Identification of repeater jamming in netted radar systems using JEM feature

Abstract:

*Introduction*:

As an effective category of deception jamming, repeater jamming generates range false targets appearing dispersedly by modulating and retransmitting intercepted radar signals. Although a distributed multiple-radar system has the ability of rejecting the false targets overstep a space resolution cell automatically in spatial registration, a repeater jamming can still deceive the netted radar system if the jammer could adjust the time-delay carefully.

Signal-level fusion is a powerful measure for netted radar systems to strengthen their functions. It can not only improve their abilities of searching and tracking targets, but also discriminate deception jamming []. However, when applying signal level fusion for the discrimination of active false targets, most existing works emphasis on the differences of the spatial scattering properties between the real targets and the false targets []. There has been a lack of paying attentions on the JEM (jet engine modulation) feature of the targets.

In this letter, the JEM feature is employed for identification of a repeater jamming in a netted radar system, on the basis of the fact that the echo comes from a real target, which is assumed to be a flight object with at least one engine, has an additional JEM feature, while the jamming signal transmitted by a repeater has not such a JEM feature.

*JEM signature model and its detection:* The parametric model of a base-band JEM signature can be represented by [1]

 (1)

where *n* is the JEM harmonic index,  and  are the Fourier series coefficients related to AM and PM, respectively, and  is the engine rotation frequency. It is obvious that, from (1), the JEM spectrum is composed of many harmonics with fundamental frequency . Additionally, some relatively dominant amplitude components exist at chopping harmonics whose fundamental frequency is , where *N* is the number of blades in the first rotor stage [1].

Since the harmonics whose fundamental frequency  are more easier to be distinguished than the harmonics whose fundamental frequency , and since it is sufficient to identify whether the JEM exists or not, only the spectral lines located at , where *k* is an integer, need to be considered.

To extract the JEM component of a received radar echo, a method employing complex empirical mode decomposition (CEMD) is proposed in [2]. Unfortunately, the CEMD is highly sensitive to the white Gaussian noise, so the robustness and the practicability of the method are not satisfactory. Furthermore, the computational complex of the method is relatively high.

A simpler and faster approach for the detection of the JEM component based on FFT is proposed. The steps of the approach are as follows.

1. Calculate the FFT of the received signal  to get the spectrum .
2. Find the location  on the frequency axis of the maximum of the spectrum, which is associated with the Doppler frequency of the target.
3. Estimate the minimum probable fundamental frequency  to get an estimated frequency  according to a prior information of the rotation speed and the number of the blades, and find all the peaks of the spectrum which are separated at least no less than , and save the locations of the peaks to a vector .
4. Differentiate the vector  to get a new vector , i.e. .
5. If , then JEM component is detected. Otherwise, the received signal without JEM component is declared.

*Method of Identifying repeater jamming in netted radar systems*:

In a radar network, the distributed multistatic radars can cooperatively identify the repeater jamming by utilizing the JEM feature. When a received signal is detected by a radar of the radar network, the parameters of this signal, such as range , velocity, azimuth angle and elevator angle, can be estimated with some signal processing techniques. Also, whether a JEM component is existed or not can be identified with **Algorithm 1** listed above. Then, based on the azimuth angle of this target, the radar could inform other radars which are located at the sector between -60 to 60 back of the target, to cooperatively check if the target is a false one based on the JEM feature. In this confirmation phase, signal level fusion in frequency domain can be carried out at the center site of the radar network as the chopping harmonics have relatively dominant and evident spectrum lines. It should be noted that frequency compensation should be performed first at the fusion center because of the different work frequencies of the different radars. The detection of JEM feature from the received signal and the entire identification process of the repeater jamming in a netted radar system are summarized in **Algorithm 2**.

**Algorithm 2** Algorithm of Repeater Jamming Identification in Netted Radar System

**Phase 1:** Mono-radar identification

Detection of a target

Estimation of the target’s azimuth angle  and elevator angle  based on radar signal processing

Detection of JEM feature with **Algorithm 1**

If JEM exist

Report a real target may represented and the parameters, and  are sent to the center site, and then go **Phase 2**

Else

If the radar is orthogonal to the target, JEM cannot be detected and a confirmation is needed, then go **Phase 2**

Else

The target must be a false one and output the identification result

Endif

Endif

**Phase 2:** Confirmation in center site

Dispatch radars within the space behind the target, which can be represented by  and  to do a checking scan

Each radar sends the received signal to the center site

Center site performs a frequency domain signal-level fusion after spatial registration and frequency compensation

Center site performs JEM detection based on the frequency domain fusion data with **Algorithm 1**

If JEM exists

The target must be a true one and output the identification result

Else

The target must be a false one and output the identification result

Endif

*Simulations*:

The performance of repeater jamming identification is examined. In the simulations, we assume all the targets have been spatial registered and all the radars working on the same frequency 5GHz. Also, frequency compensation is assumed to be perfect performed. The other parameters used in the simulations are listed below. An engine of a real target has 38 blades, and the blade rotation speed is between 1800 rpm to 3600 rpm. Two radars, no.1 and no.2, are assumed within the zone that is suitable for observing the JEM. The azimuth angle  and the elevator angle  of the target to no.1 radar are  and , respectively. The azimuth angle  and the elevator angle  of the target to no.2 radar are  and , respectively. A repeater installed on a small UAV (unmanned aerial vehicle) keep generating false targets and sending jamming signal to the victim radars. The real echo and the repeater jamming are not coexisting in a radar receiver.

untitledTo give an insight into the advantage of the Algorithm 1, Fig.1 depicts

这是在俯仰角0度的情况下，方位角1/3pi，JEM相对强度为-7db，ALGORITHM1和CEMD的比较。

ff1

这是两部不同条件雷达在JEM相对强度-10db下的表现。

*Conclusion*:

*Acknowledgement*:

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Reference

1. J.H. Park, H. Lim and N.H. Myung. Analysis of jet engine modulation effect with extended Hilbert-Huang transform. ELECTRONICS LETTERS, 2013, 49(3)