A Computational Method of Radar Jamming Cover Area for Aerial Platform Radar Countermeasures

Honghao Zuo[1, a]

[1]Electronic Engineering Institute, Hefei, 230037, China

[a]email: zuohefei@tom.com

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Abstract. There are more meaning of researching the operational efficiency of aerial radar jamming equipments and the method of using them than ever while the new aerial equipments have been widely used in air force. A novel computational method of Radar Jamming cover area is proposed in this paper, which is different from two traditional ways: exposure area method and radar's detection coverage method. Considering the different spatial relationship among the radar jammer, the cover area and the target radar, which is formed in the situation of air to air jamming and air to ground jamming, the computational method of aerial platform radar jamming cover area based on basic radar equation is given. The simulation experiments testify the new method is effective.

Introduction

Radar jamming and deception is the intentional emission of radio frequency signals to interfere with the operation of a radar by saturating its receiver with noise or false information [1][2]. Conventional radar jammer implements its combat operation by two ways, ground to ground and ground to air. Generally there are two ways to research the radar jammer's combat effectiveness. One is the exposure area of the covered target [3][4]. The other is radar detection coverage after being jammed [5]. A third way of radar jamming cover area (RJCA below) is proposed by author [6]. The computation method has some limitation in the case because ground to air modal is the only combat background that is considered in the paper. Nowadays, more and more aerial platform radar jammers are available in military troops, such as electronic warfare support aircraft, electronic warfare UAV, and airborne jammer nacelle and so on. It is important to help the air force commanders to deploy the power effectively.

It is arranged below: In Section II the definition and meaning of RJCA is introduced. Considering the different spatial relationship among the radar jammer, the cover area and the target radar, which is formed in the situation of air to air jamming and air to ground jamming, the computational method of aerial platform radar jamming cover area is given in Section III. In Section IV the simulation experiment results including   sectional views of horizontal and vertical are given. In the end the conclusion is given.

Radar Jamming Cover Area

RJCA is a new term for the moment and its definition hasn't been given out by authority. It was firstly introduced by Luo and Li [6]. Radar jamming cover area is the three-dimensional space, where the covered target can't be detected normally by the specified radar when radar countermeasures are running [7]. The RJCA is a diorama surrounding the jammer. The RJCA varies with different distance between jammer and radar and their parameters. The RJCA which joint operations commanders concerned in ground to air defense operation is a plane on the surface, while the RJCA which air force commanders concerned in air-to-air combat or air-to-ground combat is a three Dimension surrounding the jammer. Its concerning field expands from plane to 3D.

The RJCA varies according to the different spatial relationship among the radar jammer, the cover area and the target radar.   There are some laws when the parameters vary. If there is only one

variable in all parameters, the power of jammer is bigger, the size of RJCA is bigger. If the location of radar, jammer is constant, the radar cross section (RCS) of the covered target is bigger, the size of RJCA is smaller. If the RCS of the covered target is constant, the distance between radar and jammer is farer, the size of RJCA is bigger.

Although the tactical background of RJCA varies, the computational principle of RJCA is constant. Keeping the wholeness of the article, the computational principle of RJCA is repeated as below which is excerpted from [7].

Considering air-to-air and air-to-ground model, the computational principle of radar jamming cover area can be made as below.

It is assumed that radar antenna is aiming at the covered target and the vertical plane passing through the radar antenna and the covered target is a symmetrical plane on antenna pattern.

Based on radar equation, calculation method of RJCA is given as (1):

$\forall$ point $C \in \{RJCA\}$, it should satisfy:

$$\frac{P_{rj}}{P_{rs}} \geq K \tag{1}$$

where, P_{rs} is the power radar received from the target reflecting; P_{rj} is the power radar received from the jammer emitting; K is a suppression coefficient assigned by user in different situation.

From the basic radar equation, it can be concluded as below:

$$P_{rs} = \frac{P_t G_t \sigma A}{\left(4\pi R_t^2\right)^2} = \frac{P_t G_t \sigma \lambda^2}{\left(4\pi\right)^3 R_t^4} \tag{2}$$

where, $P_t G_t$ is radar equivalent radiation power; σ is RCS of the target; R_t is the distance between radar and the target; A is radar antenna equivalent receive area; λ is radar working wavelength.

$$P_{rj} = \frac{P_j G_j G_t^{'}(\theta_1, \varphi_1) \lambda^2 r_j}{(4\pi R_j)^2} \tag{3}$$

where, $P_j G_j$ is jammer's equivalent jamming power; R_j is the distance between radar and the jammer; r_j is polarization loss; $G_t^{'}(\theta_1, \varphi_1)$ is radar antenna gain at direction of aiming jammer.

From (1),(2),(3), we can get:

$$\frac{P_j G_j}{P_t G_t} \cdot \frac{4\pi r_j}{\sigma} \cdot \frac{G_t^{'}(\theta_1, \varphi_1)}{G_t} \cdot \frac{R_t^4}{R_j^2} \geq K_j \tag{4}$$

In (4) all parameters value is given except $G_t^{'}(\theta_1, \varphi_1)$. The radar array antenna model is given as below:

$$G(\theta_1, \varphi_1) = G_0 \sin c^2 \left(\frac{M d_x \pi}{\lambda} \sin \theta_1\right) \cdot \sin c^2 \left(\frac{N d_y \pi}{\lambda} \sin \varphi_1\right) \tag{5}$$

where, G_0 is radar main lobe gain; M is the number of columns of array antenna; N is the number of rows of array antenna; d_x is the distance between array column elements; d_y is the distance between array row elements; θ_1 is the angle between radar beam and the horizontal plane; φ_1 is the angle between radar beam and the vertical plane.

Computational Method of RJCA For Aerial Platform

It can be derived from II.B that the core of RJCA computation is how to calculate radar antenna gain at direction of aiming jammer. Its computational method is different from that of ground to air model because of different spatial relationship.

The air-to-air model is shown in Fig.1. Plane AB_1C_1 is a horizontal where jammer A located. We project B, C by vertical projection to plane AB_1C_1 joining B_1 and C_1. It is assumed that the center of radar antenna beam is aiming at the covered target C. If not considering the aerial platform

rolling around its body coordinate X_b, the vertical plane of radar beam is coincidence with plane BCB_1, and is perpendicular to plane AB_1C_1. We draw a line through A perpendicular to plane BCB_1 joining A_ϕ. Then the angle between jammer beam AB and vertical plane BCB_1 is θ. The angle between jammer beam AB and plane $AA_\phi B$ is ϕ. $\theta = \angle ABA_\phi$, $\phi = \angle CBA_\phi$.
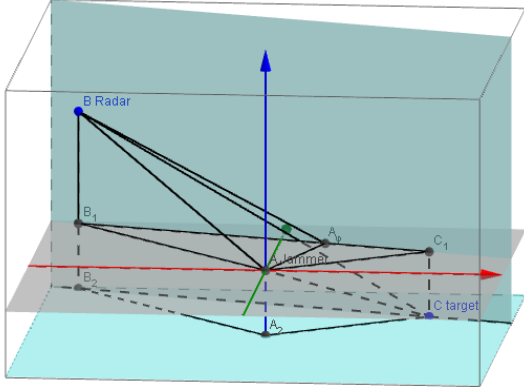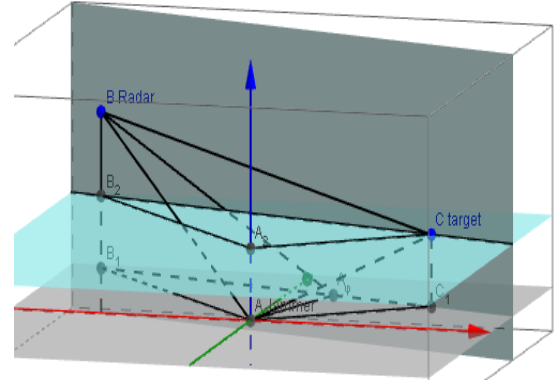

Fig.1.Radar height +, target height -   Fig.2 Radar height +, target height +

$\overline{BB_1} = H$, $\quad \overline{CC_1} = h$, $\quad \overline{AB} = R_j$, $\quad \overline{AB_1} = R'_j$, $\quad \overline{BC} = R_t$, $\quad \overline{B_2C} = R'_t$, $\quad \overline{AC} = r$, $\quad \overline{AC_1} = r'$

$$R_t^2 = R_t'^2 + (H+h)^2 \tag{6}$$

$$R_j^2 = R_j'^2 + H^2 \tag{7}$$

$$\angle AB_1C_1 = \cos^{-1}\left(\left(\overline{AB_1}^2 + \overline{C_1B_1}^2 - \overline{AC_1}^2\right) \Big/ \left(2 * \overline{AB_1} * \overline{C_1B_1}\right)\right)$$

$$= \cos^{-1}\left(\left(R_j'^2 + R_t'^2 - r'^2\right) \Big/ \left(2 * R_j' * R_t'\right)\right) \tag{8}$$

$$\overline{AA_\phi} = \overline{AB_1} * \sin\angle ABA_\phi = R_j' * \sin\angle ABA_\phi \tag{9}$$

$$\overline{B_1A_\phi} = \overline{AB_1} * \cos\angle ABA_\phi = R_j' * \cos\angle ABA_\phi \tag{10}$$

$$\overline{BA_\phi} = \left(\overline{BB_1}^2 + \overline{B_1A_\phi}^2\right)^{0.5} \tag{11}$$

in $\triangle ABA_\phi$:

$$\angle ABA_\phi = \cos^{-1}\left(\left(\overline{AB}^2 + \overline{BA_\phi}^2 - \overline{AA_\phi}^2\right) \Big/ \left(2 * \overline{AB} * \overline{BA_\phi}\right)\right) \tag{12}$$

$$\overline{C_1A_\phi} = \overline{C_1B_1} - \overline{AA_\phi} \tag{13}$$

$$\overline{CA_\phi} = \left(\overline{CC_1}^2 + \overline{C_1A_\phi}^2\right)^{0.5} \tag{14}$$

in $\triangle CBA_\phi$:

$$\angle CBA_\phi = \cos^{-1}\left(\left(\overline{BC}^2 + \overline{BA_\phi}^2 - \overline{CA_\phi}^2\right) \Big/ \left(2 * \overline{BC} * \overline{BA_\phi}\right)\right) \tag{15}$$

If the covered target is below the jammer, the diagram of spatial relationship among 3 objects, the jammer, the radar and the covered target is shown as Fig.2.

Compare to that of Fig.1, (6) turns into

$$R_t^2 = R_t'^2 + (H-h)^2 \tag{16}$$

Equation (7)~(15) are the same with that of Fig.1.

When radar is located on the ground and the jammer is on the air, it's called air to ground model, which is illustrated in Fig.3.
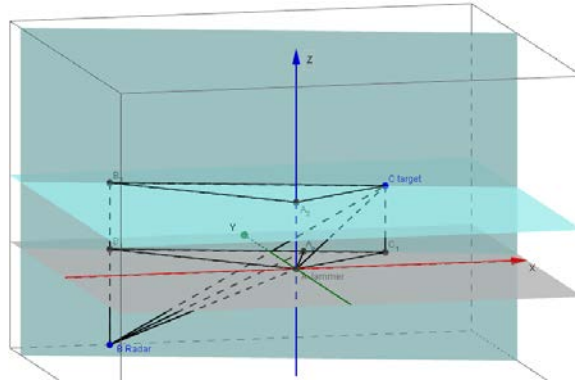

Fig.3. Air to ground model

The computational procedure is the same as that of air-to-air model. It is important to note that the height of radar in computation is a negative value.

Experiment Results

For convenience the radar in the experiment radar is a simulation of AN/APG-66(3), which has the phased array. To simulate a $1.5° \times 3°$ radar main lobe, the parameters of (5) are given as below:

$$M = 30; N = 24; \lambda = 0.03; Dx = 0.01; Dy = 0.015. \tag{17}$$

The simulation of antenna pattern is given as Fig. 4 and Fig.5.
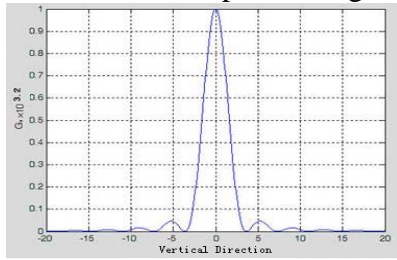
Fig.4.Vertical direction simulation of antenna
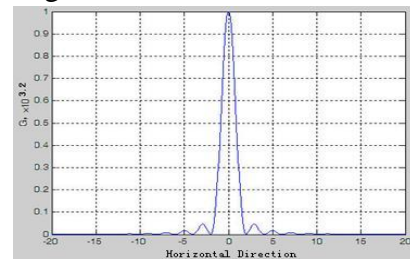
Fig.5. Horizontal direction simulation of antenna
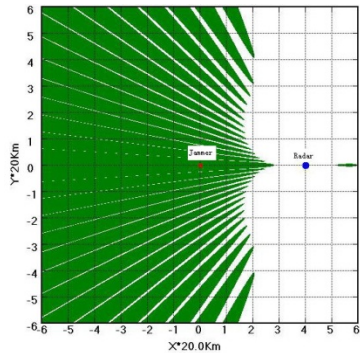
Fig.6. H=0Km
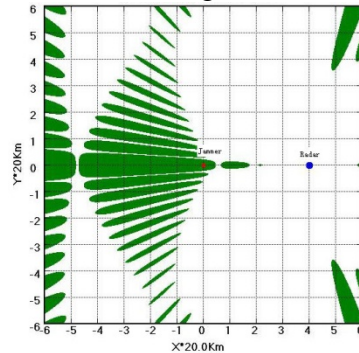
Fig.7. H=5Km
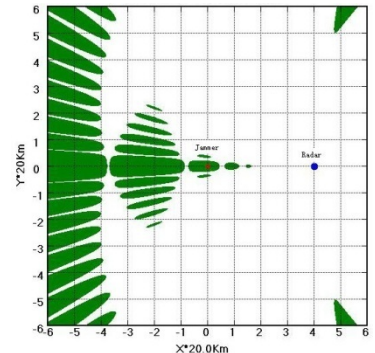
Fig.8. H=10Km
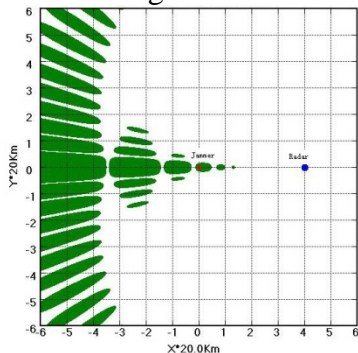
Fig.9. H=15Km
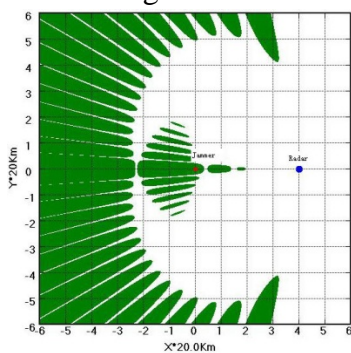
Fig.10. H=-5Km
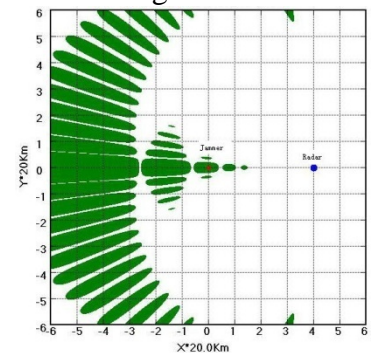
Fig.11. H=-10Km

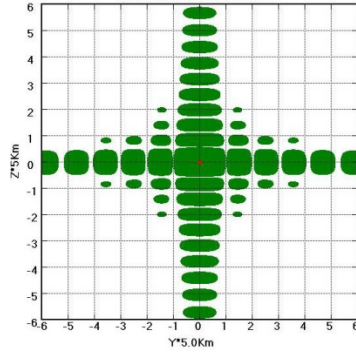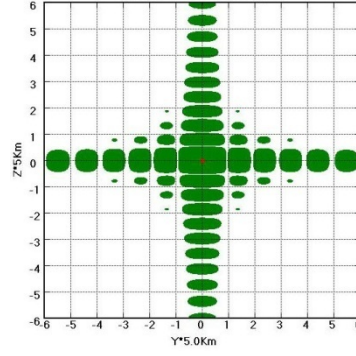Fig.6~Fig.11 are the horizontal sections of RJCS.
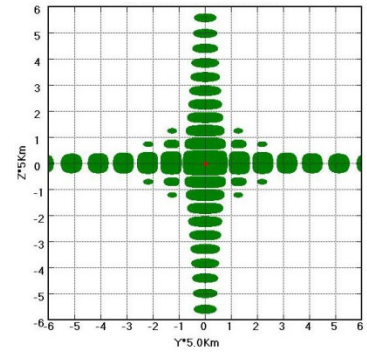

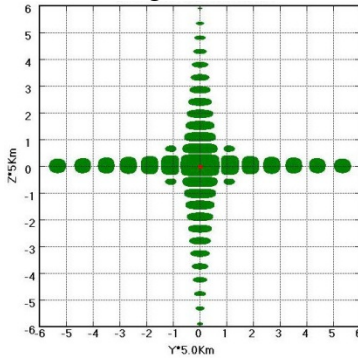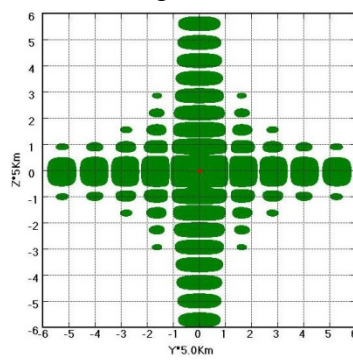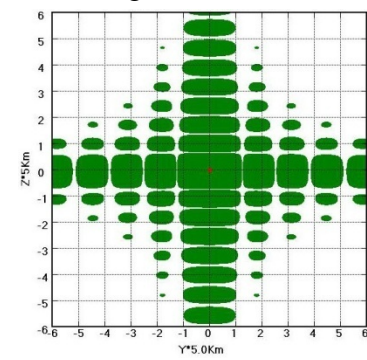| Fig.12. X=0Km | Fig.13. X=5Km | Fig.14. X=10Km |

| Fig.15. X=20Km | Fig.16. X=-10Km | Fig.17. X=-20Km |

Fig.12~ Fig.17 are the vertical sections of RJCS parallel to YOZ.
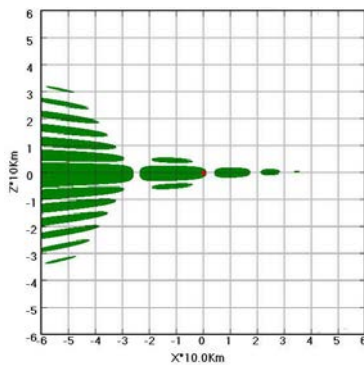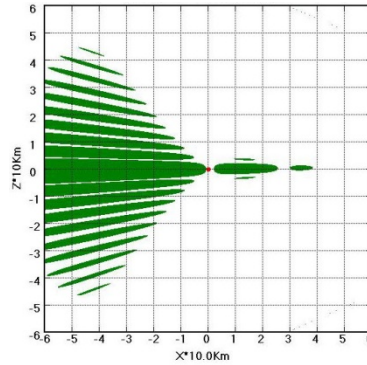

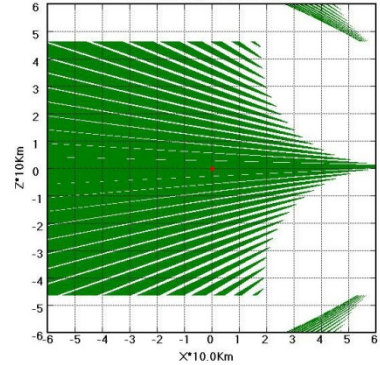
| Fig.18. Y=-20Km | Fig.19. Y=-10Km | Fig.20. Y=0Km |

Fig.18~ Fig.20 are the vertical sections of RJCS parallel to XOZ.

From the figures shown above we can construct the 3D structure of RJCS which is too complexity to be shown in a 2D image.

Conclusion

It can be concluded that RJCS is a domain centered the jammer and it is not continuous. In calculation process the jammer is set to the origin of the coordinate. By analyzing the series of RJCS section we can understand the radar jammer combat capability. It is helpful for the air force commanders to deploy the power effectively based on RJCS sections. The experiment results testify it's reasonable and effective.

Acknowledgement

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