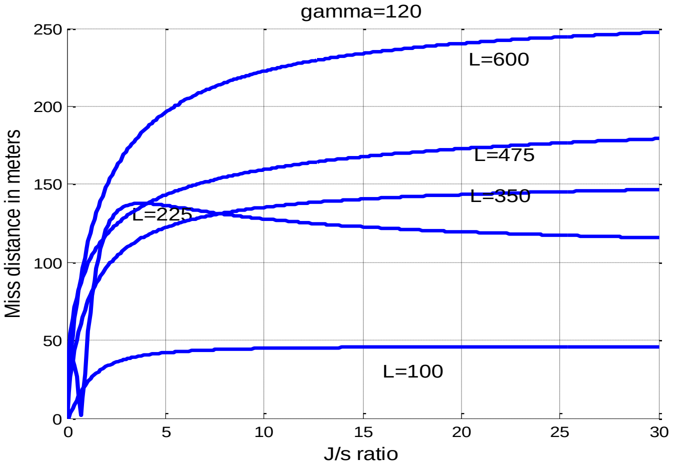

Fig. 3: E) Miss Distance Variation with J/S and L, $\Gamma=120^0$.

It can be seen that when the decoy is deployed at a distance of 600 meters, the miss distance is only around 200 to 250 meters for J/S ratios of more than 4. If J/S ratios are less than 4 the curves are not steady and cannot be depended upon.

Case (ii) With additive noise with SNR=5dB, and $\gamma=60^0$, 700, 90^0, 110^0, 1200and L=100 to 600 meters.

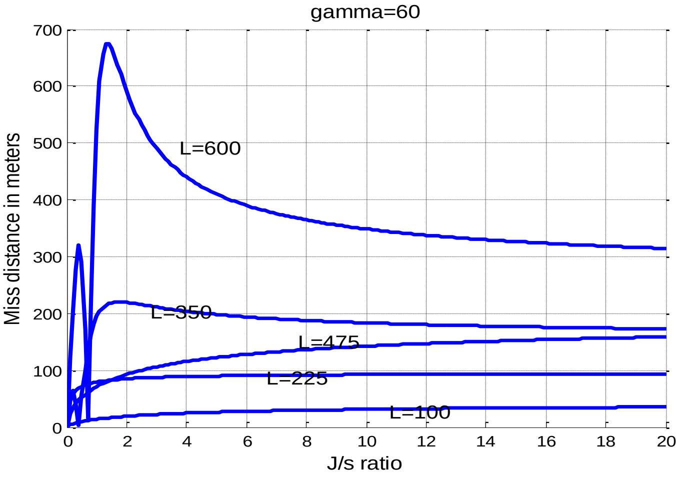

Fig. 4: A) Miss Distance Variation with J/S and L, $\Gamma=60^0$.

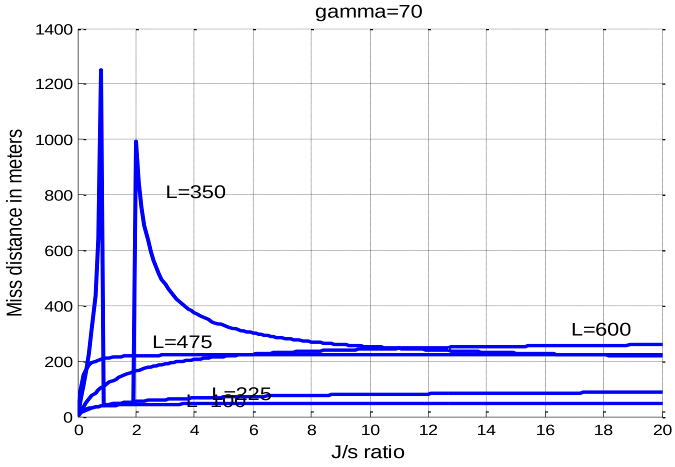

Fig. 4: B) Miss Distance Variation with J/S and L, $\Gamma=70^0$.

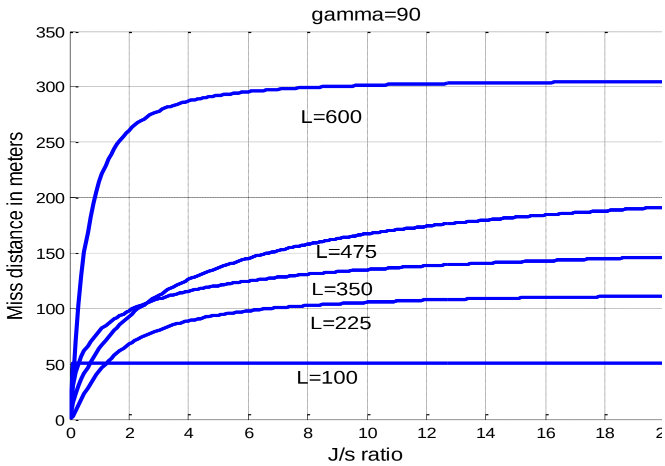

Fig. 4: C) Miss Distance Variation with J/S and L, Γ=90^0.

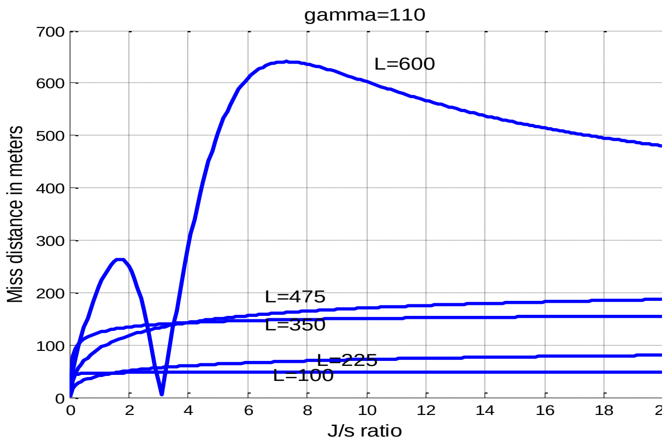

Fig. 4: D) Miss Distance Variation with J/S and L, Γ=110^0.

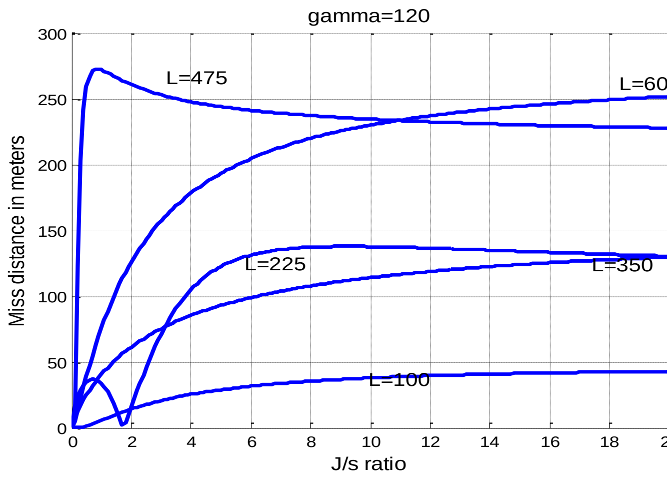

Fig. 4: E) Miss Distance Variation with J/S and L, Γ=120^0.

In the presence of additive noise with SNR of 5dB, the miss distance is only around 250 to 480 meters for J/S ratios of more than 4. If J/S ratios are less than 4 the curves are not steady and cannot be depended upon.

Case (iii) with additive noise with SNR=10dB, and γ=60^0, 700, 90^0, 110^0, 1200and L=100 to 600 meters.

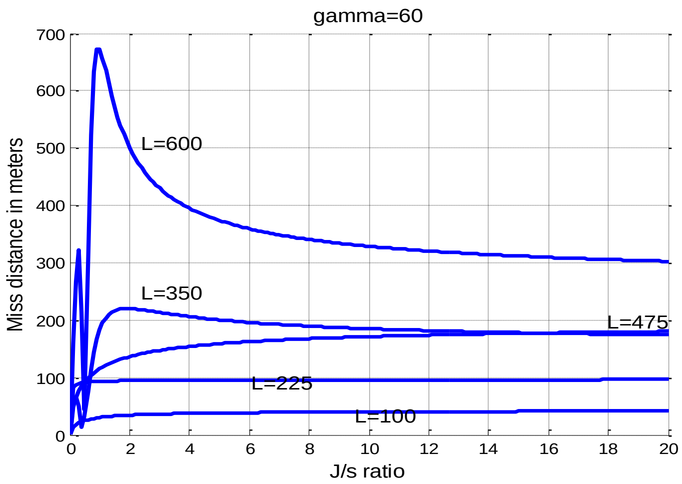

Fig. 5: A) Miss Distance Variation with J/S and L, Γ=60^0.

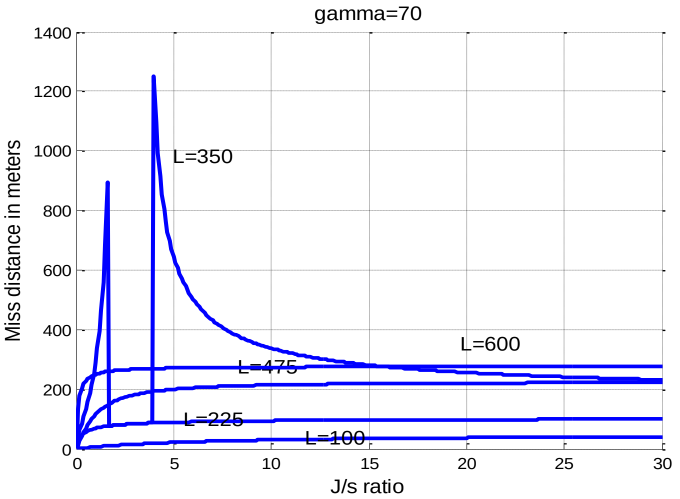

Fig. 5: B) Miss Distance Variation with J/S and L, Γ=70^0.

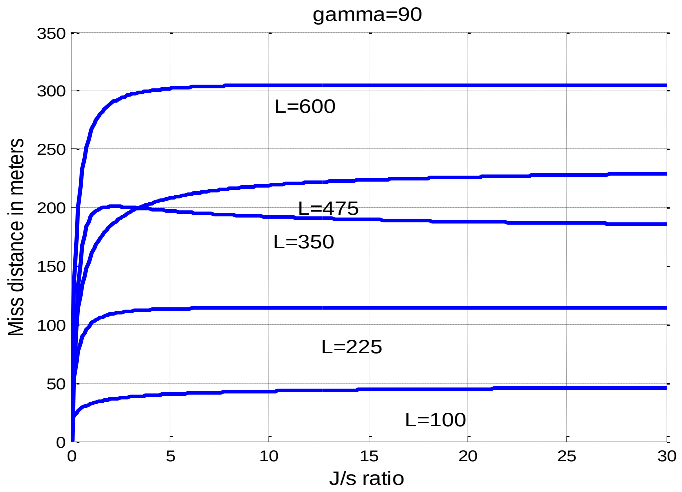

Fig. 5: C) Miss Distance Variation with J/S and L, Γ=90^0.

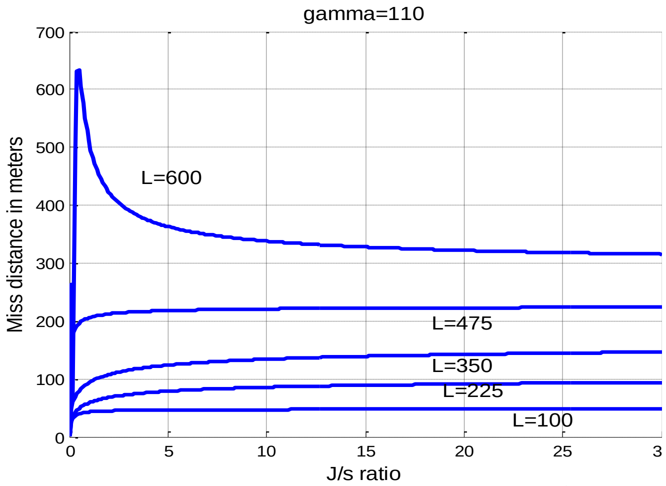

Fig. 5: D) Miss Distance Variation with J/S and L, $\Gamma=110^0$.

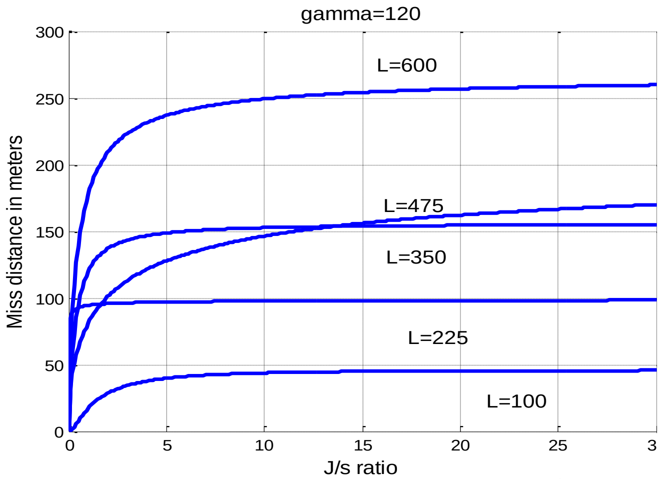

Fig. 5: E) Miss Distance Variation with J/S and L, $\Gamma=120^0$.

It can be seen that when the decoy is deployed at a distance of 600 meters, the miss distance is only around 250 to 320 meters for J/S ratios of more than 4 for all cases excepting L=350, wherein J/S required is greater than 6.0.Studies also have been carried out with decoy distance of 1Km and for $\gamma=110^0$, and a maximum miss distance of 730 meters is obtained with SNR of 5dB. A maximum miss distance of 819 meters is obtained for a γ of 70^0 without noise. The above simulations are given in the following TABLE I for various values of L.

Table 1:

L(meters)	Miss Distance (meters) withSNR=5dB	Miss distance (meters) with SNR=10dB	Miss distance (meters)without additive noise
100	47.96	47.43	45.34
500	330.4	325.8	28.67
600	487.3	315.3	233.1
1000	728.5	682.4	520.1

Miss distance without noise is the least and can be expected for obvious reasons. As the SNR reduces, miss distance increases.

5. Conclusions

Decoys with repeated jammers have been studied. In this paper, 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 repeater 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 and 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 $\gamma=90^0$ the decoy is vertically above the target platform, and hence, should not be the choice. $\gamma=110^0$ is found to be most optimum yielding maximum miss distance. This analysis is useful in EW applications in protecting valuable assets.

Acknowledgment

The authors gratefully acknowledge the constant encouragement given to our work by Dr. Ch. Saibabu, Director, Research and Development, JNTUK, Kakinada, and Dr. A. V. Ratnaprasad, Principal, V. R. Siddhartha Engineering College, Vijayawada.

References

[1] Samuel. M. Sharman, “Monopulse principles and techniques,” page 205, Artech house.

[2] E. L. Srujana and Dr. N.N. Sastry, “Noise interference effects in unbalanced monopulse receiver channels,” IETE Journal of research, vol. 54,no2,pp 169-174, Mar-Apr 2008.https://doi.org/10.1080/03772063.2008.10876196.

[3] Kilger IE and Olenberger CE, “Multiple target effects on monopulse signal processing,” IEEE AES-11, pp. 165,795-804, Sept 1975.

[4] Testuro Endo, “Analysis of interfere effects on monopulseradars,”IEEE Transactions on AES vol.24, no 6,Nov 1988.

[5] Li.N,”Radar ECCM’s new area: Anti-stealth and anti-ARM,”IEEE transactions on aerospace and electronic systems, vol.31, no.3, July 1995.

[6] Lian. W,”Discussion of radar anti anti-radiation missile technology-alarming plus decoy system,”International radar conference, CIE 2001, 2001.

[7] Wang. F, R. He, and X. Sha, “Anti-ARM technique: Feature analysis of ARM warning radar,” International radar conference, CIE 2001, 2001.https://doi.org/10.1109/ICR.2001.984676.

[8] Majid Emadi, Amir jafargholi, M. H. S Moghadam and Farokh-Marvasti,” New Anti-ARM Technology by using random phase and amplitude active decoys, “PIER 87, pp297-311, 2008.https://doi.org/10.2528/PIER08100404.

[9] Dong Wen-feng, Liu, Quancheng, Zhong-kuan, and Pan Zi-kai,”The deceptive effect of blinking decoys on ARMs”.

[10] Weiguangzhoujirunluo, Yuguijiahuabinwang,”Performance evaluation of radar and decoy system counteracting anti-radiationmissile,”IEEE transactions on aerospace and electronic systems, vol.47, no.3, July2011.

[11] Song Zhi-yong, Xiao Huai-tie,Zhu Yi-long and Lu zai-qi,”Discriminate the decoy and target using frequency profile modeling in the radar terminal guidance,”2011,3rd International Conference on signal processing systems(ICSPS 2011), IPCSIT vol.48,2012.

[12] YupengXie, Zhongjie wang, Jiangang Yan, and Yanbo song, “Research on anti-ARM Model with outboard active decoys,”ICSC 2012, partII, CCIS 327, pp.213-220, 2012.

[13] Vllemattila,Kai Virtanen, Lasse muttilainen,Juhajylha and Ville vaisanen,” Optimizing locations of decoys for protecting surface based radar against anti-radiation missile with multi-objective ranking and selection,” Proceedings of the 2014 winter simulation conference,2014 IEEE.

[14] E. Vijaya lakshmi, Dr. N. N. Sastry, Dr.b.Prabhakarrao,”Optimum active decoy deployment for effective deception of missile radars,”IEEE Xplore, vol.1, on page(s) 234-237, 2011.