PASSIVE RADAR ANALYSIS USING DTMB SIGNAL

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I. INTRODUCTION

Background and Motivations

- In recent years, passive radar system based on space-based opportunity illuminators, such as GPS[1], GLONSS[2], GALILEO[3], DVB-S[4], LEO communication satellite[5], etc., has been widely researched all over the world.
- At the same time, the biggest advantage of ground-based opportunity illuminators is that the direct wave strength is much higher, the operation frequency is relatively lower, and it has the potential to detect weak scattering targets, which is most likely to be applied for actual radar system. Therefore, digital broadcasting signal (e.g. DRM, DAB, DVB-T)[6] has attracted the great interest of scholars recently. Nowadays, the digital terrestrial multimedia broadcasting (DTMB) signal which is proposed by China independently, has covered more than 300 cities in China, and provides a good condition for the research of new system radar. In this paper, the feasibility and detection performance of DTMB signal used in passive radar is studied. Existing researches mainly focus on the reconstruction of reference signal, the analysis of micro-Doppler and cochannel interference.
- Similar to the traditional passive radar system, DTMB radar utilizes coherent processing (CP) technology for target detection, that is, at least two receiving channels are deployed in the radar system, which are respectively utilized to receive target echo and reference signal. Then, range-Doppler (RD) result is achieved by the two-dimensional cross-correlation function of direct wave channel and echo receiving channel, so as to realize stable target detection and tracking.

III. SPECTRUM AND AMBIGUITY FUNCTION

- In order to further study DTMB signal characteristics, it is necessary to analyze its spectrum and ambiguity function, which are denoted by Eq.(2) and Eq.(3), respectively.

$$U(f)=\int_0^{NT} s(t)\exp(-j2\pi ft)dt$$

$$\chi(\tau,f_d)=\int_0^{NT} s(t)s^*(t+\tau)e^{j2\pi f_d t}dt$$

- Taking typical PN420 frame structure of DTMB signal as an example, and the corresponding simulation results are carried out. Herein, the sampling frequency is 20MHz for baseband signal, and the duration of signal is 2.1ms. Fig.1 is the spectrum of DTMB signal. It is obvious that the calculated bandwidth is 7.56MHz, which is consistent with the actual value.
- The ambiguity function obtained by simulation is shown in Fig. 2. It can be clearly seen that because DTMB signal contains many periodic parts, there will be many sub peaks in its ambiguity function, which may directly lead to strong target submerges weak target. These periodic parts include frame header, transport parameter symbols, power difference between frame header and frame body, etc. They will reduce the detection performance of passive radar to a certain extent.

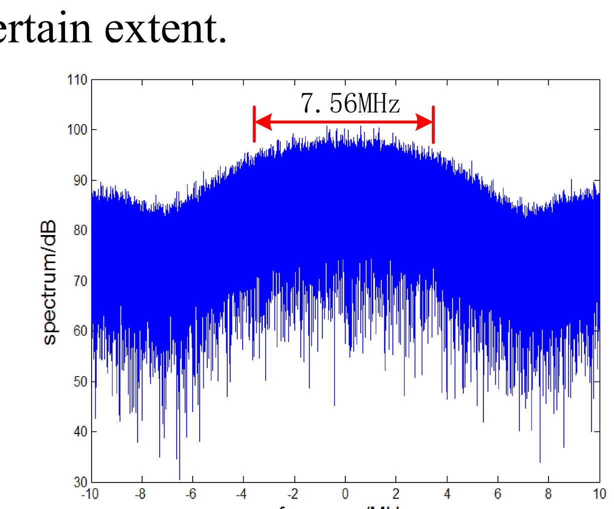

Figure 1. Spectrum of DTMB signal

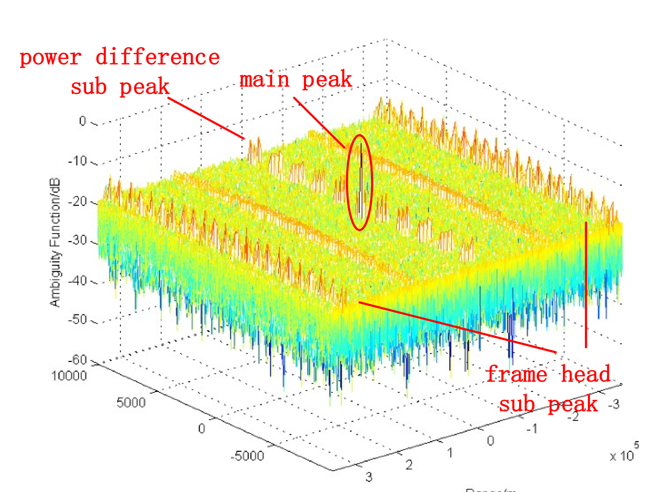

Figure 2. Ambiguity function of DTMB signal

IV. SUB PEAK SUPPRESSION TECHNOLOGY

- Conventional window function adding method is applied to DTMB ambiguity function for reducing sub peaks at the very beginning. We find that the sidelobe is reduced only near the main lobe, and the sidelobe far away from the main lobe cannot be well suppressed.
- Then, based on the structural characteristics of DTMB signal, a sub peak suppression method by setting the frame head to zero and then setting the frame body to zero at equal intervals is presented, which can decrease the sub peaks of ambiguity function both in time delay domain and Doppler domain effectively. The calculation steps mainly include the following parts.
- Step 1, signal frame synchronization is processed first.
- Step 2, the frame header and transport parameter symbols (TPS) of reference signal are set to zero.
- Step 3, the frame body of reference signal is set to zero at equal intervals.
- Step 4, two receiving channels are processed coherently, it can be seen that the processed ambiguity function has good potential to be used in practical radar system.

II. SIGNAL MODEL

- The DTMB transmission system adopts the innovative single carrier modulation of time domain synchronous orthogonal frequency division multiplexing (TDS-OFDM) based on PN sequence spread spectrum technology, which is different from DVB-T using cyclic prefix to fill the OFDM protection interval.
- It consists of system information symbols and valid data symbols. The system information provides demodulation and decoding information for each signal frame, the effective data part is the data obtained after source coding and channel coding. he time domain expression of complete signal is expressed as follows

$$s(n)=\begin{cases} PN(n) & n\in[0,N_g-1] \\ \sum_{k=0}^{N_c-1} S(k)c^{j2\pi(n-N_g)k/N_c} & n\in[N_g,N_g+N_c-1] \end{cases}$$

V. ANALYSIS OF DTMB PASSIVE RADAR PERFORMANCE

- According to radar equation, the link budget results of DTMB passive radar under different receiving distances can be obtained directly. Fig. 3 illustrates the relationship curve between echo signal-to-noise ratio (SNR) and radial distance.

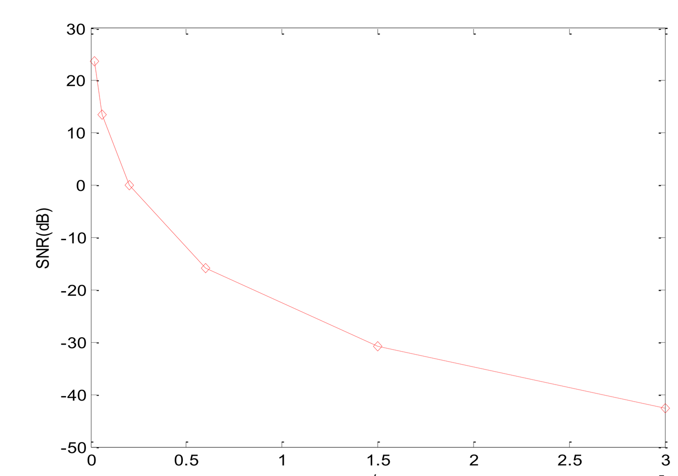

Figure 3 Relationship curve between echo SNR and receiving distance

- Next, the target detection performance of DTMB passive radar is analyzed, and simulation parameters are listed in Tab. 1. It is worth noting that signal modeling refers to multipath delay of rake receiver in communication, where two main paths are considered. The target is assumed to be a fighter aeroplane with RCS=1.5m2. Assuming the target is 1.98 km away from receiver and the target radial velocity is 159m/s, the echo SNR can be calculated as 20.73dB according to radar equation. Besides, LMS algorithm is used for echo purification, and the coherent integration time is 16.67ms.
- Fig. 4 demonstrates the detection result of target. It can be seen that the delay and Doppler calculation results are consistent with theoretical values.

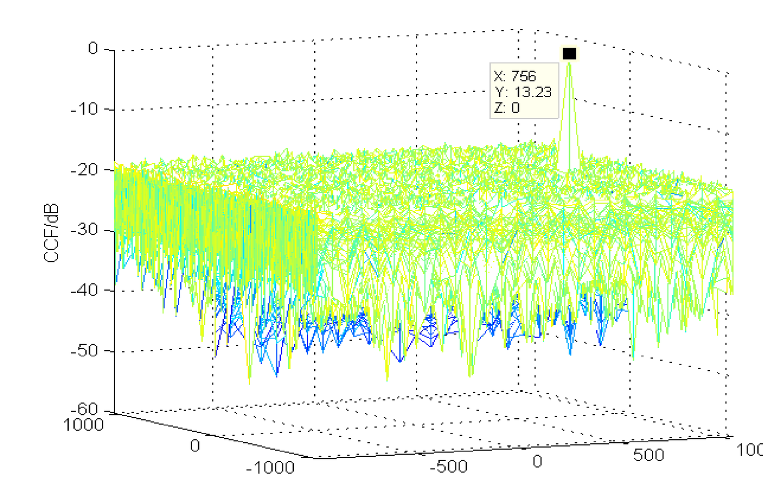

Figure 4 Detection result of fighter aeroplane by DTMB Passive radar

VI. Conclusions

- In this paper, DTMB signal for passive radar are studied.
- In future work, we will focus on direct wave and echo purification algorithms (for example using modified LMS, ECA), which is important for DTMB passive radar.

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