Research on Spread Spectrum Multi-Target Diversity and Tracking Technology

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Abstract. In recent years, the survey ship has undertaken many key measurement and control tasks for multiple satellites. At present, single stations can only self-track a single target. In the mission, signals caused by factors such as occlusion or interference into the interference area are often encountered. Fluctuation, flashing, interruption, etc., so this paper proposes a method for tracking multi-target diversity into a tracking research method, which effectively responds to the influence of single target signal changes on tracking, and will be of great significance for multi-target spread spectrum measurement and control tasks.

1. Introduction
With the application and development of the spread spectrum system in the space measurement and control system, the single-station multi-target measurement and control task has become a new measurement and control mode. The space measurement ship is the most flexible and maneuverable sea-based measurement unit in the entire space measurement and control network. Key monitoring and control tasks for multiple satellites. Since the current monitoring and control system can only self-track a single target, and the task often encounters fluctuations, flashes, interruptions, etc. caused by factors such as occlusion or interference into the interference area, the main tracking target signal cannot be satisfied. Tracking target switching or data indexing, radar guidance, and even tracking system switching must be performed when the mission requires. The reliability requirements of single-station operation are extremely high, and the risk of switching action is large. Studying a means to effectively deal with the impact of single target signal changes on tracking will be of great significance for multi-target spread spectrum measurement and control tasks.

2. Current spread spectrum multi-target tracking system
The spread spectrum main tracking receiver is composed of IF channel, AGC control, A/D bandpass sampling, and channel receiving difference channel angle error demodulation. The block diagram and working principle of the spread spectrum main tracking receiver module are shown in Fig. 1. The spread spectrum main tracking receiver simultaneously receives the left and right spin difference channel 70MHz IF signals of the front end channel input, and completes AGC control, PN code dispreading, carrier tracking, angular error tracking, angular error signal demodulation, phase correction, and differential slope correction, zero value correction, polarization correction and other algorithms. The left and right polarization modes of the input signal are switched by the front end.
The spread spectrum tracking receiving module is composed of two parts: channel receiving demodulation and difference channel angle error demodulation. Different from the PM tracking reception, the carrier of the spread spectrum signal is completely submerged in the noise after being modulated by the PN code. Therefore, the carrier tracking after the PN code coherent dispreading must be completed, and the recovered carrier is used as the difference. The channel amplitude normalized reference information realizes the demodulation of the differential channel azimuth and elevation angle error signals. The azimuth and pitch error signals obtained by the angular error demodulation are sent to the antenna control unit through the analog port together with the AGC level and the lock indication of the channel. The AGC control voltage of the difference channel is uniformly provided by the channel carrier tracking module, thereby realizing the normalization of the sum and difference channel signal amplitudes.

In the multi-target task performed in the past, according to the characteristics of the phase and angular error output of the three channels of the tracking receiver, if the main and target signals are flashed, the tracking receiver angular error output is switched between the channels 1, 2 and 3. To achieve seamless switching of tracking targets.

3. Multi-target tracking and diversity into tracking technology

The diversity combining method includes intermediate frequency synthesis, baseband synthesis, and symbol synthesis. The IF synthesis method is also called full spectrum synthesis, which compensates for the difference between the diversity signals in the intermediate frequency to achieve synthesis. Since there is no need to perform carrier recovery for each diversity signal, the intermediate frequency synthesis technique can work when the received signal is below the capture threshold, and is suitable for receiving weak signals during deep space communication. The baseband synthesis method synthesizes the delay and weighting of the baseband signal from which the carrier is eliminated. The symbol synthesis method synthesizes soft decision symbols that have undergone carrier synchronization and symbol stream synchronization. The latter two methods have lower requirements on the signal processing clock rate, and can be combined in real time or the demodulated data is stored and forwarded.
and then synthesized, which is suitable for the case where the diversity of the diversity signal changes greatly, but cannot cope with the low signal-to-noise ratio of the received signal. In the case of carrier demodulation threshold. The development direction of the diversity is to make full use of the information carried by each diversity signal to achieve the maximum synthesis gain.

The maximum ratio signal synthesis is performed on the three-channel input of the spread spectrum tracking receiver, and the aggregation module is determined by the AGC/AM weighting method. The design tracking block diagram is shown in FIG. 2.

![Figure 2. Improved spread spectrum tracking block diagram](image)

4. Analysis of synthetic calculation methods

In the task, if only the receiver's AGC voltage is used to weight the maximum ratio synthesizer, the change of the weighting coefficient will lag behind the signal change, and the composite signal distortion will occur, which will affect the reception demodulation performance. For this design, the AM envelope that is not tracked by the AGC in the intermediate frequency signal is detected, and after processing, it is added to the AGC voltage to obtain a maximum ratio weighting coefficient to be sent to the assembler. When the signal fading is relatively fast, the maximum score is integrated into energy. Fast response calculation of weighting coefficients.

The diversity signal arriving at the receiver through different paths first enters the parameter estimation module, and the parameter estimation module extracts the difference between the diversity signals, and calculates the combined weight of each diversity signal in the composite signal, and the
input signal and the corresponding synthesis. The weights are multiplied and then added to achieve synthesis. After synthesis, the signal enters the phase-locked loop for demodulation, synchronization and subsequent processing.

Let channel one input signal be:
\[ s(t) = \sqrt{2P} \sin(w_c t + \theta(t) + \theta_0) \]

In the formula, \( P \) is the signal power; the receiving carrier is recorded as \( w_c \); \( \theta(t) \) is the carrier information, and the analytic formula is different according to the modulation mode; \( \theta_0 \) is the initial phase and is set to 0.

The k-th channel signal passes through the channel and arrives at the receiver with a delay of \( \tau_k \), expressed as:
\[ r_k(t) = \sqrt{P_k} \sin(w_c t - w_c \tau_k + \theta(t)) \]

The IF carrier is recorded as \( I_\omega \), assuming that the information delays carried on the respective diversity signals are basically the same, that is, \( \theta(t - \tau_k) \equiv \theta(t) \). The signal is moved to the baseband and filtered to:
\[ r_k(i) = \sqrt{P_k / 2} e^{\frac{\theta(i) - w_c \tau_k}{2}} = V_k e^{i\theta(i)} \]
\[ V_k = \sqrt{P_k / 2} e^{-w_c \tau_k} \]

Assuming the combined weight \( w_k \) of each signal, considering the influence of noise, the synthesis of K signals is expressed as
\[ z(i) = \sum_{k=1}^{K} w_k (r_k(i) + n_k(i)) \]

Then the signal to noise ratio of \( z(i) \) is:
\[ \rho_2 = \frac{\sum_{k=1}^{K} |w_k r_k(i)|^2}{\text{Var} \left( \sum_{k=1}^{K} w_k n_k(i) \right)} = \frac{\sum_{k=1}^{K} w_k r_k^2}{\sum_{k=1}^{K} |w_k|^2 2\sigma_k^2} \]

The variance of the noise \( n_k(i) \) is \( 2\sigma_k^2 \), and the Cauchy-Schwarz inequality is as follows:
\[ \left( \sum_{k=1}^{K} w_k V_k \right)^2 \leq \sum_{k=1}^{K} \left( \sqrt{2w_k} \sigma_k \right)^2 \left( \frac{V_k}{\sqrt{2\sigma_k}} \right)^2 \leq \sum_{k=1}^{K} |w_k|^2 2\sigma_k^2 \sum_{k=1}^{K} \frac{V_k^2}{\sqrt{2\sigma_k}} \]
\[ \rho_2 \leq \frac{\sum_{k=1}^{K} \frac{V_k^2}{\sqrt{2\sigma_k}}}{\sqrt{2\sigma_k}} = \rho \]

It can be seen that when the weight of the kth signal is \( \frac{V_k^*}{2\sigma_k} \), the composite signal takes the maximum signal-to-noise ratio. From the diversity design to the algorithm design, by calculating the weighting
coefficient of each channel, the flash of a certain channel signal will not be caused. The flashing of the composite signal ensures timely and effective tracking of the stability of the multi-target signal.

5. Conclusion
In view of the effects of signal fluctuation, flashing, and interruption caused by factors such as occlusion or interference in the main tracking target in the mission, this paper proposes a method for tracking and multi-target diversity into a tracking research method. The weight value effectively responds to the impact of single target signal changes on tracking, improves the tracking capability of the measurement ship for multi-target tasks, and avoids the risk of target switching during the tracking process. This method performs multi-target spread spectrum measurement and control tasks in the future. It is of great significance.

References
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