Electronic Attack – Radar

Short Course on Radar and Electronic Warfare
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Non-adaptive jammers

DDS – Waveform Generation
Transponder Jammers

Wave Generation

DSP/DRFM

Receiver

Wave Generation
Repeater Jammer

Receiver

Modulation
Classes of Noise Jamming

- Barrage
- Narrow band
- Partial band
- Tone Jamming

- Swept Jamming
- Pulse Jamming
- Inverse Power Jamming
- Follower Jamming
Barrage Jamming
Partial Band Jamming
Tone Jamming

Frequency Shift Keying (FSK)
Two frequencies to represent 0 & 1
Follower Jammer Reaction Time

• Need to be in the ellipse defined by:

\[ \frac{D_{TJ} + D_{JR}}{c} + T_j \leq \frac{D_{TR}}{c} + \gamma T_d \]

• \( T_d \) is the dwell time
• \( T_j \) is the processing time of the jammer
• \( \gamma \) is a fraction
Noise Jamming Effects

Figure 3: The effects of broad band noise jamming against a search radar.
Effects of Frequency Hopping

Figure 4: The effects of noise jamming on a frequency agile radar, with the target located at 22 km.
Inverse Power Jamming

Figure 5: The effects of noise jamming combined with inverse power gain against a search radar.
Figure 7: A typical monostatic radar jamming scenario, shown for a separate escort jammer and radar target.
Jammer to Signal Ratio

- Power received in a radar from the target
  \[ P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R^4} \]

- Power received from the jammer
  \[ P_{r_j} = \frac{P_j G_j G_{t_j} \lambda^2}{(4\pi)^2 R^2} \]

- Jammer to signal ratio
  \[ \frac{J}{S} = \frac{P_j G_j \, 4\pi R^2}{P_t G_t \, \sigma} \]
The Bistatic Case

• For the bistatic case, we can use a similar method to develop the jammer to signal ratio:

\[ \frac{J}{S} = \frac{P_j G_j G_r_j \lambda^2}{(4\pi)^2 R_j^2} \frac{(4\pi)^3 R_t R_r}{P_t G_t G_r \lambda^2 \sigma_{bistatic}} \]

• This reduces to:

\[ \frac{J}{S} = \frac{P_j G_j G_r_j}{P_t G_t G_r} \frac{4\pi R_t^2 R_r^2}{R_j \sigma_{bistatic}} \]
Figure 8: The probability density function of noise voltage, $p_v(v)$, with the probability of $v > V_t$ represented by the shaded region.
Choosing a Threshold

Given the results of Eqn. 30, the equation can be rearranged in terms of $V_t$, 

$$V_t = \sqrt{2\sigma_n^2 \ln \left( \frac{1}{P_{FA}} \right)}$$  \hspace{1cm} (31)

However the probability of a false alarm for the case described in Eqn. 30 is only relevant for a single pulse. In most radar systems multiple pulses will be sent to a target during a sweep, and in the case of a detection the target will likely be further dwelled on to confirm the detection. The probability of a false alarm in this case is the $P_{FA}$ for a single pulse to the power of the number of pulses [2],

$$P_{FA}(n) = \left[ P_{FA}(1) \right]^n$$  \hspace{1cm} (32)

where $n$ is the number of pulses.
Figure 9: The Rayleigh distribution of $p_v(v)$, with a noise power of $\sigma_n^2 = 0.1$ Watts, and the shaded area representing the probability of a false alarm for $V_i > 0.5 V$. 
Signal and Jamming Distributions

Figure 10: The Gaussian PDF of the noise, at the left, and the Rician PDF of the signal plus noise. The threshold level is indicated by the vertical black line, with the area representing detected targets shaded in grey.
What is the effect?

Figure 11: The probability of detection for a non-fluctuating target with a $P_{FA} = 10^{-8}$
Figure 12: The probability of detection plotted against the false alarm rate, and the signal-to-noise ratio.
Range Deception

Figure 14: The effects of deception ECM against a pulse doppler radar, where the red triangle indicates the true target.
Deception and Frequency Hopping

Figure 13: The effects of deception ECM against a conventional pulsed radar with frequency agility, where the red triangle indicates the true target.
Towed Decoys

Figure 15: Spatial geometry of a aircraft, towed decoy, and missile attempting to be jammed [25].
Deception Jamming

• Range Gate Pull Off
• Velocity Gate Pull Off
• Cross–eye jamming
• Cross-polarization jamming
Cross-eye Jamming

- Antenna Align with Phase Fronts
- Cross-eye Jammers Screw with the Phase Front