Polarization Mode and Its Selective Application in Electronic Countermeasures

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Abstract: Polarization is an important parameter to describe the electromagnetic wave. In order to correctly choose the polarization mode in electronic countermeasure (ECM) activities, the conclusion that the deviation angle in vertical direction of a horizontal target is closely related to the polarization working mode, which is proposed by the selection of the polarization mode in a luring test. The polarization select ion experiment for GPS jamming was performed, which successfully realized the interference for the missile borne GPS in long distance missile. The experiment shows that the vertical polarization is better than circular polarization, and the circular polarization is better than horizontal polarization.

1. Introduction

The polarization of the antenna is related to the space direction. The polarization of the antenna usually refers to the polarization of the maximum radiation direction or the maximum receiving direction. The so-called wave polarization is the polarization of a specific field vector of radio waves [1]. This field vector is usually an electric field vector in engineering. At a fixed point in space, the polarization of a single frequency electric field vector refers to the shape, orientation and rotation direction of the motion trajectory of the vector endpoint. In other words, polarization is the moving state of the end points of a time-varying electric field. The rotation direction of the end track of the electric field vector is defined as the rotation direction observed along the wave propagation direction. The wave can be described as linear, circular or elliptic. Linearly polarized wave with constant direction of electric field, more complex antenna radiation field, its electric field vector will exist simultaneously and fractions. If the phases of these components are different, the direction of the combined electric field vector at a given point in space will rotate at an angular velocity. The end trajectory of the total electric field vector is elliptical, and the field is called elliptical polarization. When the electric field dividers have the same amplitude, the ellipse recede into a circle, which becomes circular polarization.

2. Classification of polarization

In a plane perpendicular to the propagation direction (called the polarization plane), the electric field vector E(t) can be decomposed into two mutually perpendicular components, namely

$$\mathrm{E(t)} = \hat{\mathrm{x}}\mathrm{E_x(t)} + \hat{\mathrm{y}}\mathrm{E_y(t)} \qquad (1)$$

In the formula

$$\mathrm{E_x(t)} = \mathrm{E_x}\cos(\omega \mathrm{t} + \varphi_{\mathrm{x}})$$
$$\mathrm{E_y(t)} = \mathrm{E_y}\cos(\omega \mathrm{t} + \varphi_{\mathrm{y}}) \qquad (2)$$

In the formula, Ex and Ey are the complex amplitudes of the X and Y components of the electric field; φ_x and φ_y are the initial phases. According to the amplitude and phase relation of the two perpendicular field components, polarization can be divided into three types: linear polarization, circular polarization and elliptic polarization.

2.1. Linear polarization

When$\Delta\varphi = \varphi_y - \varphi_x = n\pi$， $n = 0,1,2 \ldots$:

$$E(t) = \hat{x}E_x\cos(\omega_t + \varphi_x) + \hat{y}E_y\cos(\omega_t + \varphi_y) \qquad (3)$$

The amplitude of the resultant field is :

$$|E(t)| = \sqrt{|E_x|^2 + |E_y|^2}\cos(\omega_t + \varphi_x) \qquad (4)$$

The Angle α between the direction of the resultant field vector and the X-axis is a constant:

$$a = \pm \mathrm{arctg}(|E_x|/|E_y|) \qquad (5)$$

The locus of the end points of the electric field vector is a straight line whose Angleα with the X-axis does not change with time. Such polarized waves are linearly polarized waves [2].

2.2. Circular polarization

When$|E_x| = |E_y| = |E_0|$， and :

$$\Delta\varphi = \varphi_y - \varphi_x = \begin{cases} +\left(\frac{1}{2} + 2n\right)\pi & (\mathrm{right-handed}) \\ -\left(\frac{1}{2} + 2n\right)\pi & (\mathrm{left-handed}) \end{cases} \qquad (6)$$

When n= 0,1, 2...,the amplitude of the resultant field is:

$$|E(t)| = E_0 \qquad (7)$$

Angle between the resultant field vector and X-axis:

$$\alpha = \mathrm{arctg}\left(\frac{E_x(t)}{E_y(t)}\right) = \mp(\omega t + \varphi_x) \qquad (8)$$

The locus of the end points of the resultant electric field vector is a circle in a plane perpendicular to the direction of propagation. This polarization is called circular polarization [2]. Observed along the direction of propagation, the rotation of the electric field vector clockwise is called right-handed circular polarization (minus sign in Equation (8)), and the rotation of the electric field vector counterclockwise is called left-handed circular polarization [3] (plus sign in Equation (8)).

2.3. The elliptical polarized

If $|E_x| \neq |E_y|$,and:

$$\Delta\varphi = \varphi_y - \varphi_x = \begin{cases} +\left(\frac{1}{2} + 2n\right)\pi & (\mathrm{right-handed}) \\ -\left(\frac{1}{2} + 2n\right)\pi & (\mathrm{left-handed}) \end{cases} \qquad (9)$$

In the formula：n= 0,1,2... .

$$\mathrm{Or}\ \Delta\varphi = \varphi_y - \varphi_x \neq \pm n/2\pi \qquad (10)$$

In the formula：n= 0,1,2...； $\Delta^{\varphi}>0$ is right-handed,$\Delta^{\varphi}<0$for left-handed

No matter | Ex | is equal to | Ey |, synthetic vector trajectory endpoint Is a inclined ellipse.

3. Selection of polarization mode in decoy test

To achieve the ideal purpose of decoy, it is often required that the sub-station should be consistent with the working formula of the master station, regardless of frequency or phase, especially the polarization information. However, this is not the case. When the polarization working mode of the sub-station is different from that of the master station, the decoy effect is the best[4]. If the polarization works in the same way as that of the main station, the deflection Angle can only swing back and forth between the sub-station and the main station. If the polarization method is different, the apparent deflection Angle for the seeker will deflect the connection between the ion station and the main station and swing back and forth around, making the seeker unable to capture the real target. Based on the above discussion, a theoretical deduction is made and the test layout is assumed as shown in Figure 1.

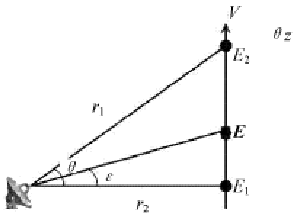

Figure 1 Schematic diagram of calculating radar target angular glint.

The decoy Angle was solved by calculating the Electromagnetic wave Inting vector [5]:

$$S_{av} = \frac{1}{2}\mathrm{Re}(\vec{E} \times \overrightarrow{H^*}) \tag{11}$$

When the phase and polarization working mode of the sub-station and the master station are the same, the electromagnetic field can be assumed as:

$$E_a = \vec{z}E_1 e^{jkr_1}, \quad H_a = \vec{y}(1/\eta)E_1 e^{jkr_1} \tag{12}$$

$$E_a = \vec{z}E_2 e^{jkr_2} H_b = (b/\eta)E_2 e^{jkr_2} \cdot (\vec{y}\cos\theta - \vec{x}\sin\theta) \tag{13}$$

Decoy Angle is:

$$\varepsilon = \arctan[E_2 \sin\theta/(E_1 + E_2\cos\theta)] \tag{14}$$

If the influence caused by the echo phase is considered, it can be set:

$$E_a = E_1 E_b = E_2 e^{j\varphi} \tag{15}$$

The phase gradient and the Boingting vector can be obtained [6] :

$$\varepsilon = \arctan\frac{\sin\theta(b^2 + b\cos\varphi)}{1 + b^2\cos\theta + b(1+\cos\theta)\cos\varphi} \tag{16}$$

In the formula:$b = E_2 \ / \ E_1$

If the influence brought by different polarization is considered, it can be assumed that:

$$E_a = E_1 \vec{z} E_b = E_2 e^{j\varphi}(\sin\theta\,\vec{x} - \cos\theta\,\vec{y}) \tag{17}$$

The declination Angle between horizontal plane and vertical plane can be obtained by using boying Ting vector:

$$\varepsilon_{\text{horizontal plane}} = \arctan\frac{E_2^2\sin\theta}{E_1^2 + E_2^2\cos\theta}$$

$$\varepsilon_{\text{vertical plane}} = \arctan\frac{\sqrt{(E_2^2\sin\theta)^2 + (E_1^2 + E_2^2\cos\theta)^2}}{E_1 E_2\cos\varphi\sin\theta} \tag{18}$$

From the above derivation, it can be seen that the horizontal target actually produces a vertical deviation Angle, and the deviation Angle is closely related to the working mode of polarization.

4. Selection of polarization mode in GPS jamming

However, the selection of the working polarization mode of jammer has not been generally paid attention to [4]. Generally, the GPS antenna on the missile is the microstrip circularly polarized antenna. When it is loaded on the missile, the plane E and H of the antenna's circular pole have become the horizontal plane for the long-range jammer, that is, for the long-range jammer, GPS antennas operating in circular polarization mode can be considered to be operating in horizontal polarization mode. If the water level polarization working mode of jammer interference GPS is wrong.

GPS antenna is usually microstrip antenna [7], and the radiation of microstrip antenna is usually equivalent to the radiation generated by magnetic current around the belt line. Therefore, when electromagnetic waves enter the antenna horizontally (as shown in Figure 2), vertically polarized signals are stronger than horizontally polarized ones. More importantly, when the GPS antenna is loaded on the metal surface, the horizontal polarization signal is attenuated, but the vertical polarization signal is enhanced. The reason is that due to the increase of the metal surface, due to the action of mirror, the polarization direction of the horizontally polarized reflected wave is opposite to the polarization direction of the original incident wave, and is attenuated. Vertically polarized reflected waves have the same polarization mode and are enhanced, as shown in Figure 3.

In conclusion, vertical polarization is better than circular polarization, while circular polarization is better than horizontal polarization in the interference of missile-borne GPS at a long distance.

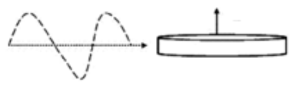

Figure 2 GPS schematic diagram of jamming wave entry

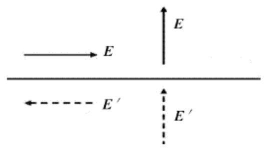

Figure 3 Schematic diagram of radio wave reflection

5. Conclusion

As is well known, theoretically radar cannot receive electromagnetic signals that are orthogonal to the polarization of the electromagnetic waves it emits, and left-circularly polarized antennas cannot receive right-circularly polarized waves. Polarization selection is the first threshold of jamming and anti-jamming in electronic countermeasures, and usually plays a very important role. The horizontal polarization RCS of airborne targets is much larger than that of vertical polarization, so many radars choose the horizontal polarization working mode[8]. In order to reduce the interaction between iff and working radar, vertical polarization is usually selected[9]. Circular polarization is usually used in airport navigation radar. All electronic equipment has a choice of mode of polarization. Polarization is an important parameter to describe electromagnetic wave, but our research in polarization domain is not deep enough, and the utilization of polarization information is still in the primary stage. The Americans have initially developed a target recognition system based on the polarization and scattering characteristics of the target, which can identify the target by measuring the polarization characteristics of reflected waves[10]. Polarizing radar by variable polarization transmitting and matched receiving is also developed successfully. The full use of polarization information in ew needs further study.

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