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THE EFFECT OF SELF SCREENING (STAND ON) JAMMING UPON THE PERFORMANCE OF RADAR DETECTION

MOHAMMED JASIM AL- SUMAIDAEE **(B.D.S., M.Sc. Communication' Engineering)**

Ph.D. Student, Department of ECE, KL University India.

M SIVA GANGE PARASAD **(B.D.S.M.Sc., Ph.D. Antenna and (Wireless Communication))**

Professor, Department of ECE, KL University India.

DHAHIR ABDULHADE ABDULAH **(B.D.S., M.Sc., Ph.D. Computer Science)**

Department of Computer College of Science University of Diyala.

Abstract

There are various types of jammers and self-screening jammers are the most protecting jammers, hence, it will be analyse and optimize all parameters. By calculating the range between target and radar and observing the power transmitted by source station and power received at the radar which has been estimated the crossover range. Jamming interference is usually linearly added to the signal at the receiver input and is therefore called additive interference. In this paper has been going to optimize and enhance the detection for the fixed frequency radar and frequency agility radar in preseume of jamming environment

Keywords: Self Screening Jamming, Radar Detection ,Noise Ampilitude

INTRODUCTION

Electronic countermeasure can be divided into two classes, depending upon whether they are intended primarily for confusion or for deception. The purpose of a confusion countermeasure is to mask or hide real targets by cluttering the radar display. Usually covers more area on the radar display than does clutter. In fact, effective jamming should completely obliterate the radar screen, an example of a confusion countermeasures is high –power CW transmission modulated noise.

The self-screening is found by equating the received signal in the two-way radar to received signal in the one –way transmission.

Differences in bandwidths must be taken into account. Also the received jammer signal power required for effective jamming may be different from received radar signal. Self –screening jammer are a close of ECM systems carried on the vehicles they are protecting, since it has been going for analyzing the parameters of self –screening jammers.

Optimizing of the Detection Capability

In the presence of jamming at self-screening (stand –on) case in this paper has been going to calculate the detection capability for the fixed frequency radar and frequency agility radar in the presence of jamming including the compensation analysis of the detection capability of radar set, when the target (i.e aircraft) is equipped with a jammer in case of self-screening (stand-on).

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Active jamming may be divided into three classes: continuous noise, random pulse noise and regular pulse noise: Any type of jamming reduces the probability of correct signal detection, increases the probabiity of false alarm and reduces measurement accuracy.

1. **Continuous noise:** This kind of interference is most common: It may be used successfully to overwhelm all kinds of radio system in all operating modes and can conceal useful signals on the time and frequency axes, and also their direcion of arrival.

There are some kinds of continuous jamming like:

a. Direct Noise Jamming

Direct-noise jamming most closely approximates Gaussian noise. There are two ways to make direct noise jamming. The first is to use an SHF noise generator. The signals produced at the output of such a generator are amplified and radiated into a space. Gas discharge tube may be used as a primary SHF noise generator. A noise generator consists of a gas discharge tube, a segment of a high-frequency transmission line, and a matching system. Coaxial and waye guide generators are used, depending on the type of high-frequency line employed. Wave guide noise generators are built for 0.2 to 0.10 cm wavelengths, and coaxial for 10-12 to 120-140 cm wavelengths.

The other way to generate direct-noise jamming is to use the heterodyning method to transfer the noise from a low-frequency oscillator to the high frequency range, primary noise sources on low frequencies are directly heated diodes, magnetic field thyratrons and photomultiplier tubes.

b. Amplitude - Modulated Noise Jamming

Amplitude-modulated noise consists of continuous sine waves, amplitude-modulated by noise. Since only the modulation components of the spectrum produce a jamming effect, not more than 50% of jamming power is used for the direct jamming effect in amplitude modulation.

c. Frequency Modulated Noise Jamming

In the case of frequency modulation, the frequency deviation, which is equal to the product of frequency deviation index B_f and the effective spectral width of the modulating voltage B_m(i.e.) $f_{de}=B_f$. B_m when narrow band noise is used for modulation, i.e., when $B_f > >1$, the spectral width of the jamming may be assumed equal to 2f de.

2. **Random pulse noise**: in general, Jamming of this kind may be represented as a burst of radio pulses with a given duty factor, the amplitude and durations of which, and also the spaces between adjacent pulses, change randomly, in practice such Jamming is difficult to produce. It is considerably easier to generate a burst of radio pulses with a constant amplitude and with randomly changing duration and time spaces.

3. **Bursts of regular pulses**: This kind of jamming is multiple synchronous pulses, which consists of a series of radio pulses, radiated in response to a signal received from a radar by an electronic counter measure system. The jamming pulses match the useful signal in terms of shape and duration. The synchronization of the envelopes of jamming pulses relative to

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the radar timing is an important factor. At the same time the jamming differs in several ways from the useful signals. The jamming is usually considerably stronger than the signal (in terms of amplitude (power)) consequently amplitude selection becomes very important in term of ECCM.

Jamming pulses often have a constant amplitude and repetition frequency, which suggests the feasibility of using inter period cancellation system, for example, for countering jamming.

The frequency difference between the signal and jamming may be very important for countering this type of jamming. For example, when coherent processing is used, the frequency of the jamming after the phase detector may be far outside of the passband of its filter.

A change of the pulse repetition frequency from period to period or of the carrier frequency of radar signals is of considerable importance in terms of reducing the effectiveness of jamming. When these steps are taken, the jamming can cancel only regions that are separated from the radar by a distance greater than the distance to the jammer.

Stand-on (self-sucreening)

In this type of jamming, through the main beam as shown in figure (1)

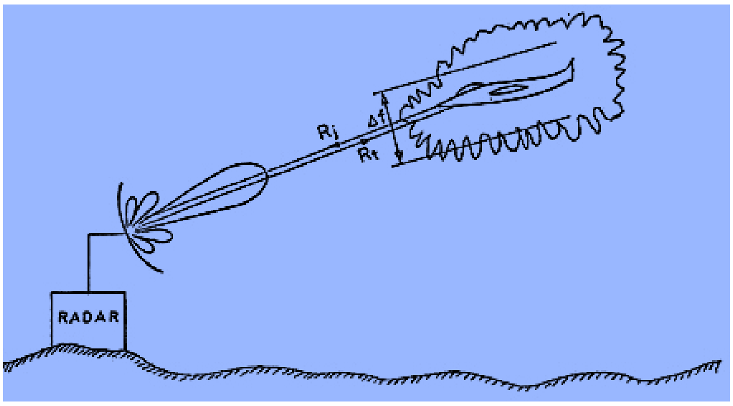

Fig 1: A radar set with airborne jammer

In this case when the jammer is off the classical radar equation is auppoed (in free space)

$$q = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R_t^4 K T_S B} \dots\dots\dots\dots\dots\dots.\dots\dots (1)$$

And with attenuation of atmosphere

$$Q = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R_t^4 e^{-2\alpha R_t} K T_S B} \dots\dots\dots\dots..(2)$$

Where

P_t : The transmitted power in watt

q: Signal – to-noise ratio in dB

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g: Antenna gain of a radar set in dB

λ: Wavelength in meter

R_t: Range from radar set to target in km

K: Boltzmanns constant = $1.38.10^{-23}$. Joule/deg.)

T_s: System noise temperature in. (degree Kalvin)

B: bandwidth of the receiver in MHz

$e^{-2\alpha Rj}$. Two-way attenuation of atmosphere

α: one-way attenuation coefficient

But, if the target switch on his jammer, then the power enering the radar and added to the receiver noise is dependent on the aperture area of the radar and the relative bandwidth of the jammer (spectral frequency of the jammer Δf), and the radar receiver bandwidth B; it is convenient to assume that Δf ≥B otherwise the jammer would be a spot jammer and the radar system response would become intimately involved with the type of signal processing.

At the receiver input, the total noise power is:

$$NT = KT_S B + j \ldots\ldots\ldots\ldots (3)$$

Where:

(J) Is the effective noise which enter across the bandwidth of the receiver and equals to:

$$J = \frac{P_j G_j G_r \lambda^2}{(4\pi)^2 . R_j^2} \cdot \frac{B}{\Delta f} \ldots\ldots\ldots\ldots (4)$$

Then, the signal to total noise ratio is:

$$q_j = \frac{P_t G^2 \lambda^2 \alpha}{(4\pi)^3 . R_j^4 e^{-2\alpha Rj} \left(KT_S B + \frac{P_j G_j G_r \lambda^2}{(4\pi)^2 \, R_j^2 e^{-2\alpha Rj}} \cdot \frac{B}{\Delta f} \right)} \ldots\ldots (5)$$

Where:

qj: Singal-to total noise ratio at jamming environment

Pj: the power of the jammer in watt

Gj: antenna gain of jammer in dB

Gr: antenna receiver gain of radar in dB

Rj: range from jammer to radar set in km

Δf: spectral frequency of jammer in MHZ

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Supposing that there is the same probability of detection, probability of false alarm, and signal –to-noise ration then

$P_d = P_{dj}, P_{faj} = P_{faj}, \quad q = q_j$

Then, by equaling the two equations (5), (4)

$$\frac{1}{(4\pi)^3 R_t^4 e^{-2\alpha Rt}} = \frac{1}{R_j^4 e^{-2\alpha Rj}\left(KT_S B \frac{P_j G_j G_r \lambda^2}{(4\pi)^2 R_j^2 e^{-2\alpha Rj}} \cdot \frac{B}{\Delta f}\right)} \dots\dots\dots..(6)$$

By simpliflying this equation we get:

$$a_1 R_j^4 e^{2\alpha Rj} + a_2 R_j^2 e^{2\alpha Rj} - a_1 R_t^4 e^{\alpha Rt} = 0 \dots\dots\dots\dots\dots\dots\dots..\dots\dots.(7)$$

Where

$$a_1 = KT_S (4\pi)^2 . \Delta f \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..\dots..(8)$$

$$a_2 = P_j G_j G_r \lambda^2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots(9)$$

Finally

$$R_t = \sqrt[4]{\frac{KT_S (4\pi)^2 . \Delta f R_j^4 e^{2\alpha Rj} + P_j G_j G_r \lambda^2 R_j^2 e^{2\alpha Rj}}{KT_S (4\pi)^2 . \Delta f e^{2\alpha Rt}}} \dots\dots\dots\dots\dots.(10)$$

Because the 'jammer is carried by the aircraft so, the dimension of its antenna should be very small for that reason the diameter of the antenna should be not more than 0.50 meter.

$D \le 0.50$ meter

Therefore, we are going to find the gain of jammer according to this value of diameter.

Then:

$$A_{gff} = p . A_{geom} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots\dots.\dots\dots(11)$$

Where

A_{eff} = effective aperture

A_{geom} = geometrical aperture

P: standard coefficient and its value (0.5 -0.7)

Then:

$$A_{geo} = r^2 . \pi \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..\dots\dots(12)$$

Where r is radius of antenna,.

The gain of the jammer will be:

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$$G_j = \frac{4\pi}{\lambda^2} A_{eff} \text{..................}(13)$$

$$G_j = \frac{4\pi}{\lambda^2} Pr^2\pi = \frac{4\pi}{(0.1)^2} . 0.6(0.25)^2\pi \dots\dots\dots\dots\dots\dots (14)$$

Where λ = 0.1m (s band)

Then:

Gj=148 21.7 = 22 dB

For expression (8) has done for showing a range of radar which affected by a jammer against the radar range when there is no jamming is applied. The result is denoted by the fig (2) for fixed frequency radar, and Fig (3) for frequency agility radar according to the following standard values for s-band.

Pj = 10w

λ = 0.1 m

Gr: 30 dB

Gj = 22 dB

K = 1.38 .10^{-23} joul/ deg

To = 290^{o} k

T_A = 100^{o} k

F = 6 d B (noise figure)

Assuming now the probability of detection is not the same, but the detecting range is the same. That means

Rt = Rj

In this case it has been obtained that the signal – to –Noise ratio at jamming environemtn as a function of the power of the jammer.

The classical radar equation when there is no jamming is:

$$R_t^4 = \frac{PG^2\lambda^2\sigma}{(4\pi)^3 q(P_d P_{fa}) KT_S B} \dots\dots\dots\dots\dots\dots\dots\dots (15)$$

In the case of jamming environemtn the radar equation becomes

$$R_t^4 = \frac{PG^2\lambda^2\sigma}{(4\pi)^3 q_j(P_d P_{fa}) \left(KT_S B \frac{P_j G_j G_r \lambda^2}{(4\pi)^2 R_j^2} . \frac{B}{\Delta f} \right)} \dots\dots\dots (16)$$

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By supposing that

$$Rt = Rj \ldots\ldots\ldots\ldots (17)$$

Then:

$$\frac{q_j}{q} = \frac{KT_SB}{KT_SB + \frac{P_jG_jG_r\lambda^2}{(4\pi)^2R_j^2}\cdot\frac{B}{\Delta f}} \ldots\ldots\ldots\ldots (18)$$

Therefore:

$$T_S = T_A + T_O(F - 1) \ldots\ldots\ldots\ldots (19)$$

Where:

Ts = system noise temperature in Kelvin

T_A = antenna noise temperature in ^{o}k

To = standard noise temperature in ^{o}k

F = noise figure of the receiver

Finally:

$$q_j = q.\frac{1}{1 + \frac{P_jG_jG_r\lambda^2}{(4\pi)^2R_j^2\Delta f}\cdot\frac{1}{K(T_A + T_O(F - 1))}} \ldots\ldots\ldots (20)$$

Then:

q = 16.6 dB because we took the probability of detection = 80% and the probability of false alarm = 10^{-6}. Because we have a self-screening case, so the power of jammer which carried by aircraft should be not more than (10w), for this situation a computer program was made and the results were plotted as shown in fig. (4) And (5) by taking the noise figure as a parameter and changed from (2.20) dB. The ploting has done for a signal-to-noise ratio at jamming environment as a function of spectral frequency of jammer in two cases, fixed frequency radar when (Δf) is changed from (5-50) MHz, and frequency agile radar, according to the following standard values for S-band:

Gj = 22 dB

Cr= 30 dB (full gain because it is in the main beam)

Rj= 10^5 m

T_A= 100 ^{o}k

To= 290 ^{o}k

P_d= 80%

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P_{fa}=70-6

q = 16.6 dB

λ = 0.1m

Pj = 10W

K = 1.38 .10^{-23} joul/deg.

Table 1: Fixed Frequency

Radar range (km)	Jamming range (km)	Fixed frequency (MHz)
200	12	5
200	42	50

Table 2: Agile Frequency

Radar range (km)	Jamming range (km)	Agile frequency MHz
200	42	50
200	105	300

Table 3: Fixed Frequency

Spectral frequency Δf (MHz)	Signal –to- noise ratio at jamming environment (db)	Noise figure (db)
50	-35	2
50	-8	20

Table 4: Agile Frequency

Spectral frequency Δf (MHz)	Signal –to- noise ratio at jamming environment (db)	Noise figure (db)
200	-29	2
200	-8	20

CONCLUSION

The frequency agility technique performs signal processing in the video portion of the receiver after phase information has been removed. It can be suggested that target –to- cultter enhancement can be obtained by using pulse –to-pulse frequency agility. In detection and tracking radars frequency agility can reduce the range and angle tracking errors caused by finite target extent and multipath effects. As shows in tables (1), (2) (3) and (4).

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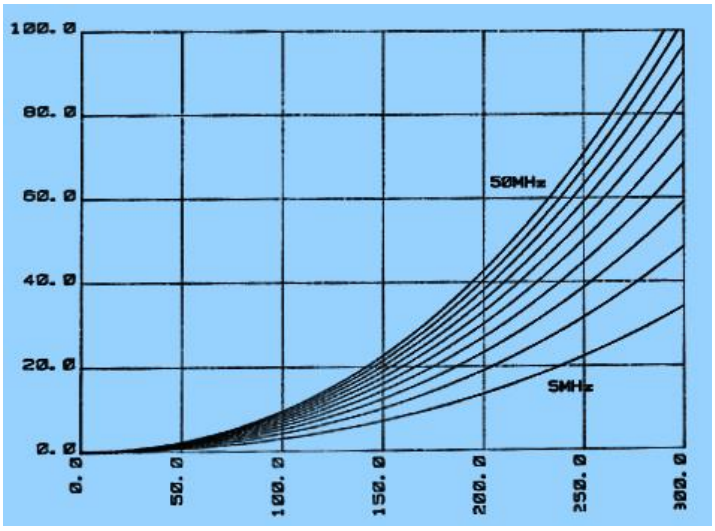
Fig 2: Effect of Jammer on Radar detected Range for Fixed Frequncy Radar

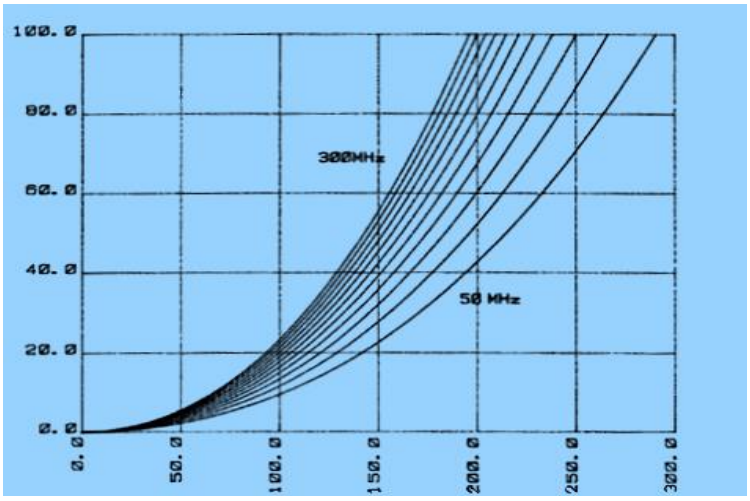
$R_J^{[km]}$



$R_J^{[km]}$

Fig 3: Effect of Jammer on Radar detected Range for frequency Agile Radar

$R_J^{[km]}$



$R_J^{[km]}$

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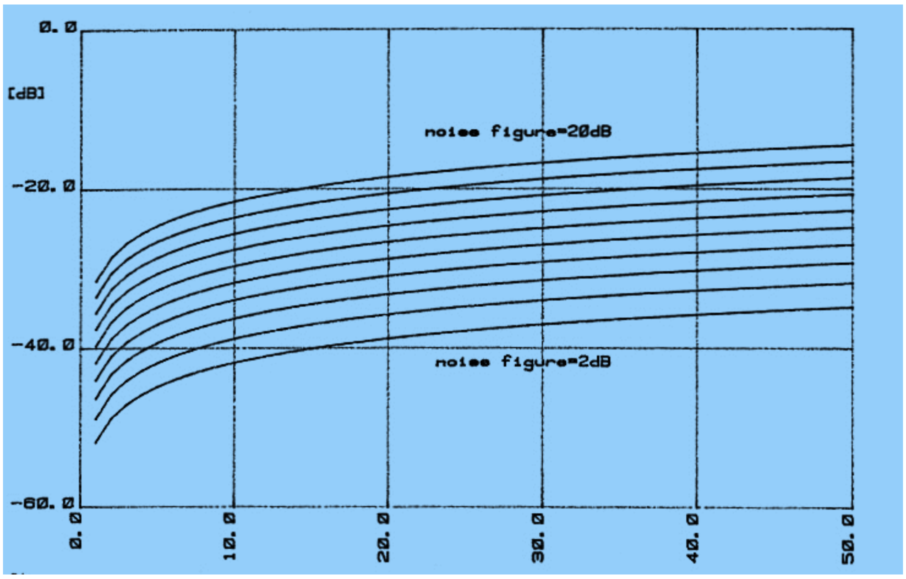
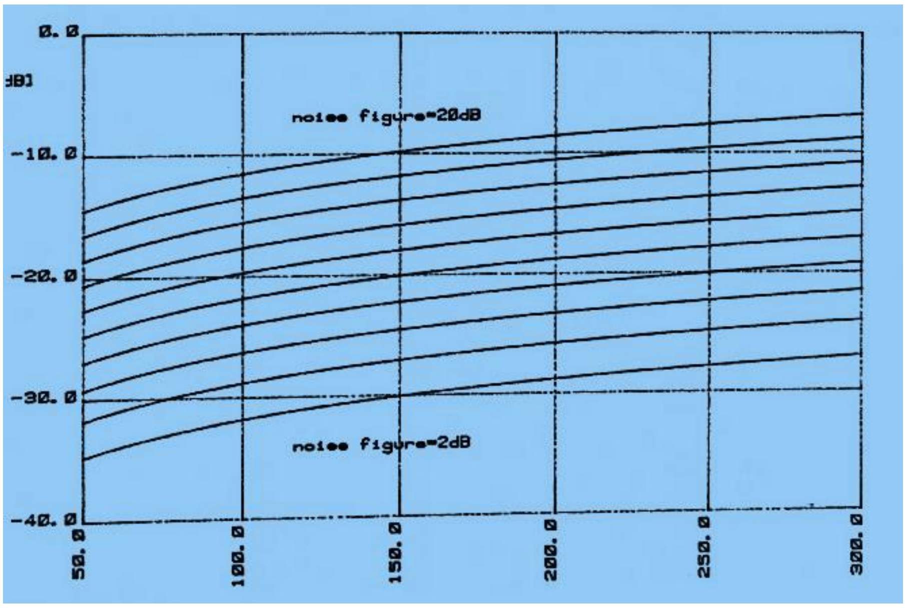
Fig 4: Signal-to-Noise Ratio at Jamming Environment Vs. Spicral Frequency of Jammer for Fixed Frequency Radar



ΔF [MH_Z]

Fig 5: Signal-to-Noise Ratio at Jamming Environment Vs. Spicral Frequency of Jammer for Frequency Agile Radar



ΔF [MH_Z]