Doppler frequencies which can be caused by the missile slightly changing course to create a range of Doppler shifts. Several possible missile trajectories for DBS were proposed in [3] and [4].

The scenario of an Anti-Ship Missile (ASM) attacking a ship, DBS can be used to differentiate valid ship targets and decoys from clutter such as waves or coastline [2] by using the changing uses the relative motion between the target and the radar platform to resolve targets, or dominant scatterers, within the same target in cross-range by exploiting the Doppler effect [1].

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Introduction

Modern Radio Frequency (RF) seekers are becoming increasingly more capable of medium to high resolution target imaging capabilities. Doppler Beam Sharpening (DBS) is a technique that uses the relative motion between the target and the radar platform to resolve targets, or dominant scatterers, within the same target in cross-range by exploiting the Doppler effect [1]. In the scenario of an Anti-Ship Missile (ASM) attacking a ship, DBS can be used to differentiate valid ship targets and decoys from clutter such as waves or coastline [2] by using the changing Doppler frequencies which can be caused by the missile slightly changing course to create a range of Doppler shifts. Several possible missile trajectories for DBS were proposed in [3] and [4].

Repeat jamming against pulsed DBS

During the scenario, the missile transmits the first pulse at the origin and moves perpendicular to the target with a velocity V to transmit again. The transmitted wave will propagate along a distance P1 to the jammer located on ‘T1’ and will then be reflected or instantly re-transmitted back to the missile along P2.

To insert the false target FT1, the jammer needs to repeat the seeker waveform to have a delay time which reflects the propagation distances of:

$$J_{T_{\text{total}}} = \frac{J_1 + J_2}{c}$$

The targets and seeker are assumed to be at the same elevation for the entire scenario. The required delay time at the point of transmission for each jamming pulse can be calculated by:

$$J_{T_{\text{FT}}} = \frac{[P_1 + (J_1 - P_1) + (J_2 - P_2)]}{c}$$

The simulated scenarios in this paper used four separate single point targets with two pairs at the same ranges but separated in cross-range plus one inserted jamming false target. The transmitted waveform for the scenarios was a Linear Frequency Modulated (LFM) or Chirped waveform. This gives a transmitted pulse train of:

$$s_f(t) = \sum_{m=0}^{M_{\text{max}}} A_m \cos(2\pi f_c t)$$

It is assumed that the jammer knows the missile velocity, trajectory, bandwidth, pulse width, carrier frequency, chirp rate, PRI and therefore the PRI. If the jammer local oscillator is perfectly matched to the seeker carrier frequency, this will then give a downmixed signal of:

$$J_R(t) = \sum_{m=0}^{M_{\text{max}}} A_m x(t - t_m(m) - m\text{PRI}) e^{-i2\pi f_c t_m(m)}$$

The downmixed signal is then processed to obtain the parameters of the victim radar and calculate the required delay times to create a desired false target:

$$J_{T_{\text{F}}} = \sum_{m=0}^{M_{\text{max}}} A_m x(t - t_m(m) - m\text{PRI}) e^{-i2\pi f_c t_m(m)}$$

Using this method and parameters in table 1, Figures 2 and 3 show that a false target can be generated in a DBS image.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Carrier frequency</td>
<td>3450MHz</td>
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<tr>
<td>Bandwidth</td>
<td>2MHz</td>
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<tr>
<td>Pulse width</td>
<td>30µs</td>
</tr>
<tr>
<td>Chirp rate</td>
<td>2x10¹⁴Hz²</td>
</tr>
<tr>
<td>Dwell time</td>
<td>T_d</td>
</tr>
<tr>
<td>Pulse repetition frequency</td>
<td>PRI</td>
</tr>
<tr>
<td>Pulse repetition interval</td>
<td>PRI</td>
</tr>
<tr>
<td>Range resolution</td>
<td>7.5m</td>
</tr>
<tr>
<td>Missile velocity</td>
<td>270m/s</td>
</tr>
</tbody>
</table>

Table 1: Signal variables

Conclusion

The simulations show that false targets further away than the location of the jammer can be inserted into a DBS image assuming the missile trajectories are known. In practice, the main challenge with jamming is maintaining accurate missile velocity and trajectory estimations to constantly change the delay time to create the perfect false target. The practical implementation of jamming with respect to Low Probability of Exploitation (LPE) waveforms has not been assessed in this paper but will be addressed in future work.

References


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