Chapter 13

Methods and Algorithms for Technical Vision in Radar Introscopy

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ABSTRACT

Optimization of technical characteristics of radio vision systems is considered in the radars with ultrawideband sounding signals. Highly noisy conditions, in which such systems operate, determine the requirements that should be met by the signals being studied. The presence of the multiplicative noise makes it difficult to design optimal algorithms of echo-signal processing. Consideration is being given to the problem of discriminating objects hidden under upper layers of the ground at depths comparable to the probing pulse duration. Based upon the cepstrum and textural analysis, a subsurface radar signal processing technique has been suggested. It is shown that, however the shape of the probing signal spectrum might be, the responses from point targets in the cepstrum images of subsurface ground layers make up the texture whose distinctive features enable objects to be detected and identified.

INTRODUCTION

One of the main goals of technical vision systems, based on radar technology is to detect and identify target covered by obstacle. It is important that signal can penetrate throughout and return to receiver. For example, the problems that arise with probing earth subsurface layers using video pulse signals is the ability of discriminating the objects hidden under upper ground layers at depths comparable to the probing pulse duration (Grinev, 2005). The discrimination criteria for two targets are based on personal opinions and feelings. The following criteria are of considerable current use: a) Rayleigh resolution (Born, 1973) and b) statistical criteria (Levin, 1966). In accordance with the first one two point targets

DOI: 10.4018/978-1-5225-5751-7.ch013
the returned signals from which has identical power at the receiver input and the signals delayed relative to a probing pulse for \( \tau_1 \) and \( \tau_2 \) respectively can be regarded as defined ones using both a certain system of observation and an algorithm. The latter helps determine signal intensities if the total signals power measured at \( \tau = \left( \tau_1 + \tau_2 \right) / 2 \) is equal to 74% against the intensities of received signal at \( \tau_1 \) or \( \tau_2 \). This resolution criterion is usually employed where to ensure target delay resolution it is the power of received signals is solely utilized but not all their possible characteristics. This criterion is referred to as the Rayleigh resolution criteria. It is evident that, when in use, this criterion makes it fairly difficult to deal with objects’ resolution problems, the objects featuring a significant difference in radar scattering cross section (RCS). According to the Rayleigh criterion the resolving power of the observation system involving such an algorithm implies the minimal delay time of signals returned from two point targets having an identical RCS, this time ensuring that the condition of this criterion is satisfied. The shorter is this time, the higher is the resolution of the observation system.

The statistical criterion formulation can be defined in the general form in the following way: two point targets described by identical probabilistic models and the delays of signal arrival from which are \( \tau_1 \) and \( \tau_2 \) can be considered to be resolvable with the observation system and as well as with the algorithm that processes the received signal-interference mix if the probability of correct indication of two sources is equal to \( P_r \). In this instance the resolving power of the returned-signal processing algorithm under the statistical criterion is taken to be the minimal angular distance between sources, at which the prescribed probability of correct detection of two sources is ensured. It should be noted that in this particular case no constraints are imposed upon the resolution algorithm structure (in contrast to the Rayleigh criterion). Similar to the Rayleigh criterion it is necessary that the algorithm in question should be able to form the estimates of \( \tau_1 \) and \( \tau_2 \) delays. In the statistical criterion the probability \( P_r \) is the criterion parameter in the same way as for the Rayleigh criterion the number 74% is the basic parameter.

Thus, one can suggest a great number of resolution algorithms for one and the same observation system. Clearly, of all possible algorithms one might as well refer to the one which in fact provides for the best resolving power.

THE CEPSTRUM METHOD OF DELAY MEASUREMENT

The concept “cepstrum” (Noll, 1967) has been known since the middle of the last century and is defined by the following expression:

\[
C_S(q) = \frac{1}{2\pi} \cdot \int_{-\infty}^{\infty} \ln|S(\omega)|^2 \cdot e^{jq\omega} d\omega
\]  

(1)

where \( S(\omega) \) is the amplitude spectrum of signal \( s(t) \).

However, expression (1) is not valid for a totally arbitrary signal. For a finite-energy signal the condition \( \int_{-\infty}^{\infty} S^2(\omega) d\omega < \infty \) should be met, from which it follows that at \( |\omega| \to \infty \), then \( S^2(\omega) \to 0 \).
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