Research on the Angular Glint of Targets in the Near-Zone

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Abstract: This paper presents a method to analyze and calculate the angular glint of targets. By partitioning the target to very small size cells, using high-frequency approximation, the near-field radar cross section (RCS) is calculated based on the scattering from complex targets and environments (SCTE) system, and the angular glint is calculated by the phase grads. The results show that the angular glint can be calculated exactly in the SCTE system, and this method is correct and efficient. In the near-zone, the far-field theory is not applicable and the angular glint should be calculated by the near-field theory.

Key words: RCS; angular glint; near-zone

1 Introduction

The tracing error often comes from two reasons. One is the noises of the environment and the tracing system, and that the signal processing is not perfect. But if the performance and precision of the system is advanced, it can be improved. The other one is the noise that target itself owns. This is the angular glint.

At earlier 1950’s, Howard put forward the concept of angular glint[1,2]. He thought that the random change of the scattering magnitude and relative phase makes aberrance of the front of back wave. It will bring about the angular glint that the wave front lean on the caliber of the receiving antenna. Later, Lindsay calculated the angular glint by the grads of the phase function.

The angular glint is the inherent error as the extended target’s angle is measured. It is as important as RCS in studying the electromagnetic characteristics from complex targets in the near-zone[3-7]. So it is very valuable to research the angular glint of targets in the near-zone.

1 Theoretical Method

There are two methods to analyze the angular glint, the method of Poynting vector and the method of phase’s grads[8]. In the scattering from complex targets and environments (SCTE) predict system[9], it is more convenient and precise to calculate the angular glint by phase’s grads.

Under the condition of two dimensions, the back signals of the point target and the broad target are re-
\[ E_o = A(r)e^{\frac{j\omega r - 4\pi r}{\lambda}} \]  
\[ E_r = A(r, \theta)e^{\frac{j\omega r - 4\pi r}{\lambda} - \delta(\theta)} \]

where \( \omega = 2\pi f \), \( f \) is the frequency of transmitted wave, \( \lambda \) is its wave-length, \( r \) is the distance between the radar and the target.

The front of back wave is the face on which the points' phase is the same.
\[ \phi(r, \theta) = \frac{4\pi r}{\lambda} + \delta(\theta) = C \]

It is obvious that the phase front of the point target is a spherical surface, and the direction of its grad \( \nabla (4\pi r/\lambda) \) is the same as the direction of the target to the radar. The angular glint is zero certainly.

When the target is broad, the phase front is no more a spherical surface, and the angular glint is no more zero.

In the polar coordinates, the phase's grad is as follows:
\[ \nabla \phi = \frac{\partial \phi}{\partial r} \cdot a_r + \frac{1}{r} \frac{\partial \phi}{\partial \theta} \cdot a_\theta \]

where \( a_r \) and \( a_\theta \) are the unit vectors in the direction of \( r \) and \( \theta \), respectively. So under the condition of two dimensions, the angular glint on the direction of \( a_\theta \) is
\[ e_\theta = r \cdot \tan(\Delta \theta) = \frac{\partial \phi}{\partial \theta} = \frac{\lambda}{4\pi} \frac{\partial \delta}{\partial \theta} \]

The above formulas can be applied to the far-zone and the near-zone. The angular glint is a signed physical value, and its international unit is the meter.

2 Calculating the RCS and Angular Glint in the Near-Zone

In the SCTE predicting system, by parting the target to very small size cells, the RCS and phase of back electromagnetic wave can be calculated in the near-zone\(^9\).

It is supposed that the transmitting antenna is located at \( r_0 \), so the incident electric field in the near-field zone can be written as a spherical wave\(^10\)
\[ E'(r') = E_o r_0 e^{\frac{jk(r' - r_0)}{r' - r_0}} e_r(r') \]

where \( r_0 \) is the reference distance of the point at which the incident electric field is \( E_0 \), \( k = 2\pi/\lambda \), \( e_r(r') \) is the electric field unit vector of the point \( r' \) on the cell. On a very small area of the surface of the target, the incident field may be approximated as a local plane wave:
\[ E'(r') = E_o r_0 e^{\frac{jkr' - 4\pi r'}{R_{CT}}} e_r(r') \]

where \( R_{CT} \) is the distance between the cell's center, and \( R_{CT} \) is the vector of the cell's center, and \( R_{CT} \) is the distance between the cell and the transmitting antenna, \( R_{CT} = |r_c - r_1| \). In the rectangular coordinates, \( a_i = a_e \cdot i + a_o \cdot j + a_k \cdot k \) is the unit vector of incident direction on the local surface.

According to Geometrical Optics(GO), the scattering magnetic field from a cell is\(^11\)
\[ \mathbf{H}'(r) = \left\{ \left( -\frac{2}{\eta} \mathbf{n} \times (\mathbf{a} \times \mathbf{E}'(r')) \right) \times \mathbf{G}(r - r') \right\} ds \]

\[ = \left\{ \left( -\frac{2}{\eta} \mathbf{n} \times (\mathbf{a} \times \mathbf{E}'(r')) \right) \times \mathbf{a} - (1 + jkR_{CT}) \mathbf{G}(r) \right\} ds \]

where \( R_{CT} = r - r' \), \( R = |r - r'| \), \( \mathbf{a} = R_{CT}/R \), \( \eta \) is the intrinsic impedance in the free space, and \( \mathbf{n} = (n_x, n_y, n_z) \) is the outward normal of the surface, \( G(r - r') \) is the Green function in the free space:
\[ G(r - r') = e^{\frac{j\pi r}{4\pi r}} \]

In situational mono-station, it can be written as follows:
\[ \mathbf{H}'(r) = \frac{1 + jkR_{CT}}{2\pi R_{CT}} e^{\frac{j2\pi x}{R_{CT}}} e_0 r_0 \]
\[ \cdot \int_s e^{\frac{j2\pi x}{R_{CT}}} e(n \times (\mathbf{a} \times \mathbf{e}_r(r'))) ds \]

\[ = \frac{1 + jkR_{CT}}{2\pi R_{CT}} e_0 r_0 \]
\[ \cdot \int_s e^{\frac{j2\pi x}{R_{CT}}} e(n \times (\mathbf{a} \times \mathbf{e}_r(r'))) ds \]

\[ = \frac{1 + jkR_{CT}}{2\pi R_{CT}} e_0 r_0 \]

\[ \cdot \int_s e^{\frac{j2\pi x}{R_{CT}}} e(n \times (\mathbf{a} \times \mathbf{e}_r(r'))) ds \]

where \( R_{CT} = r - r_c, R_{CT} = |r - r_c| \), \( e_0(r') = a_e \times e_r(r') \).

In the SCTE predicting system, the projection of a parted cell on the plane \( xoy \) is a rectangle of \( a \times b \), and its two sides are respectively parallel to \( x \)-axis and \( y \)-axis. So
\[ \int_s e^{\frac{j2\pi x}{R_{CT}}} e(n \times (\mathbf{a} \times \mathbf{e}_r(r'))) ds \]

\[ = ab \cdot \frac{\sin(ak(a_e - a_o n_z))}{n_z}, \frac{\sin(bk(a_e - a_o n_z))}{n_z} \]

\[ = ab \cdot \frac{1}{n_z} \frac{ak(a_e - a_o n_z)}{b a_o - a_o n_z} \frac{bk(a_e - a_o n_z)}{a_o - a_o n_z} \]

To describe the characteristic of the near-field, the RCS can be defined as follows:
\[ \sigma = 4\pi R^2 \left\| \mathbf{H}' \cdot \mathbf{e}_0 \right\|^2 \]

\[ \left\| \mathbf{E}'(r) \right\|^2 = 4\pi R^2 \left\| \frac{\mathbf{H}' \cdot \mathbf{e}_0}{\mathbf{H}'(r)} \right\|^2 \]

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