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Interference Signal Suppression by Polarization Filters under Estimate Error

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Abstract

For the polarization estimate operation of polarization filter, the polarization filter performance is fully analyzed from antenna polarization property, channel amplitude and phase error, channel noise effect and polarization estimate algorithm in four aspects. The validity of polarization filtering is proved under polarization estimate error condition. The study indicated that, adding polarization filter process in radar sensor to cancel interference and evaluate the performances, optimizing the output of polarization channel and processing method is the key point. The polarization estimate precisions will not directly constraint the performance of polarization filtering. The conclusion will be significant to help single polarized radar improving the polarization measurement and anti-interference ability.

Keywords: polarization estimate, polarization filter, validity, estimate error, interference suppression

1. Introduction

In recent years, with the rapid development of radar Polarimetric theory, polarization technique and radar device level, polarization filter has occupied a more important position in the radar anti-jamming areas1-5. Scholars designed multiple polarization filters including single-notch polarization filter(SPC), multiple-notch polarization canceller(MLP), adaptive polarization canceller(APC), frequency polarization filter, interference suppression polarization filter(ISPF), optimal polarization filter(OPC), MPWF, SINR polarization filter etc6-15. It can suppress the interference effectively when the target and jamming polarization are different. It will improve the expected signal quality of incoming signals. However, refer to the pre-studies, they all considered the jamming is from the main-lobe, the antenna polarization property was ignored. And the effect of amplitude and phase imbalance of receive channel, channel noise and polarization states estimates algorithm effect are all not considered. Intuitive thinking that polarization filter performance only depend on the polarization estimate precision and the difference between the real polarization and estimated polarization 1516. In fact, the object of polarization filter is not real polarization but received polarization. Detailed, the receiving channel output signal directly coupled the antenna

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spatial polarization characteristics, beam pattern property, channel amplitude/phase property and polarization estimation error. Therefore, polarization channel output can not be seen as the unbiased estimation of real polarization. It contained some polarization error. The paper pointed out and proved that the polarization filter is built on the polarization error. The polarization estimate error can be compensated in polarization filtering. It will not influence validity of polarization filter. The detailed mathematical analysis is given in this paper. It will help single polarized radar to obtain polarization measurement ability and enhance anti-jamming ability.

2. Polarization estimate based on orthogonal polarized channel

Choosing Horizontal, Vertical polarization as polarization base, the incoming plane wave in this polarization base can be expressed as $\boldsymbol{h}_J = \begin{bmatrix} h_{JH} & h_{JV} \end{bmatrix}^T$, $\|\boldsymbol{h}_J\| = 1$, so in the radar receiving antenna, the jamming signal can be written as

$$\boldsymbol{e}_J(t) = \boldsymbol{h}_J J(t) \tag{1}$$

Where $J(t)$ is the blanketing jamming modulated signal which closed to zero-mean white noise, the power spectral density is σ_J^2。

Supposing the normalized co-polarized antenna pattern is $g_H(\theta)$, the normalized cross-polarized pattern is $g_V(\theta)$, the peak level gain is G_r, so the spatial polarization vector of antenna can be written as followed

$$\boldsymbol{g}(\theta) = G_r \cdot \begin{bmatrix} g_H(\theta) \\ g_V(\theta) \end{bmatrix} \tag{2}$$

Detailed speaking, for horizontal polarized antenna, the polarization purity in the center position of is the highest, so the expression can be simplified as $\boldsymbol{g}(\theta) = G_r \cdot \begin{bmatrix} 1 \\ 0 \end{bmatrix}$, for vertical polarized antenna, $\boldsymbol{g}(\theta) = G_r \cdot \begin{bmatrix} 0 \\ 1 \end{bmatrix}$, for other spatial direction θ, the polarization vector of antenna is the function of θ.

Supposing $\boldsymbol{\Gamma}$ is the inconsistent coefficient matrix of orthogonal polarized channel, $\boldsymbol{\Gamma} = \mathrm{diag}\left[r_{\mathrm{H}}, r_{\mathrm{V}}\right]$. The $r_{\mathrm{H}} = A_{\mathrm{H}} e^{j\varphi_H}$, $r_{\mathrm{V}} = A_{\mathrm{V}} e^{j\varphi_V}$ is amplitude and phase error between the channel separately.

Therefore, the real received voltage of jamming signal in horizontal polarized channel can be expressed as

$$V_{\mathrm{H}}(t) = r_{\mathrm{H}} \cdot P_{\mathrm{S}} \cdot \frac{k_{RF} G_r}{L_R} \cdot \boldsymbol{g}^{\mathrm{T}}(\theta) \cdot \boldsymbol{h}_J \cdot J(t) + n_{\mathrm{H}}(t) \tag{3}$$

Where P_{S} is jamming signal power, k_{RF} is the RF amplification coefficient, $L_R = \dfrac{\lambda^2}{(4\pi R)^2 \cdot 10^L}$ is the loss factor when considered electromagnetic wave propagation loss, antenna feeder loss and measurement system loss factor. The loss factor can be seemed as the same in the dual polarization channel. $n_{\mathrm{H}}(t)$ is the channel noise in H polarized channel which is under normal distribution. $n_{\mathrm{H}} \sim N(0, \sigma_m^2)$.

The real received voltage of jamming signal in vertical polarized channel is

$$V_{\mathrm{V}}(t) = r_{\mathrm{V}} \cdot P_{\mathrm{S}} \cdot \frac{k_{RF}^* G_r}{L_R^*} \cdot \boldsymbol{g}^{\mathrm{T}}(\theta) \cdot \boldsymbol{h}_J \cdot J(t) + n_{\mathrm{V}}(t) \tag{4}$$

From formulas (3) and (4), we know that the received signal was modulated by receiving channel property, spatial polarization characteristic of antenna, channel noise effect. etc in orthogonal polarized channel. As a result, in order to analysis the polarization estimate performance, the factors above should be considered. The polarization estimate method has to be considered either. The detailed analysis is given as followed.

2.1. Antenna spatial polarization property effect

In the real radar attack and defending confrontation, the jammer position change and antenna offset the normal direction, the radar and jamming will all deviated from the electric axis direction. Especially, for mechanical