Jamming of Reticle-Based Seekers

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Introduction

The use of infrared (IR) energy in warfare is a practice that dates back to the early 1960s, and the IR-based missile has become one of the most successful weapons used in warfare. First- and second-generation man portable air defence systems (MANPADS) employ the use of reticle-based seekers for missile guidance and these devices are still widely used. As a result, it is necessary to develop effective countermeasures against reticle-based missile seekers.

Conventional countermeasures such as flares and decoys are not always effective in deceiving MANPADS, as effective counters exist. Jamming can be categorized into omnidirectional and directional infrared countermeasure (DIRCM) methods. Omnidirectional jamming is power intensive since it requires more energy to transmit light in all directions, whereas the DIRCM method directs all the energy in one direction. A DIRCM thus requires the knowledge of the direction to the missile in order for the jamming signal to be effective.

This project will thus seek to implement a jamming code for a DIRCM system that will be used for deception of spin-scan and con-scan missile seekers.

Basic Operation of a Reticle Seeker

In order to develop an effective jamming code, it is necessary to understand the operation of missile seekers and the important parameters to consider for successful jamming. Spin-scan and con-scan reticle seekers are the most widely used reticle-based seekers in missiles. These seekers can employ the use of amplitude modulation (AM), frequency modulation (FM) and phase modulation (PM) for target tracking. In order to describe the basic operation of the seeker, the simple AM reticle will be used.

An AM reticle consists of an equal number of transparent and opaque sections which either permit or stop the radiation of the target to reach the detector. The reticle modulates or chops the IR energy into pulses with the amplitude of the pulses indicating the distance of the target from the centre and the angle to the target is indicated by the pulse phase pattern. Figure 1 illustrates how the reticle modulates the radiated energy as seen by the detector. When the target is in position A, the output of the detector will be a DC value since the energy does not change with the spinning reticle and as such no modulation will take place. As the target moves away from the centre of the reticle to position B, the radiation energy will increase but the full radiation of the target is not completely captured at an instant in time. As the target moves to position C, the modulation amplitude reaches the peak value as the full radiation energy can be seen and thus amplitude modulation results.

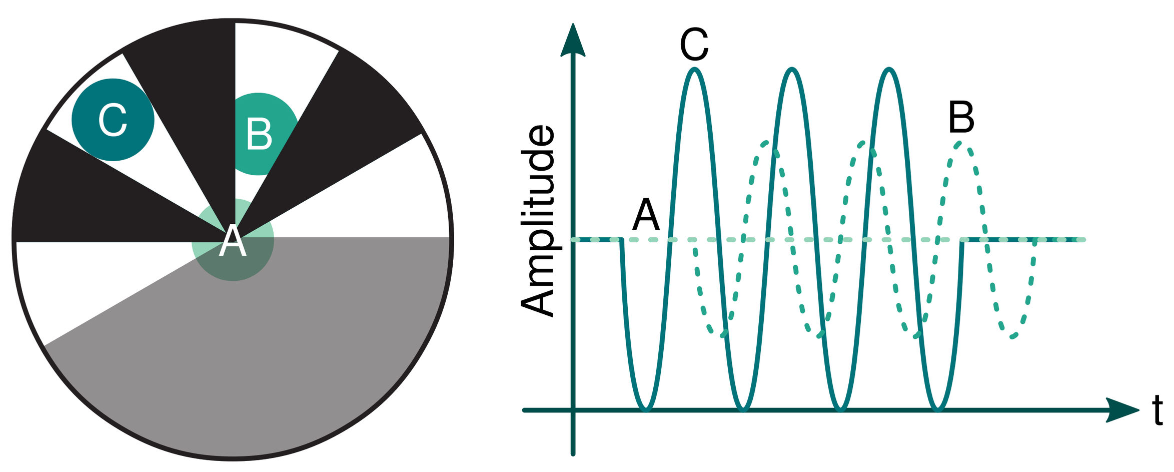

Figure 1. Illustration of the spin-scan modulation process.

The amplitude of the detector becomes significantly increased when a jammer signal is introduced and since the amplitude information in the pulses is used to determine the radial distance of the target from the centre of the reticle, the seeker will see the target as further from optical axis 1than it really is. The signal processing diagram for the spin-scan seeker is illustrated in Figure 2. The output of the IR detector is passed through a bandpass filter which is centred at the carrier frequency of the detector signal. The filtered signal is then demodulated using an envelope detector in order to detect the amplitude of the pulses. The demodulated signal is then passed through a bandpass filter that is centred at the spin frequency of the reticle in order to determine the phase of the signal. The output of the bandpass filter is a square wave that indicates the portion where the signal starts and where the phasing sector starts. This output is compared to a reference phasing signal and the output is the phase error which will be used to drive the tracking circuit. The phase error will determine whether the missile turns left or right while the AM demodulator output will determine whether the missile goes up or down.

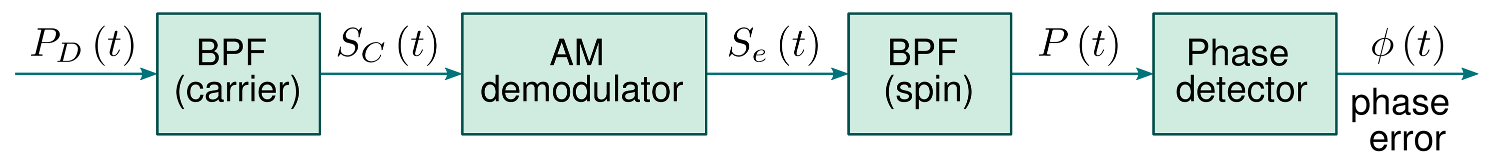

Figure 2. Signal processing of a spin-scan seeker.

Jamming of a Reticle Seeker

Several simulation programs have been developed to test the effectiveness of DIRCM jamming and it was shown that the effectiveness of jamming is largely influenced by the frequency, phase and intensity of the jammer signal [1] and these parameters should be optimally set to ensure jamming success. The phase error rate of the output signal can be approximated by

$$\Delta\phi(t)\approx\alpha\left(A+\frac{B}{4}\right)+\frac{B}{2}\left(1+\frac{\alpha}{2}\right)e^{\,j\beta(t)} \qquad (1)$$

where α is the ratio of the target radius and the reticle radius ($0 \leq \alpha \leq 1$), A is the target intensity, B is the jammer intensity and $\beta(t) = (\omega_m - \omega_j)t - \varphi_j(t)$ with ω_m and ω_j being the reticle and jammer frequencies respectively. From equation 1 it can be seen that the addition of the jammer signal introduces sinusoidal perturbations in the error rate and the target cannot be brought to the centre of the reticle. The phase error rate can be illustrated by a phasor diagram as shown in Figure 3 with a target illustrated by the point A in red. If a jammer successfully causes the seeker to break the lock on the target that the seeker already has, then optical break lock (OBL) occurs. This can be achieved if the phasor characteristics can be set such that the point target A is dragged away from the reticle centre which in this case is the centre of the circle and this can occur when the resultant vector lies on the real axis in the opposite direction as the reticle centre. This requires optimal setting of the amplitude, phase and frequency of the jammer signal.

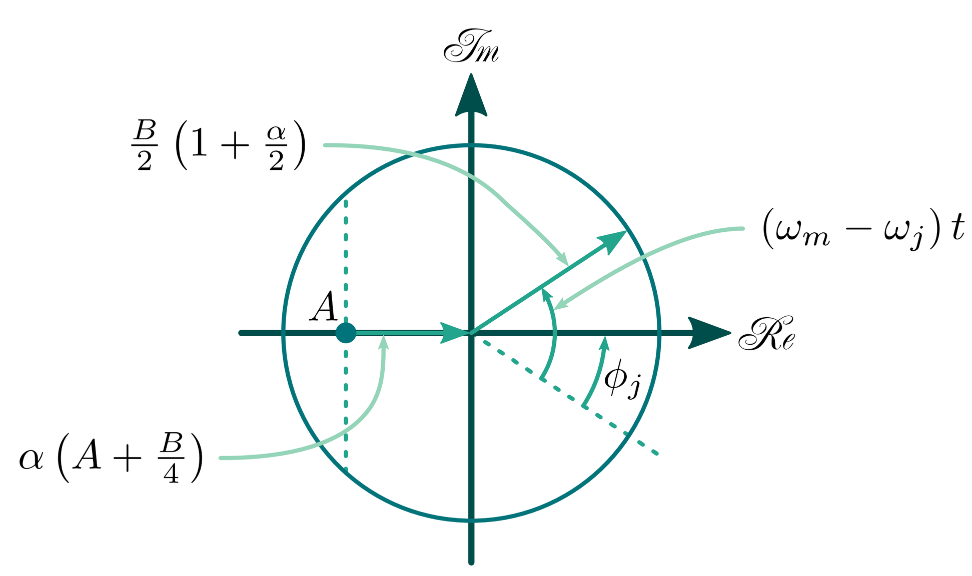

Figure 3. Phasor illustration of phase error rate.

Conclusion

The research questions that result are what the phase shift should be to ensure optimal jamming and the maximum amplitude that the jammer can be set to ensure successful jamming. It was suggested that the frequency of the jammer signal is the parameter that has the greatest influence on the jamming effect and as such another area that this research will address is automatic detection of the reticle frequency for jamming [1-2].

References

[1] T. Bae, et al., " Jamming effect analysis of infrared reticle seeker for directed infrared countermeasures," *Infrared Physics & Technology*, vol. 55, no. 5, pp. 431-441, Sep. 2012.

[2] G. Kim, et al., " Implementation of a reticle seeker missile simulator for jamming effect analysis," in *Int. Conf. on Image Processing Theory Tools and Applications (IPTA)*, 7-10 July 2010, Coimbatore, India.

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