



# International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 7, July 2015

## Performance Evaluation of Radar Systems

Akash Kumar Shrivastava, Anirudh Mudaliar

Assistant Professor, Dept. of ETC, SSEC, (SSTC), Bhilai, Chattisgarh, India

Assistant Professor, Dept. of ETC, SSGI, (SSTC), Bhilai, Chattisgarh, India

**ABSTRACT:** After warfare II radio detection has been more and more used as an integral part of complicated applications like air-traffic management, reconnaissance mission and police investigation, navigation and weather, and missile targeting and defence. Analysis of measuring systems for such applications needs representing the radar operation and performance within the context of the system and also the external setting. The measuring system performance should be evaluated, and also the impact of measuring system operation on system performance should be quantified. fashionable measuring system systems area unit procured with tight specifications on an outsized range of various parameters. This paper describes analysis of SNR versus detection vary for various values of RCS conjointly evaluating the performance of various modes of recent measuring systems and discusses the accuracy of that they're capable. it's within the interests each of the client and of the provider that the procedures used appraise measuring system performance area unit mathematically rigorous, precise and as efficient as attainable.

**KEYWORDS:** Modern radar systems, SNR, RCS.

### I. INTRODUCTION

Radar is An instrument that radiates non particulate radiation within the area, that detects and locates of objects. Today, it's wide used for speed estimation, imaging, and plenty of different functions. The principle of measuring device operates likes to undulation reflection. If any wave sound incident on the thing (target) (like rocky ravine and cave), it'll be mirrored and detected, this undulation reflective is termed echo. If sound speed is thought, we will estimate the gap and direction of the objects. measuring device systems area unit composed of a transmitter that radiates magnetic attraction waves of a selected wave shape and a receiver that detects the echo came back from the target. solely a little portion of the transmitted energy is re-radiated back to the measuring device. These echoes can processed by the measuring device receiver to extract target info like (range, speed, direction, position and others).

The vary to the target is evaluated from the travelling time of the wave. The direction of the target is set by the arrival angle of the echoed wave. The relative speed of the target is set from the propagation of the came back signal. measuring device may be classified in terms of ground based mostly, air borne and ship based mostly measuring device systems can also be classified into varied classes supported the particular measuring device characteristics, like the band, antenna sort, and waveforms used, conjointly classified by the categories of waveforms or in operation frequency.

The goal of this paper includes a discussion of many varieties of the measuring device equations, and one in all the equations of theory is that the radar vary equation, together with those most frequently employed in predicting measuring device performance. during this paper, we tend to use MATLAB simulation program to representing the measuring device vary equation, and outline it versus with the signal to noise magnitude relation (SNR) for many selections of parameters (like measuring device cross section – RCS, and peak transmit power – platinum), and their effecting on the detection vary and SNR performance. combined refers to low pulse repetition frequency (PRF), and high PRF.

# International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 7, July 2015

## II. RELATED WORK

In the signal-processing environment, computer simulation is used extensively in developing complex systems, including radar performance systems [1]. Second paper deals with the minimum detection range versus maximum signal to noise ratio (SNR) for several choices parameters like (peak power percent, radar cross section (RCS), antenna gain, coherently pulses, and duty cycle) by using MATLAB simulation program, these programs have been developed to make them easy for any user of evaluating the radar range and SNR equations and make them so faster and more convenient [2]. This paper has presented a modeling scenario which includes multiple-input multiple-output (MIMO radar in a cooperative high altitude aeronautical platforms (HAAPs) relay with conventional radar system . Radar detection range and probability of detection simulation based on cooperative diversity in presence of a fluctuation target model is performed for the cases of single ground radar, with one cooperative HAAP relay and with two cooperative HAAP relays[3]. The RPAS software package developed in MATLAB can be fully integrated into any course with little effort and can provide a viable method for solving problems in engineering and technology curriculum. To analyze the performance of these radars at a system level, it is practical to rely on basic radar principles to model their performance, using the top-level parameters to characterize the radar design. Computer simulation is the most practical method of supporting system analysis due to the complex system interactions between radars and parameters relating to the environment [4]. The transmitted signal for pulse radars are divided into pulse modulated with the fixed carrier frequency signal that is used to measure the range and radial velocity and pulse modulated with compression carrier such as linear frequency modulation (LFM) that is used to improve the range resolution of the radar[5].

## III. RADAR RANGE EQUATION

The distance of the target (object) is determined by traveling of magnetism waves at speed of light-weight,  $C = 3 \times 10^8 \text{ m/sec}$ . The target's vary (R), is computed by measure the time delay Dt , it takes a pulse to travel two means path between the radio detection and ranging and therefore the target, as following :

$$R = \frac{\Delta t \cdot C}{2} \quad (1)$$

The factor of (1/2) is needed for two way time delay. If the respective travel time Dt is known, the distance between a target and the radar can be calculated by using this equation. In general, most functions of radar are time dependent. The time synchronization between the transmitter and receiver of a radar is required for range measurement. Radar radiate each pulse during transmit time or pulse width  $t$ , and wait for returning echoes during listening or rest time, and then radiate the next pulse, as illustrated in figure (1). The time between the beginning of one pulse and the start of next pulse is called pulse repetition time (PRT), and is equal to inverse of pulse repetition frequency (PRF) as follows:

$$PRF = \frac{1}{PRT} \quad (2)$$

The radar transmitting duty cycle ( $d_t$ ) is defined as a ratio ( $d_t$ ) =  $\frac{\tau}{T}$ . The radar average transmitted power is:

$$P_{ave} = P_t \times d_t \quad (3)$$

Where (Pt) indicate to the radar peak transmitted power. The pulse energy is:

$$E_p = P_t \tau = P_{ave} T = \frac{P_{ave}}{f_r} \quad (4)$$

# International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 7, July 2015

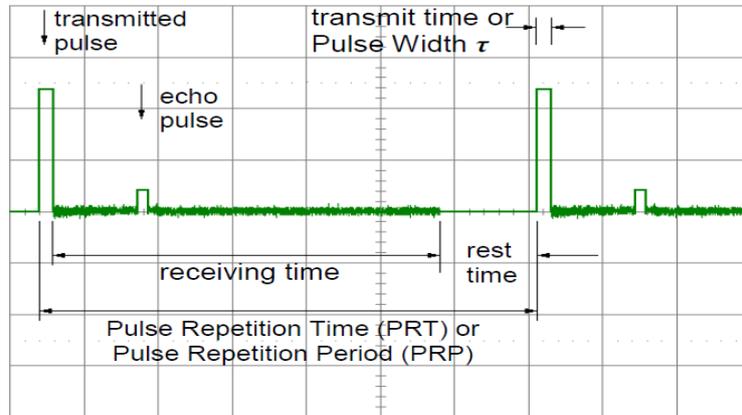


Fig1.- Transmitted and received pulse

## IV. THEORETICAL MINIMUM DETECTION RANGE AND MAXIMUM SNR EQUATION

The radar range equation is not derived from first principle, but it has been developed from several steps. The total peak power (watts) developed by the Radar Transmitter ( $P_t$ ), is applied to the antenna system. Consider the antenna had an isotropic or omnidirectional radiation pattern (one that radiates energy equally in directions), the power density ( $P_D$ ) at a distance ( $R$ ) from the radiating antenna would be the total power divided by the surface area of a sphere of radius ( $R$ ).

$$(P_D) = \frac{\text{Peak transmitted power (watt)}}{\text{Sphere area (m}^2\text{)}}$$

The power density at range ( $R$ ) away from the radar:

$$P_D = \frac{P_t}{4\pi R^2} \quad (5)$$

Where ( $P_t$ ) = The peak transmitted power

$4\pi R^2$  = The area of sphere of radius ( $R$ )

Radar systems use a directional antenna pattern in order to concentrate the power density in a certain direction, which is usually characterized by the gain ( $G$ ) and the antenna effective aperture ( $A_e$ ) they are related by:

$$A_e = \frac{G\lambda^2}{4\pi} \quad (6)$$

The antenna gain ( $G$ ) is directly proportional to aperture, and the dimensions of an antenna depend on the gain ( $G$ ) and wavelength ( $\lambda$ ). The higher the frequency, the smaller the antenna, or the higher is its gain by equal dimensions. The relationship between the effective of antenna aperture ( $A_e$ ) and aperture ( $A$ ) is,

$$A_e = \rho A \quad \text{where } 0 \leq \rho \leq 1$$

$\rho$  is indicated to aperture efficiency, when  $\rho = 1$ , the gain in transmitting is equal to receiving. When using a directive antenna of gain ( $G$ ), then the power density is given by:

# International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 7, July 2015

$$P_D = \frac{P_t G}{4\pi R^2} \quad (7)$$

When the incident transmitted signal collide on the target, the signal will induce time varying currents on the target so that the target now becomes a source of radio waves, part of which will propagate return at the radar, the power reflected by the target toward the radar ( $P_r$ ) is defined as the product of the incident power density and the Radar cross section (RCS), which is symbolized ( $\sigma$ ) of the target, and is given by:

$$P_r = P_D \times \sigma \quad (8)$$

By substituting equation (7) in equation (8), we get:

$$P_D = \frac{P_t G \sigma}{4\pi R^2} \quad (9)$$

When the signal reflected from the target toward the radar systems over a distance ( $R$ ), the power density ( $P_{Dr}$ ) return at the radar is:

$$P_{Dr} = \frac{P_r}{4\pi R^2} \quad (10)$$

By substituting equation (9) in equation (10) we get:

$$P_{Dr} = \frac{P_t G \sigma}{(4\pi)^2 R^4} \quad (11)$$

The total power received ( $S$ ) by antenna receiving of effective area of ( $A_e$ ) from a target at range ( $R$ )

$$S = P_{Dr} \times A_e \quad (12)$$

From equations (6, 11, 12) we get:

$$S = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4} \quad (13)$$

The received power ( $S$ ) can be written in terms of signal-to-noise ratio (SNR), and thermal noise power ( $kT_0BF$ ), where ( $k$ ) is Boltzmann's constant and is equal to  $1.38 \times 10^{-23}$ , ( $T_0$ ) is the noise temperature of the radar, ( $B$ ) is the noise bandwidth of the radar receiver and noise figure ( $F$ ), Substituting in to equation (13), we get:

$$S_{\min} = kT_0BF(SNR)_{0_{\min}} \quad (14)$$

From equations (13) and (14) we get:

$$R_{\max} = \left[ \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 kT_0BF(SNR)_{0_{\min}}} \right]^{\frac{1}{4}} \quad (15)$$



# International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 7, July 2015

Or equivalently:

$$SNR_{\min} = \left[ \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 k T_0 B F R^4} \right] \quad (16)$$

SNR is signal to noise ratio units in decibel (*dB*), when transform the units from system international of units (*SIU*) to *dB* we use the relationship:

$$dB = 10 \log_{10}(SIU)$$

And inversion, when transform from (*dB*) to (*SIU*) we use:

$$SIU = 10^{\frac{dB}{10}}$$

## V. SIMULATION RESULTS

There are the various input and output parameters are required to obtaining the plot which is show in Table 1.

SYMBOL	DESCRIPTION	UNITS	STATUS
$P_t$	Peak Power	Watts	INPUT
$G$	Antenna Gain	<i>dB</i>	INPUT
$\sigma$	Target Cross Section	$m^2$	INPUT
$T_0$	Effective noise temperature	Kelvin	INPUT
<b>B</b>	Bandwidth	Hz	INPUT
<b>Loss</b>	Radar Loss	<i>dB</i>	INPUT
<b>Range</b>	Target Range (Can be either a single value or a vector)	meters	INPUT
<b>SNR</b>	SNR	<i>dB</i>	OUTPUT

Table 1. Various Input and Output Parameters

Here various parameters like peak power, antenna gain, target cross section, effective cross section, band width, different types of radar loss are taken as an input & SNR (Single value or a vector, depending on the input range) are the output. Figure (2) and (3) represent the equations (15 and 16), which are programmed by MATLAB simulation, observation of these plots shows the detection range versus SNR or (SNR versus detection range) for several choices like peak transmit power, antenna gain, and RCS. Can be seen that the detection range increases exponentially with SNR decreases.

In Fig. 2 takes three different transmitting power or peak power 3.6 MW, 2 MW and 0.8 MW. observation of those plots shows the detection vary will increase exponentially with SNR decreases. we observe that the curve lines are separated and spaced between them which is very clear and significant, which represents the detection range be approaching each other and there is a little different.

# International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 7, July 2015

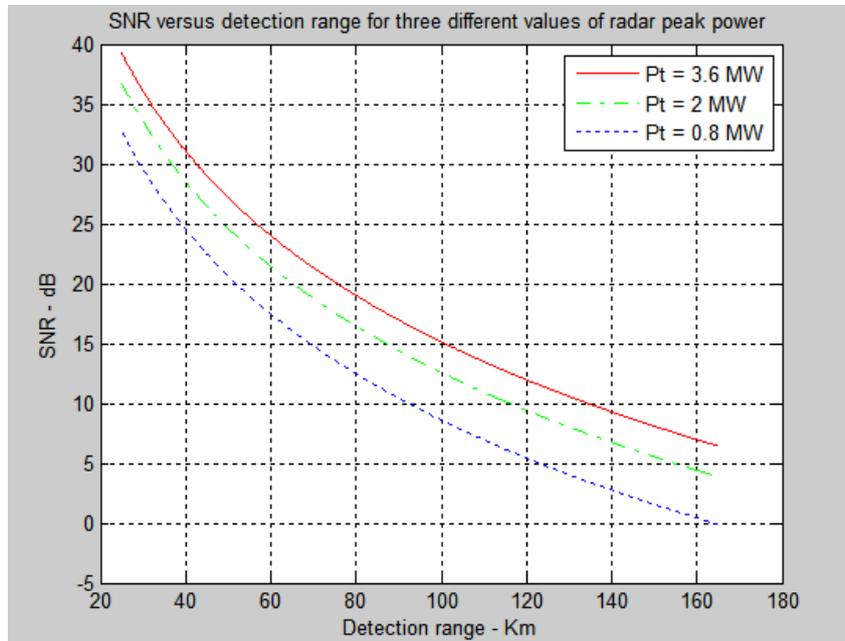


Fig2. SNR versus Detection range for three different values of Radar peak power

Also we found that the peak power has a little effect on improving the detection range or SNR when compared with other radar parameters such as RCS and antenna gain, because the transmitted and received signal power is proportional to the fourth power of the range while in communication systems is proportional to square power of the range, that means the radar's received energy drops with the fourth power of the distance. In this case, the radar needs high power often in MWatt to be effective at long range.

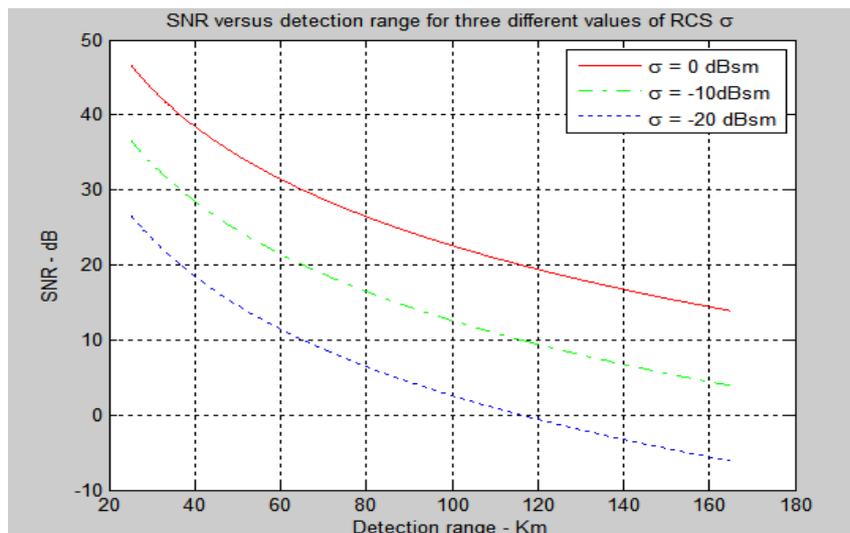


Fig3. SNR versus Detection range for three different values of RCS

# International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 7, July 2015

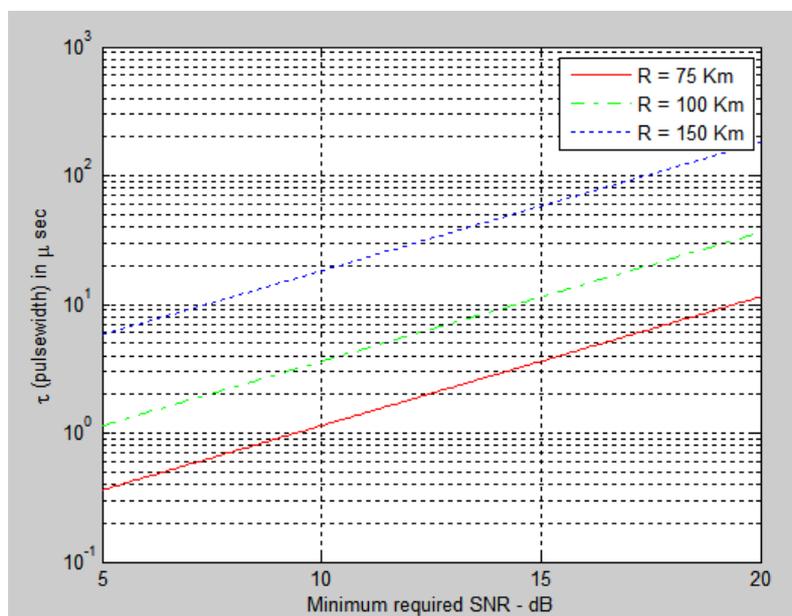


Fig4. Pulse width versus required SNR for three different detection range values

Figure (4) represents analysis of Pulse width versus required SNR for three different detection range values.

## VI. CONCLUSION AND FUTURE WORK

These programs have been developed to make them so easy and faster for all users to determine the detection range and signal to noise ratio – SNR for several choices parameters as a function of the radar range equations. They used to plot curves of detection range versus SNR for several choices parameters.  $SNR_{min}$  is the minimum detectable SNR of the system. It is an important relationship for radar designers. If greater detection range is desired, then significant improvements to antenna gain or transmitted power must be realized, and the other parameters are often fixed.

## REFERENCES

- [1] G. Desodt, D. Muller, D. Puzenat, "OSCAR, a simulation environment dedicated to the design and performance assessment of RADAR system, "International Conference on Radar, Paris, 1994.
- [2] Sulaiman H. M. Al Sadoon<sup>1</sup>, Badal H. Elias<sup>2</sup> "Radar theoretical study: minimum detection range and maximum signal to noise ratio (SNR) equation by using MATLAB simulation program" 2013; 2(4): 234-241 Published online July 20, 2013 doi: 10.11648/j.ajmp.20130204.20
- [3] Ashagrie Getnet Flattie," Performance Evaluation of MIMO Cooperative Radar by Considering High Altitude Aeronautical Platforms" International Conference on challenges in IT, Engineering and Technology (ICCIET'2014) July 17-18, 2014 Phuket (Thailand).
- [4] Ying Roger Lee and Asad Yousuf," Radar performance analysis system: A software package of learning simulations for electronic laboratories" journal of applied science and engineering technology 2007.
- [5] Andreas Arnold-Bos, Student Member, IEEE, Ali Khenchaf, Associate Member, IEEE, and Arnaud Martin, Member, IEEE "Bistatic Radar Imaging of the Marine Environment—Part II: Simulation and Results Analysis" IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 45, NO. 11, NOVEMBER 2007.
- [6] Mahmud A. Al-Zubaidy, Samaa K. Al-Saffar " Targets Signals Simulation in Radar System" International Journal of Emerging Science and Engineering (IJESE) ISSN: 2319-6378, Volume-2, Issue-1, November 2013"
- [7] Nathanson, F.E.: 'RADAR DESIGN PRINCIPLES' (McGraw- Hill, New York, 1969), pp.452-469