ULTRAWIDE BAND RADAR SIGNAL DETECTION, ESTIMATION AND EXPERIMENT

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Abstract With reference to the air target detection of ultra-wide band (UWB)/impulse radar (IR), the transient signal processing techniques was discussed. In weak UWB signal detection, the wavelet transforms and high order spectrum estimation techniques were preferred. In target characteristic analysis, a time domain bispectrum estimation algorithm was used to analyze the target impulse response, which could estimate accurately local scattering distribution of complex target. A free field IR experimental system installed in an anechoic chamber was used. With this system, experiments to several target models were made. The results of these experiments verified the signal processing method efficiency.

Key words Ultrawide band radar; Signal detection; Target characteristics

I. Introduction

Ultrawide band(UWB) radar, as a new detection techniques, is being paid more and more attention in the world. Because this type of system is one with a very large relative bandwidth, generally greater than 25%. The UWB radar has presented a more powerful potential use in target identification, stealing object detection and imaging. In UHF/VHF, some UWB/SAR imaging systems have been experimented. The results showed these system’s preliminary power in foliage and ground penetration (FOPEN/GOPEN) and detection of hidden targets[1]. In the research of target characteristics, because of the large relative bandwidth and high resolution, the UWB radar could obtain the complex response of complicated targets, which, in turn, could be used in target identification.

Different from the other UWB radar systems, impulse radar(IR) transmits and receives transient signal. The scattering and propagation of transient signal are different from stationary situation significantly. Although the theory about transient radar has not yet been systematized, many experimental results have shown the differences[2].

For IR, the signal processing techniques would be a little different from that of carrier radar. New techniques of signal processing should be studied. IR could distinguish the different regional responses, global and local responses. With global response of target, poles of target transform function could be get. Independent of angle of incidence, these poles are only related to the construction and materials of target and are the innate characteristics of the target. But when signal noise ratio is not adequate, it is difficult to obtain fine information of target characteristics if using the time domain impulse response or the spectrum of impulse response only. There would be also false scattering center from the interaction of multiple scattering center. Bispectrum could get over this drawback. At the same time, bispectrum could suppress Gaussian or other symmetric noise.
Transient signal detection is the foundation of IR signal processing. But the presence of unknown parameters, low signal noise ratio(SNR) and possible unstationary of noise, signal detection would be very difficulty. In this paper, we discussed how to use wavelet transform to the analysis of echoes of target.

In Section II of this paper, bispectrum detection procedure is presented. Two wavelet transform algorithms are analyzed in Section III. An overview of experimental IR system is given in Section IV. Finally, the target characteristic analysis using bispectrum estimation is discussed in Section V.

II. Signal Bispectrum Detection

Consider the following detection problem:

\[
H_1 : \quad x(t) = s(t) + n(t) \\
H_2 : \quad x(t) = n(t)
\]

The bispectrum \(B_x(\omega_1, \omega_2)\) of \(x(t)\) is defined as 2-D Fourier transformation of its 3rd-order cumulant \(c_x(t_1, t_2)\), that is

\[
B_x(\omega_1, \omega_2) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} c_x(t_1, t_2) e^{-j\omega_1 t_1} e^{-j\omega_2 t_2} dt_1 dt_2
\]

where

\[
c_x(t_1, t_2) = E\{[x(t) - \mu][x(t - t_1) - \mu][x(t - t_2) - \mu]\}, \quad \mu — the \ mean \ of \ x(t)
\]

If signal and noise are independent, then we change Eq.(1) to following detection problem:

\[
H_1 : \quad B_x(\omega_1, \omega_2) = B_s(\omega_1, \omega_2) + B_n(\omega_1, \omega_2) \\
H_2 : \quad B_x(\omega_1, \omega_2) = B_n(\omega_1, \omega_2)
\]

The typical noises, such as Gaussian, sinusoidal and uniform have zero bispectrum. But the signal of interest in IR has a non-zero bispectrum. Therefore the bispectrum could suppress Gaussian and RF interference.

In the situation of small samples, it is difficult to obtain the required resolution and accuracy with traditional bispectrum. Parameter method, which could get over the limit of small samples and suppress the noise, has very high accuracy of bispectrum estimation. Through the analysis of signal bispectrum, Eq.(3) can be converted into following form:

\[
\frac{H_1}{H_0} \Rightarrow T^2_c \geq T^2_0
\]

where \(T^2_c = \sum_{n=1}^{p} (|u_n|^2 / \sigma_n^2)\).

where \(p\) is the number of frequency pair, \(u_n, \sigma_n^2\) are the estimated mean and variance of the \(n\)-th frequency respectively. Threshold \(T^2_0 = \text{erf}^{-1}(P_F)/\sqrt{2} + \sqrt{(2p - 1)/2}\).