Simulations of repeat jamming against anti-ship missile seekers which use Doppler beam sharpening modes

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.

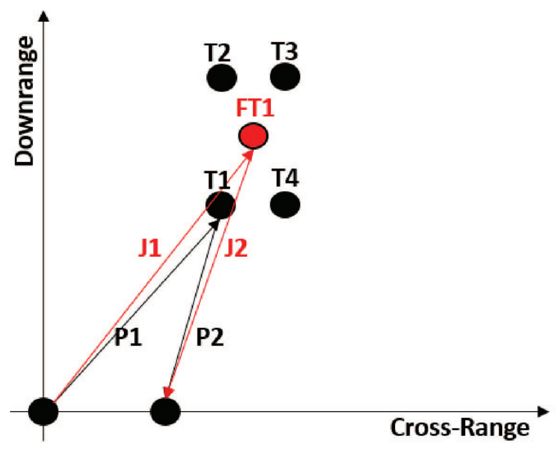

Figure 1: Example jamming scenario

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:

$$J_{Total} = \frac{J1 + J2}{c}$$

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:

$$J_{FT} = \frac{[P1 + (J1 - P1) + (J2 - P2)]}{c}$$

Jamming signal overview

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:

$$s_T(t) = \sum_{m=0}^{M_{pulses}} A_T x(t - mPRI) e^{i2\pi f_c t}$$

It is assumed that the jammer knows the missile velocity, trajectory, bandwidth, pulse width, carrier frequency, chirp rate, PRF 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:

$$J_R(t) = \sum_{m=0}^{M_{pulses}} A_{p1} x(t - t_{p1}(t) - mPRI) e^{-i2\pi f_c t_{p1}(t)}$$

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:

$$J_T(t) = \sum_{m=0}^{M_{pulses}} A_{JT} x(t - J_{FT}(t) - mPRI) e^{i2\pi f_c (t - J_{FT}(t))}$$

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

Variable	Symbol	Value
Carrier frequency	f_c	36GHz
Bandwidth	B	20MHz
Pulse width	τ	$3\times10^{-6}s$
Chirp rate	γ	$2\times10^{13}Hz^2$
Dwell time	T_d	$\approx 26ms$
Pulse repetition frequency	PRF	20kHz
Pulse repetition interval	PRI	$5\times10^{-5}s$
Range resolution	ρ	7.5m
Missile velocity	V_m	$270ms^{-1}$

Table 1: Signal variables

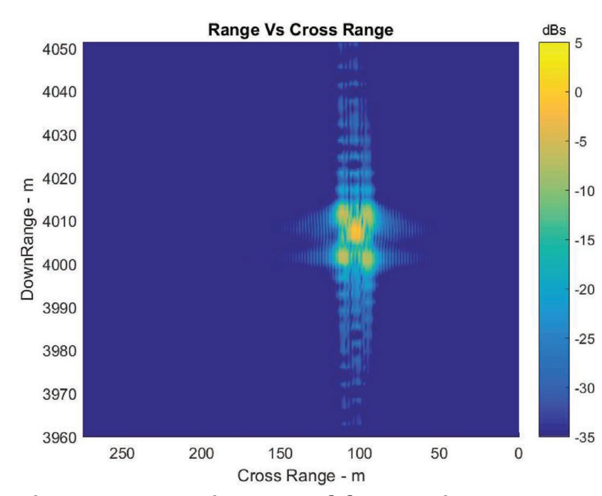

Figure 2: DBS image of four point targets with one false target

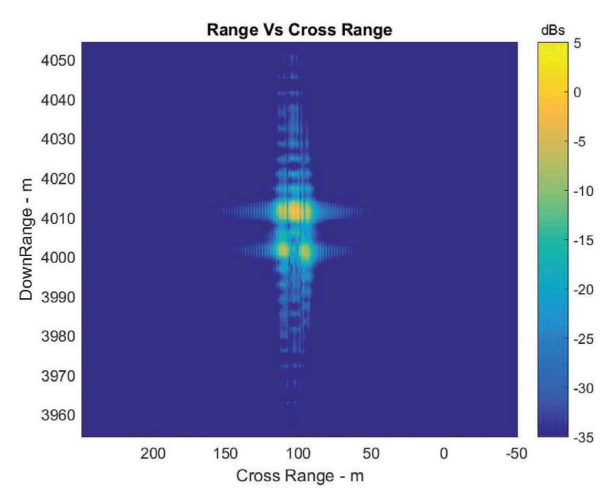

Figure 3: DBS image with masked target

Velocity estimation errors

The scenarios in this paper have been used to create false targets under the assumption that all the victim radar parameters have been perfectly estimated as well as the seeker velocity and trajectory. Based on the perpendicular trajectories used in this paper, the effects of incorrect velocity estimations are shown in figure 4. The location/point reflector of the jammer is shown as T1 and the intended location of the false target is at 'V.' All other targets are shown to have errors in cross range. The targets shown in the figure have been separated in downrange for ease of presentation. The error of the velocity estimation directly translates into a cross-range error.

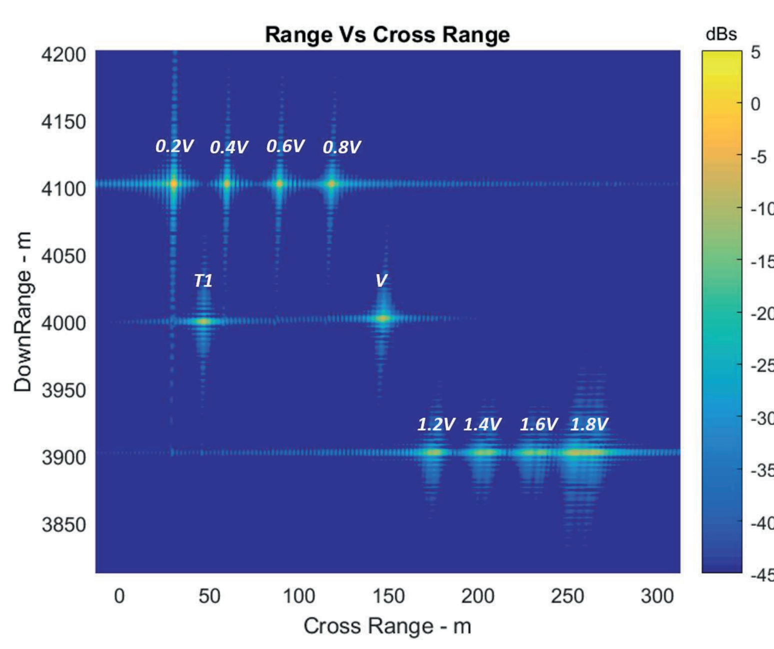

Figure 4: Effects of velocity estimation errors on false target cross-range position with zero error in downrange

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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