Accurate Multistatic Radar Stealthy Aircraft Detection Using Monte-Carlo Simulation

Hassan El-Kamchouchy, Khaled Saada, Alaa El-Din Sayed Hafez
Electrical Engineering Department, Faculty of Engineering, Alexandria University, Alexandria, Egypt
El-Kamchouchy@ieee.org, Khaledsaada@yahoo.com, and Alaahafez@ieee.org

***Abstract*—** In this paper a system geometry with two transmitters and six receivers is used to extends the radar stealthy aircraft detection . Monte-Calro simulation for the stealthy aircraft RCS is used from accurate RCS estimation in the literature [1]. Radar systems, based on Multistatic radar concept attracted a substantial attention in the recent years. The simulation of the geometrical structure is studied with different radars spacing to extend the detection coverage over the Monostatic radar used for air surveillance. The radar detection coverage is also studied with all possible stealthy aircraft paths to find the improvement achieved from using this type of radar. The simulation is done using Matlab program. The results show a non-ideality differences between constant and fluctuated target RCS which reflect that this effect may be increase the S/N in critical or degrade it in other situations. The achieved SNR from these system geometries guarantee a high probability of detection for small and stealthy aircraft detection.

***(Pt.9)Keyword*—**

I. INTRODUCTION

Multistatic radar uses antennas at different locations for transmission and reception. This means that the transmitter and receiver are not co-located in the same place. There are different versions of Multistatic radar system does not specify how far the transmitting and receiving sites must be separated. In recent years, an extended growth of activities in the area of radar systems, based on the concept of the Multistatic radar is reported from many research centers and universities. Hassan El-Kamchouchy [1] presents the design and simulation of Multistatic and netted radars geometries. The simulator places few limits on the simulated system, and supports systems with arbitrary numbers of receivers, transmitters, and scatterers. Bezousek et. al. [2] described the Multistatic arrangement system with non-cooperative transmitters and various aspects of signal processing and signal parameters. Benson [3] investigates modeling method to optimize the location of receivers in order to achieve maximum coverage of aircraft moving around Cape Town International Airport. Several researches deal with improving the detection coverage using Multistatic radar systems [4-6]. These researches didn't study the radar coverage with different system geometry and various radar spacing. In this paper a system geometry with two transmitters and six receivers is used to extends the radar stealthy aircraft detection . Monte-Calro simulation for the stealthy aircraft RCS is used from accurate RCS estimation in the literature [1]. The simulation of the geometrical structure is studied with different radars spacing to extend the detection coverage over the Monostatic radar used for air surveillance. The radar detection coverage is also studied with all possible stealthy aircraft paths to find the improvement achieved from using this type of radar. The radar detection coverage is also studied with all possible stealthy aircraft paths to find the improvement achieved from using this type of radar. The first section of the paper introduces theoretical description of the Multistatic radar. The second section presents the simulation results and the findings from this paper. The last section displays the conclusion of the paper.

Manuscript received February 12, 2013. This work was supported in part by the Electrical Engineering Department, Alexandria University, Alexandria, Egypt.

Hassan El-Kamchouchy, Professor of the Communications, Faculty of Engineering, Alexandria University, Alexandria, Egypt.
(Email: El-Kamchouchy@ieee.org)
Khaled Samir Saada, Ph.D. student, Faculty of Engineering, Alexandria University, Alexandria, Egypt.
(Email: Kaledsaada@yahoo.com)
Alaa El-Din Sayed Hafez, Affiliate Instructor, Faculty of Engineering, Alexandria University, Alexandria, Egypt.
(Email: Alaahafez@ieee.org).

II. THEORETICAL BACKGROUND

A Multistatic radar system contains multiple spatially diverse Monostatic radar or bistatic radar components with a shared area of coverage. An important distinction system based on these individual radar geometries is the added requirement for some level of data fusion to take place between component parts. The spatial diversity afforded by Multistatic systems allows for different aspects of a target to be viewed simultaneously. The potential for information gain can give rise to a number of advantages over conventional systems. Multistatic radar is often referred to as 'Multisite' or 'netted' radar. Fig. 1. shows the idea of using all available sources of transmission for target localization and co-located receiver module, [7]. An obvious advantage of separating the receiver and the transmitter is that the receiver is passive and difficult to locate and which doesn't make it a target for e.g. Anti Radiation Missiles (ARM). Personnel are safe from

ARM when located at the Rx. Separation also has effect on the effectiveness of Electronic Counter Measures (ECM) since the Tx and Rx are not co-located and therefore the Rx may be outside the main-lobe of the jammer or even outside the Line Of Sight (LOS). Since the receiver is not readily discovered it is suitable for covert operations. Several receivers can operate without disclose of their positions with the transmitter stand off by a large distance. Relations of Signal to Noise ratio (S/N) will be discussed. The range equation for a bistatic radar is derived in a manner completely analogous to that for a Monostatic radar. With this analog, the bistatic radar maximum-range equation can be written as [8-9],

$$(R_T R_R)_{\max} = \left(\frac{P_T G_T G_R \lambda^2 \sigma_t F_T^2 F_R^2}{(4\pi)^3 K T_s B_n (S/N)_{\min} L_T L_R} \right)^{\frac{1}{2}} \quad (1)$$

where R_T, R_R are the transmitter and reciever to target range respectively, P_T is the transmitted power, G_T, G_R are the transmit and receive antenna power gain respectively, λ is the transmitted signal wavelength, σ_t is the bistatic radar cross section, F_T, F_R are the transmit and receive propagation factor respectively, K is the Boltzmann constant, T_s is the receive system noise temperature, B_n is the noise bandwidth of the receiver, S/N is the signal to noise ratio and L_T, L_R, are the transmit and receive system losses. The Multistatic from the radar equation is developed to evaluate Multistatic radar sensitivity properties. A fully coherent radar network is considered, which means that the radars comprising the whole network have a common and highly precise knowledge of time and space. The whole radar network is composed of m transmitters and n receivers. It is assumed that the whole network is well synchronized and works cooperatively such that each receiver is capable of receiving echoes due to any transmitters in the network. Under these assumptions, it is reasonable to calculate the overall radar sensitivity by summing up the partial signal to noise ratio, which is given by, [10].

$$(S/N)_{netted} = \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{P_{Ti} G_{Ti} G_{Rj} \lambda_i^2 \sigma_{tij} F_{Ti}^2 F_{Rj}^2}{(4\pi)^3 K T_s B_{ni} R_{Ti}^2 R_{Rj}^2 L_{Ti} L_{Rj}} \quad (2)$$

Considering the simplest case where the radar parameters for every transmitter-receiver combination are the same, the Multistatic radar equation can be simplified as,

$$(S/N)_{netted} = \frac{P_T G_T G_R \lambda^2 \sigma_t F_T^2 F_R^2}{(4\pi)^3 K T_s B_n L_T L_R} \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{1}{R_{Ti}^2 R_{Rj}^2} \quad (3)$$

From this equation it is clear to see that the Multistatic radar geometry, i.e. the positions of target and radar in the network, will have great influence on the overall Multistatic radar sensitivity.

III. The Multistatic Radar System Geometry

The system geometry are demonstrated in Fig. 2. The system geometry consists of two transmitters and six receivers. The spacing between radar stations is constant for the system geometry. The coordinate system must be converted for each radar station according to the following equations,

$$R_{yref} = R_{ref} \cos(\theta_{ref})$$
$$R_{xref} = R_{ref} \sin(\theta_{ref})$$
$$R_{y2} = R_{yref}$$
$$R_{x2} = R_{xref} - a$$
$$R_{y3} = R_{yref} + 2a$$
$$R_{x3} = R_{xref}$$
$$R_{y4} = R_{yref} + 2a$$
$$R_{x4} = R_{xref} - a$$
$$R_{y5} = R_{yref} + a$$
$$R_{x5} = R_{xref} + a$$
$$R_{y6} = R_{yref} + a$$
$$R_{x6} = R_{xref} - a$$
$$R_{yx1} = R_{yref} + a$$
$$R_{xx1} = R_{xref}$$
$$R_{yx2} = R_{yref} + a$$
$$R_{xx2} = R_{xref} - a$$

IV. Simulation Results

The system geometries are simulated under Matlab program environment to obtain the radar sensitivity under the proposed conditions, and demonstrate all possible radar spacing to achieve an optimum radar arrangement satisfying the optimum detection. The radar transmitter parameters are illustrated in table 1. Multistatic radar system geometry are simulated with radar spacing from 5 Km to 70 Km for aircraft range from 50 Km to 140 Km. It is found that the optimum radar spacing for the system geometry is 50 Km. Fig. 3 shows Received S/N at different azimuth angels and target ranges with Stealthy aircrafts (a) RCS= 0.025 m2 G1, (b) Accurate Monte-Carlo Values. Fig. 4. shows Received S/N at different radar spacing and azimuth for system geometry with stealthy Aircrafts, (a) RCS= 0.025 m2 G1, (b) Accurate Monte-Carlo Values. Fig. 5. shows S/N differences between monostatic and multistatic radar (a) Radar Range,

(b) Radar Spacing. It is concluded that the S/N fluctuation from actual and ideal situations in the range of 5 dB tolerances.

TABLE I
Radar Transmitter Parameters

Parameter	Value
P_T (Kwatt)	200
G_T, G_R (dB)	33
F (MHz)	2450
B_n (MHz)	1
F_T, F_R	1
L_T, L_R (dB)	5

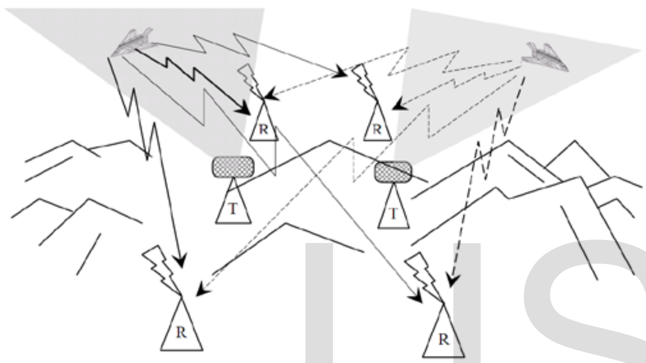


Fig. 1. The combined use of available sources in the process of producing the air picture

V. Conclusion

The paper study a system geometry with two transmitters and six receivers is used to extends the radar stealthy aircraft detection . Monte-Calro simulation for the stealthy aircraft RCS is used from accurate RCS estimation in the literature [1]. The simulation of the geometrical structure is studied with different radars spacing to extend the detection coverage over the Monostatic radar used for air surveillance. The radar detection coverage is also studied with all possible stealthy aircraft paths to find the improvement achieved from using this type of radar. The simulation is done using Matlab program. The results show a non-ideality differences between constant and fluctuated target RCS which reflect that this effect may be increase the S/N in critical or degrade it in other situations. The achieved SNR from these system geometries guarantee a high probability of detection for small and stealthy aircraft detection.

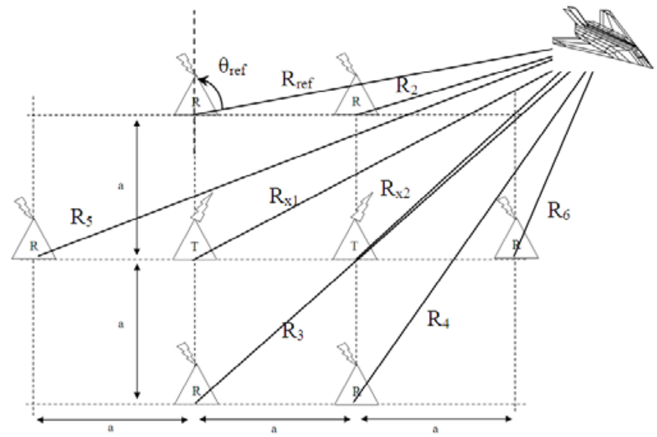
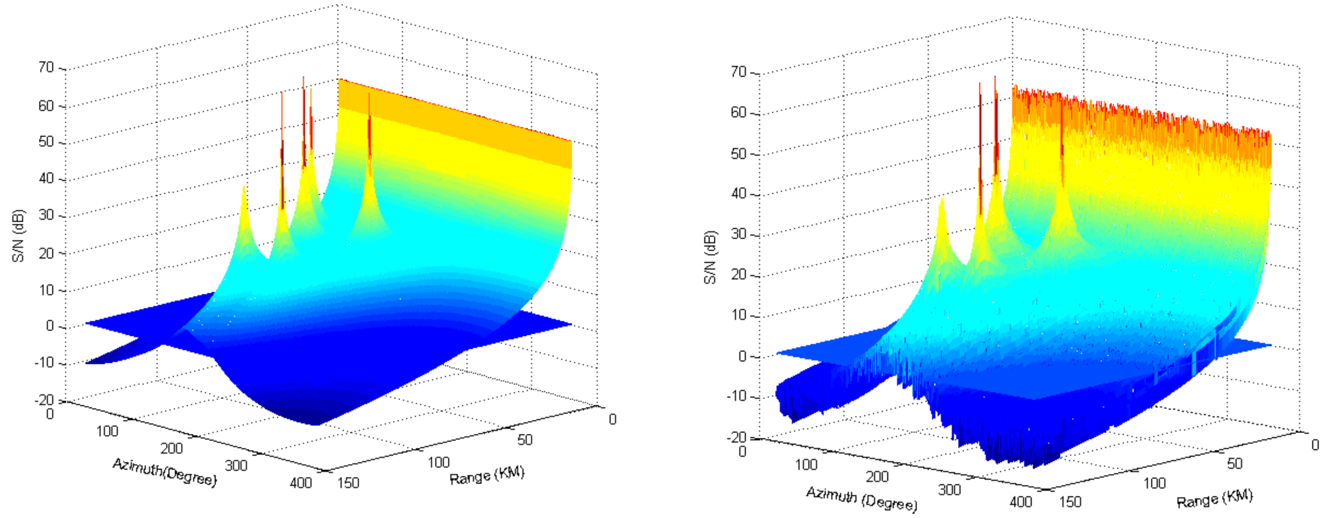
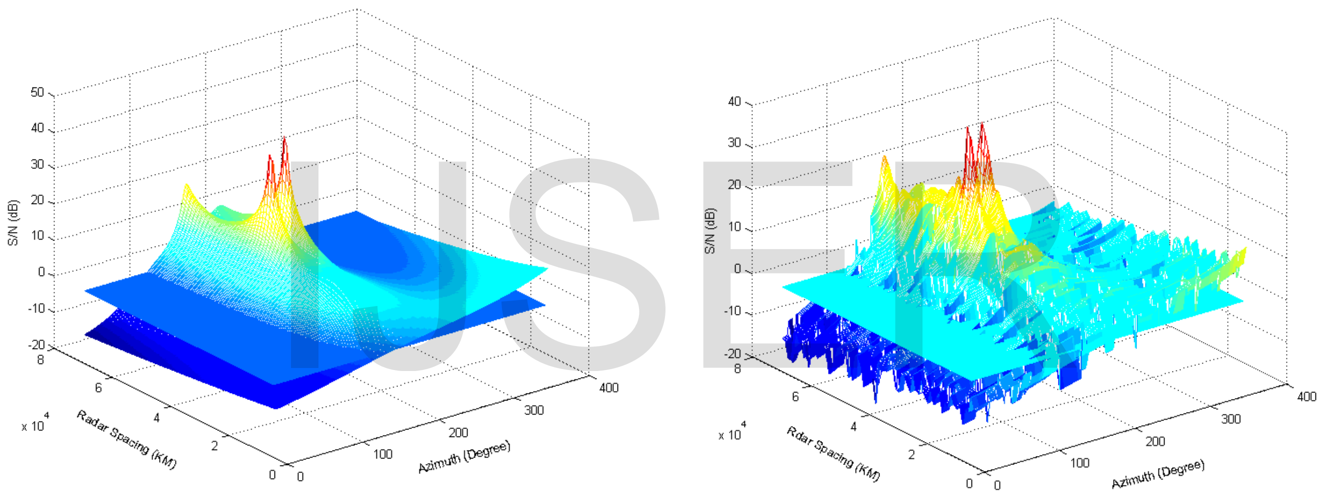


Fig. 2. Multistatic Radar System Geometry



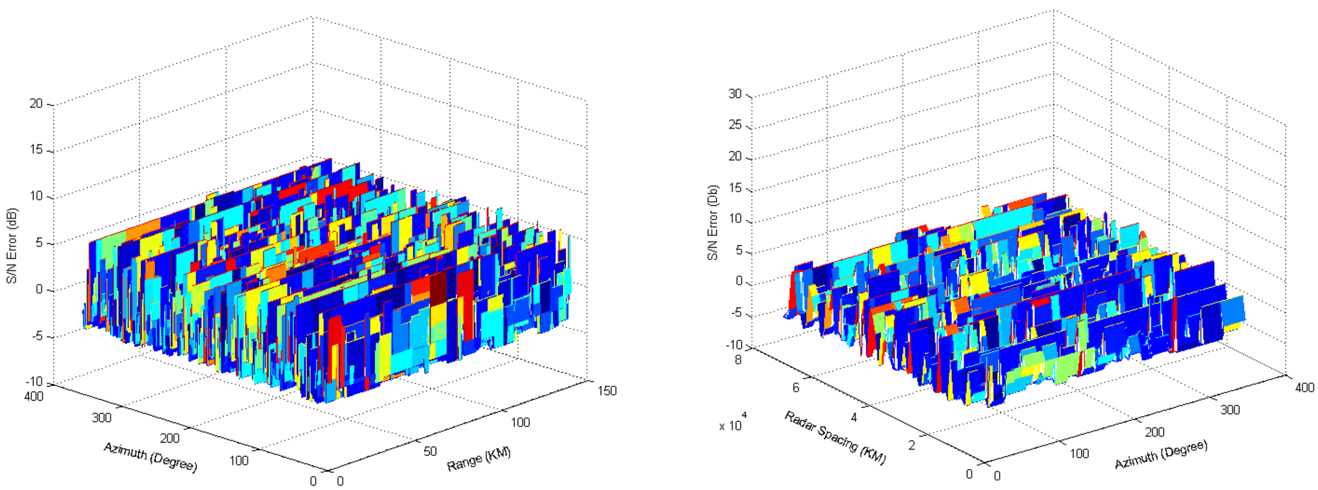
(a) (b)

Fig. 3 Received S/N at different azimuth angels and target ranges with Stealthy aircrafts (a) RCS= 0.025 m^2 G1, (b) Accurate Monte-Carlo Values



(a) (b)

Fig. 4. . Received S/N at different radar spacing and azimuth for system geometry with stealthy Aircrafts, (a) RCS= 0.025 m^2 G1, (b) Accurate Monte-Carlo Values



(a) (b)

Fig. 5. S/N differences between monostatic and multistatic radar (a) Radar Range, (b) Radar Spacing

REFERENCES

[1] Alaa El-Din Hafez, Hassan El-Kamchouchy, Khaled Saada," Optimum Stealthy Aircraft Detection Using a Multistatic Radar," ICACT Transactions on Advanced Communications Technology (TACT), Volume2 Issue6, November 2013.

[2] Pavel Bezousek, Vladimir Schejbal," Bistatic and Multistatic Radar Systems," Radioengineering, Vol. 17, No. 3, Sep. 2008.

[3] Benson Chan, " Receiver Site Optimisation for Passive Coherent Location (PCL) Radar System,"Graduation Project, University of Cape Town, Oct., 2008.

[4] Vladimír S., Dušan Č., Zdeněk N., Jan P., Jiří K., Pavel B., Ondřej F.," Multipath Propagation of UWB Through-Wall Radar and EMC Phenomena," Radioengineering, Vol. 15, No. 4, Dec. 2006.

[5] Pavel Bezoušek, Marek Pola, Jan Pidanič," Detection of Multiple Targets by a Multistatic Radar," Number 4., Volume IV., Dec. 2009.

[6] Steven Kay," Waveform Design for Multistatic Radar Detection," Dept. of Electrical, Computer, and Biomedical Engineering, University of Rhode Island Kingston, RI 02881, 2007.

[7] Terje Johnsen and Karl Erik Olsen," Bi- and Multistatic Radar," Advanced Radar Signal and Data Processing Educational Notes RTO-EN-SET-086, Paper 4. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp, visited Oct. 2010

[8] Merril I. Skolnik," Radar Handbook, Second Edition," McGraw-Hill, 1990

[9] Bassem R. Mahafza," Radar Systems Analysis and Design Using MATLAB," CRC Press, USA, 2000

[10] Chris Baker, "Multistatic radar processing and systems," Advanced Radar Signal and Data Processing Educational Notes RTO-EN-SET-133, Paper 4. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp, visited Oct. 2010

Biographies

Hassan El-Kamchouchy is professor in Faulty of Engineering, Alexandria University, Alexandria, Egypt. He holds B.Sc. in Electronics and Communications from Faculty of Engineering, Alexandria University, He also holds M.Sc. and Ph.D. in Electrical Engineering from Faculty of Engineering, Alexandria University. He received many technical courses in Electronic system design and Implementation, work as System Engineer for more than 20 years, teach up to 30 undergraduate subjects, supervising more than 75 thesis, publish more than 150 papers in different international conferences and Journals

Khaled Samir Saada is a Post Graduate Studen (Ph.D.), Alexandria University, Alexandria, Egypt. He holds B.Sc. in Electronics and Communications from Faculty of Engineering, Alexandria University, M.Sc. in Electrical Engineering from Faculty of Engineering, Alexandria University. He received many technical courses in electronic engineering design and Implementation.

Alaa El-Din Sayed Hafez is an affiliate instructor in Faulty of Engineering, Alexandria University, Alexandria, Egypt. He holds B.Sc. in Electronics and Communications from Faculty of Engineering, Alexandria University, M.Sc. in Electronics and Communication from Arab Academy for Science and Technology and Maritime Transport, Alexandria. He also holds M.Sc. and Ph.D. in Electrical Engineering from Faculty of Engineering, Alexandria University. He received many technical courses in Surveillance Radar design and Implementation, work as Radar System Engineer for more than 5 years, teach up to 20 undergraduate subjects, supervising more than 12 thesis, publish more than 40 papers in different international conferences and journals.