Interpreting Radar Signal-to-Clutter-and-Noise-Ratio as a Stochastic Process

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Abstract—This paper illustrates and defines basic stochastic factors required for computing the target and clutter return for non-distributed field objects. It is shown that path-dependent stochastic changes in polarization and random target response can adversely affect the SCNR.

Keywords-component: ***Non-distributed clutter, stochastic process, SCNR***

I. BACKGROUND

Accurately determining the SCNR is a complex problem arising from the electromagnetic interaction between the incident radar signal and the target and/or clutter. As targets and decoys become more sophisticated and complicated it is more risky to rely only on test data. We need to push harder on rigorous theoretical fundamentals if we are required to deal with man-made and non-normal electromagnetic environments. Because of these difficulties semi-empirical formulas based on combining probability theory with experimental data have been of significant value, but may often result in uncertainties in SCNR and ultimately system performance.

II. APPROACH

In this paper we: (1) define basic stochastic factors required for computing the target and clutter return for non-distributed field objects, and (2) show that rigorous application of basic stochastic process techniques and probability theory can accurately account for path-dependent stochastic changes in polarization and random target response that seriously affect the SCNR in a complex electromagnetic environment. By keeping rigorous account of the target and clutter interactions the uncertainties in predicting the SCNR can be minimized. We determine target and clutter return for a point and/or collection of non-distributed objects: the direction of the Poynting vector does not change over the size of the field object (target or clutter) on the macroscopic scale.

III. THEORY

Our starting point assumes that clutter is modeled as a non-random and Memoryless System—the behavior only depends on the current time. Aside from the time delay between the radar and the field point, its radiating power is proportional to the radar power $P_0(t)$. However, targets and clutter may be classified as Systems with Memory which include Linear Time Invariant (LTI) systems. For LTI systems the target/clutter power generated is [1]

$$P_\Theta(t) = \int_{-\infty}^{+\infty} h_\Theta(t-\tau) P_0(\tau) d\tau$$

where $h_\Theta(t)$ is a non-random and linear transfer function, and is adequate for use in the calculation of SCNR. We consider three causes of random effects: (a) propagation path from radar to object, (b) interaction between the incident field and object, and (c) propagation path from object back to radar. For illustrative purposes we consider random propagation effects to be caused by fluctuations in polarization and is represented by a random polarization vector $\vec{\rho}$. If $\vec{u}_z$ is a unit vector in the direction of propagation, the two orthogonal directions of random polarization are $\vec{u}_x$ and $\vec{u}_y$. Assuming that the energy (but not the direction) is constant allows us to write

$$\vec{\rho} = \gamma(l_p \mid \vec{\rho}_0)\vec{u}_x + \left(1-\gamma(l_p \mid \vec{\rho}_0)\right)\vec{u}_y$$

The function $\gamma(l_p \mid \vec{\rho}_0)$ is the conditional probability that polarization is in the $\vec{u}_x$ direction after the wave has travelled a distance l_p starting with polarization: $\vec{\rho} = \vec{\rho}_0$, and $1-\gamma(l_p \mid \vec{\rho}_0)$ is the corresponding conditional probability for the $\vec{u}_y$. The statistical properties of $\vec{\rho}$ are assumed to be known from actual measurements. Using the statistical properties of $\vec{\rho}$ we derive the probability density function of SCNR.

REFERENCES

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