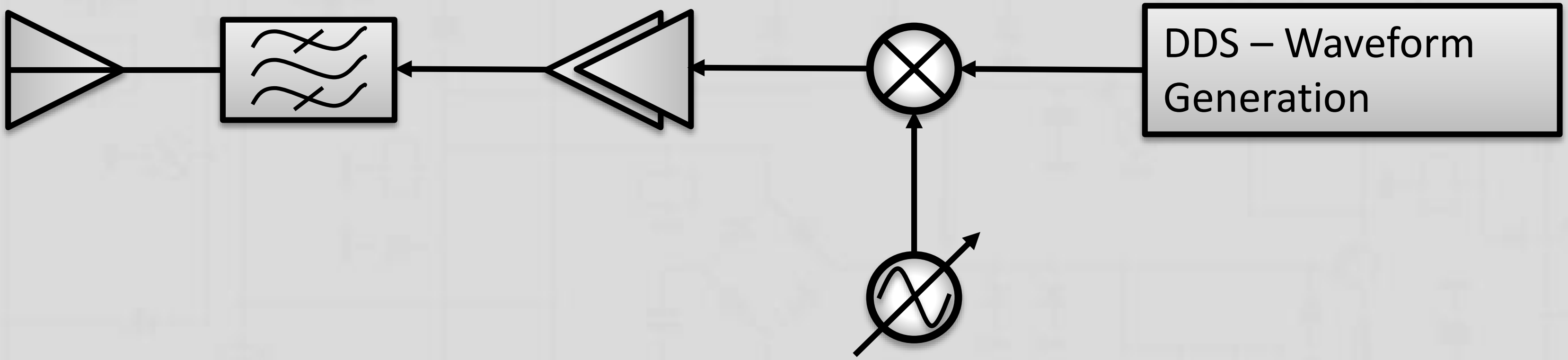
Electronic Attack – Radar

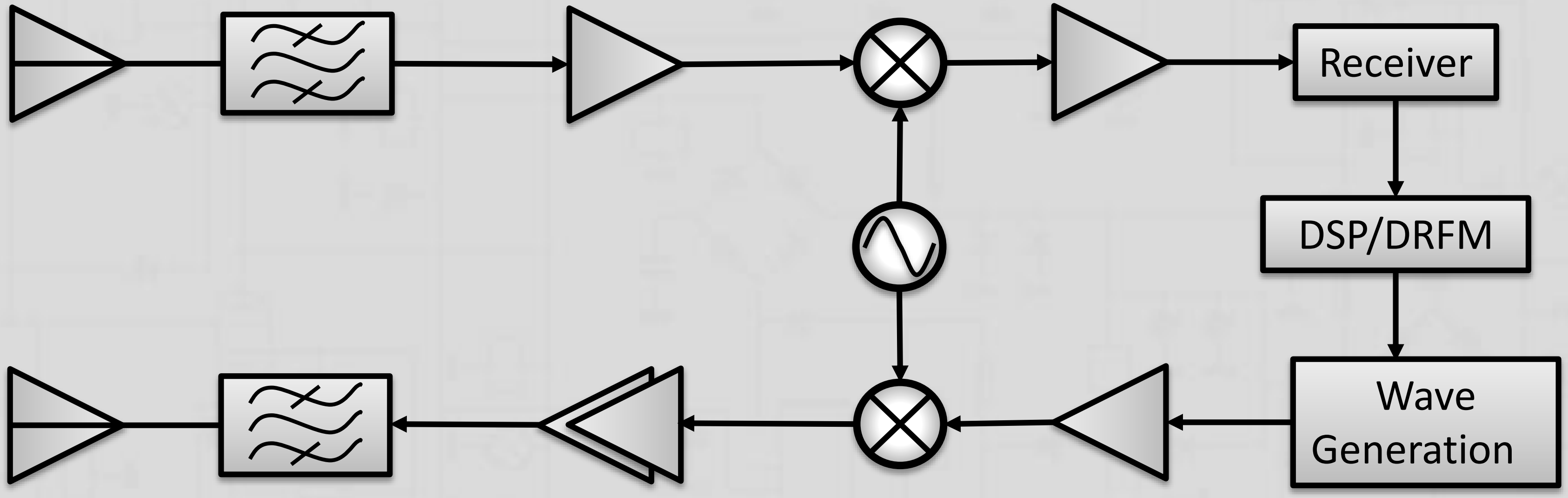
Short Course on Radar and Electronic Warfare

Kyle Davidson

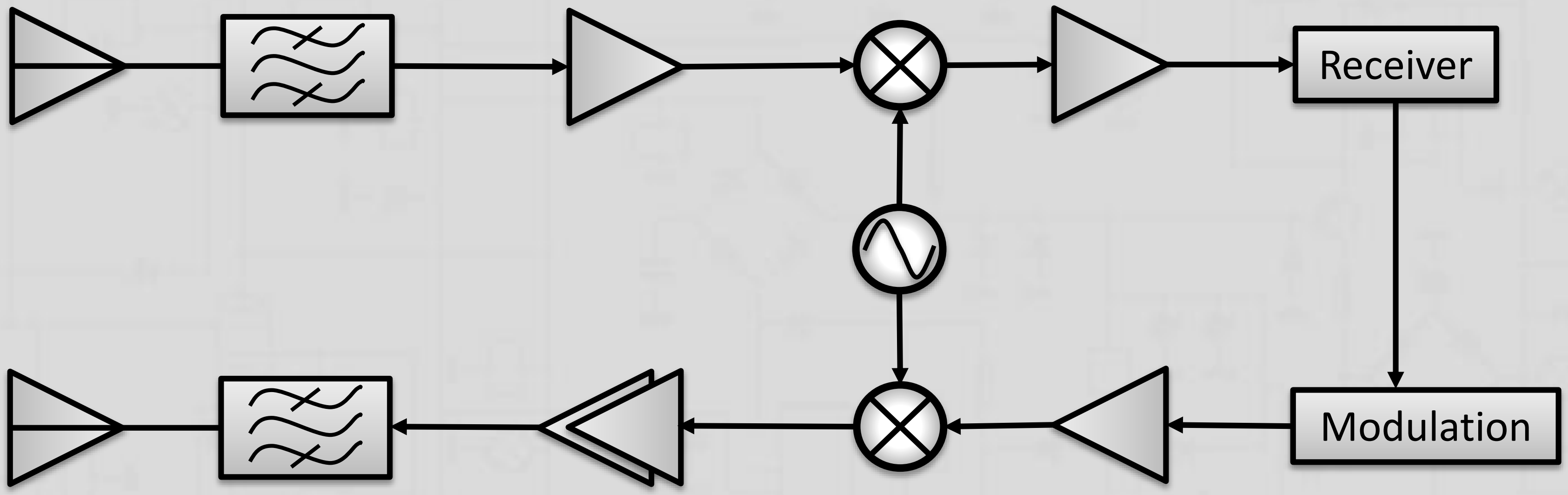
Non-adaptive jammers



Transponder Jammers



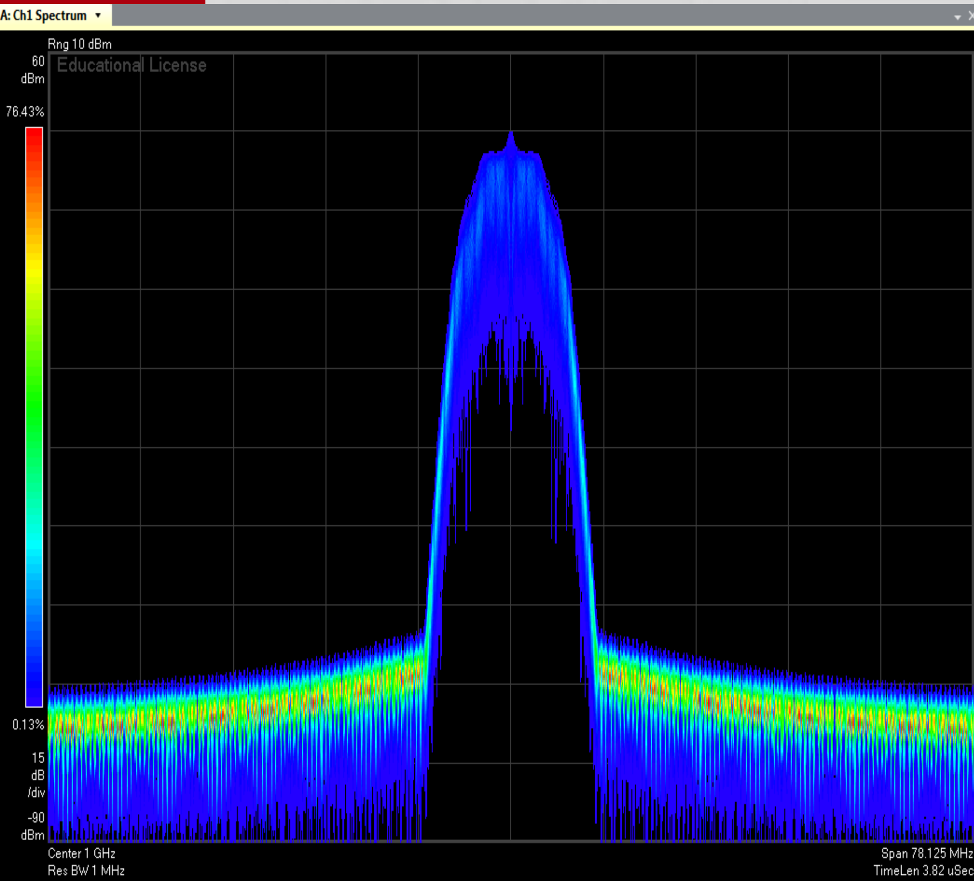
Repeater Jammer

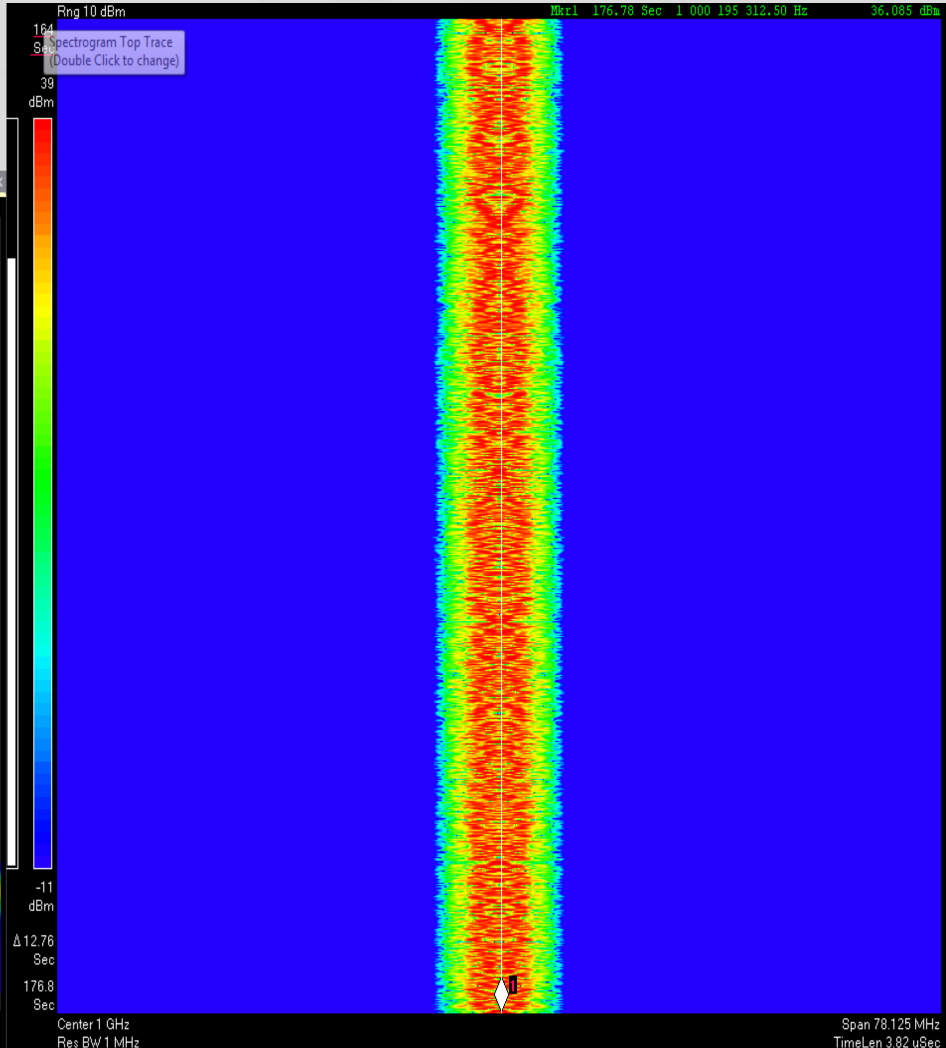


Classes of Noise Jamming

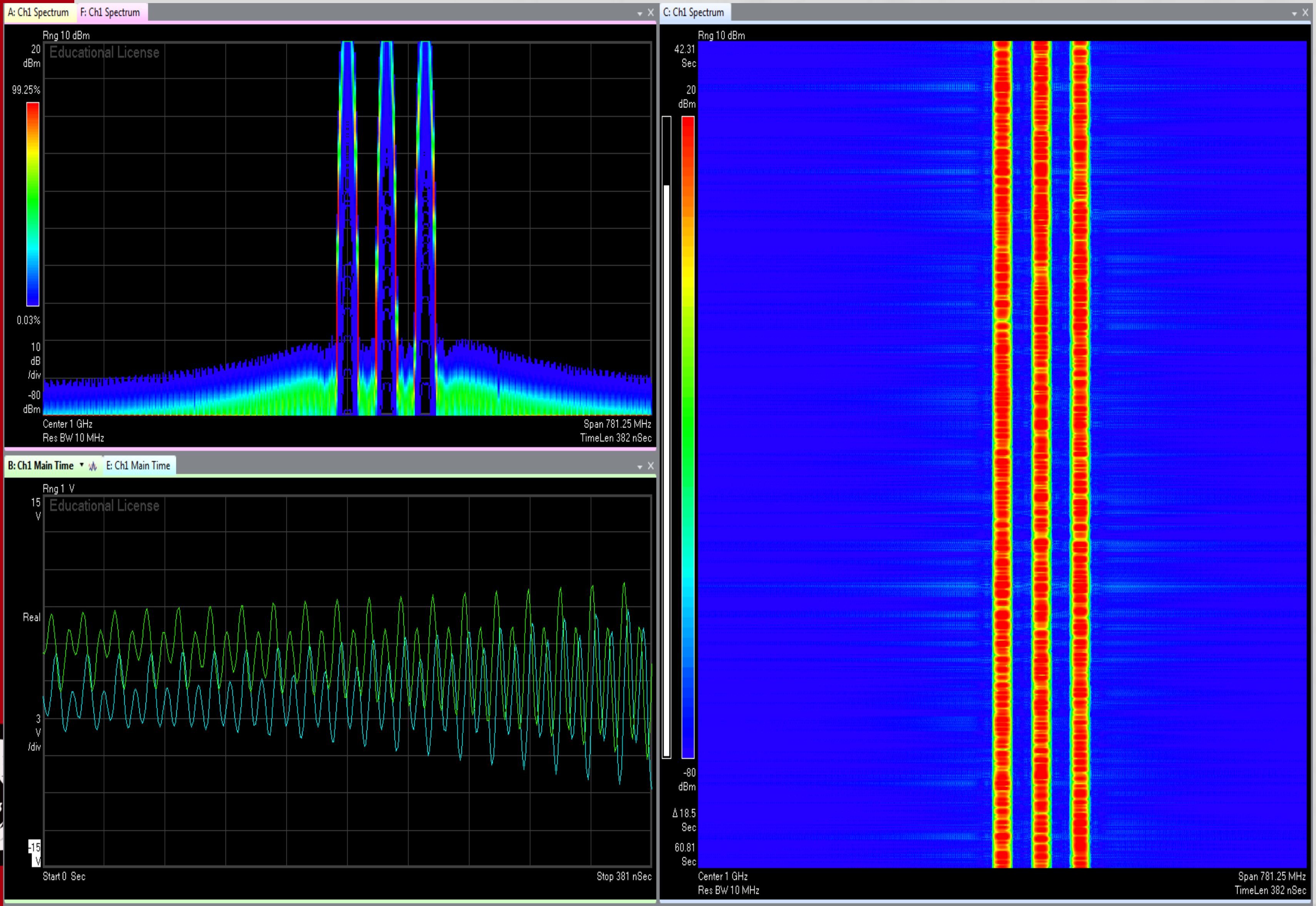
- Barrage
- Narrow band
- Partial band
- Tone Jamming
- Swept Jamming
- Pulse Jamming
- Inverse Power Jamming
- Follower Jamming

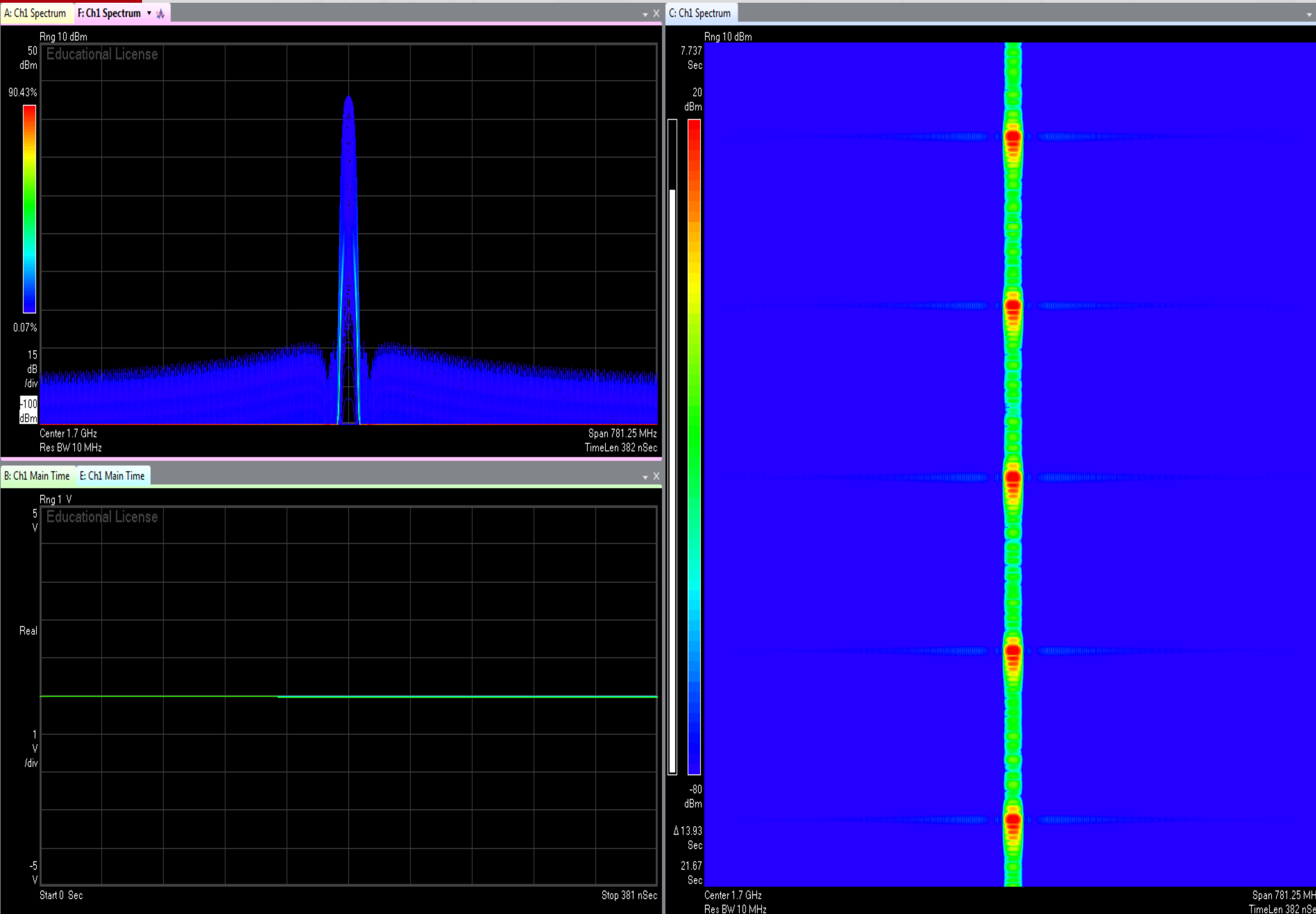
Barrage Jamming



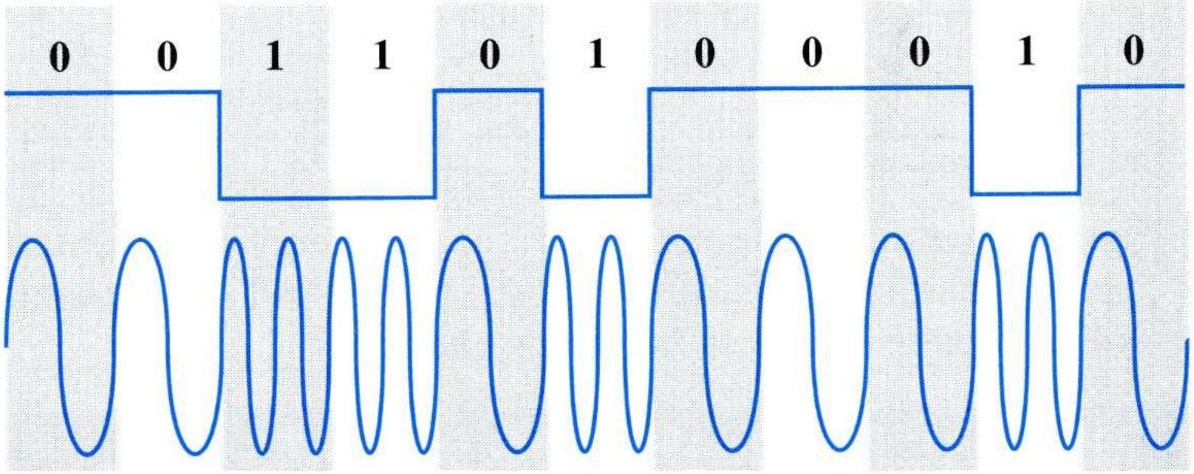


Partial Band Jamming




A: Ch1 Spectrum
F: Ch1 Spectrum
Rng 10 dBm
50 dBm
Educational License
90.43%
0.07%
15 dB /div
-100 dBm
Center 1.7 GHz
Res BW 10 MHz
Span 781.25 MHz
TimeLen 382 nSec
B: Ch1 Main Time
E: Ch1 Main Time
Rng 1 V
5 V
Educational License
Real
1 V /div
-5 V
Start 0 Sec
Stop 381 nSec
C: Ch1 Spectrum
Rng 10 dBm
7.737 Sec
20 dBm
-80 dBm
Δ 13.93 Sec
21.67 Sec
Center 1.7 GHz
Res BW 10 MHz
Span 781.25 MHz
TimeLen 382 nSec

Tone Jamming



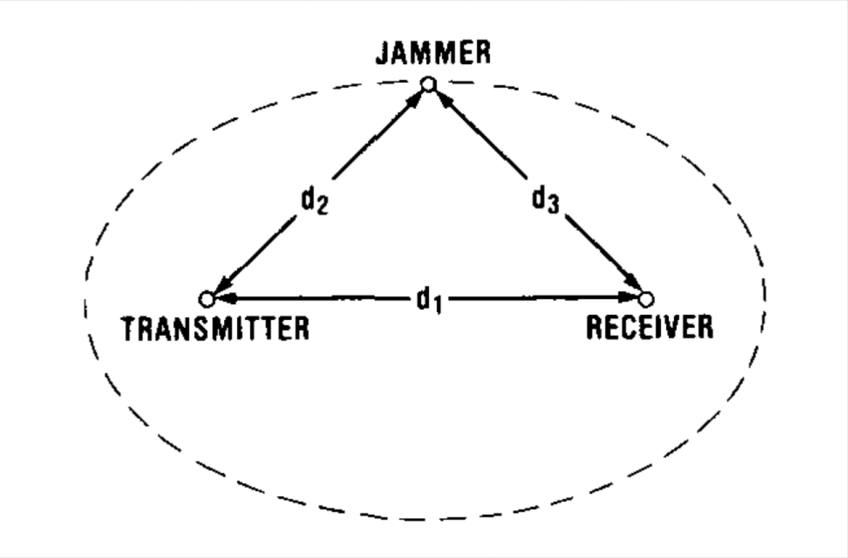
Frequency Shift Keying (FSK)

Two frequencies to represent 0 & 1

Follower Jammer Reaction Time

- Need to be in the elipse defined by:

$$\frac{D_{TJ} + D_{JR}}{c} + T_j \leq \frac{D_{TR}}{c} + \gamma T$$



- T_d is the dwell time
- T_j is the processing time the jammer
- γ is a fraction

Noise Jamming Effects

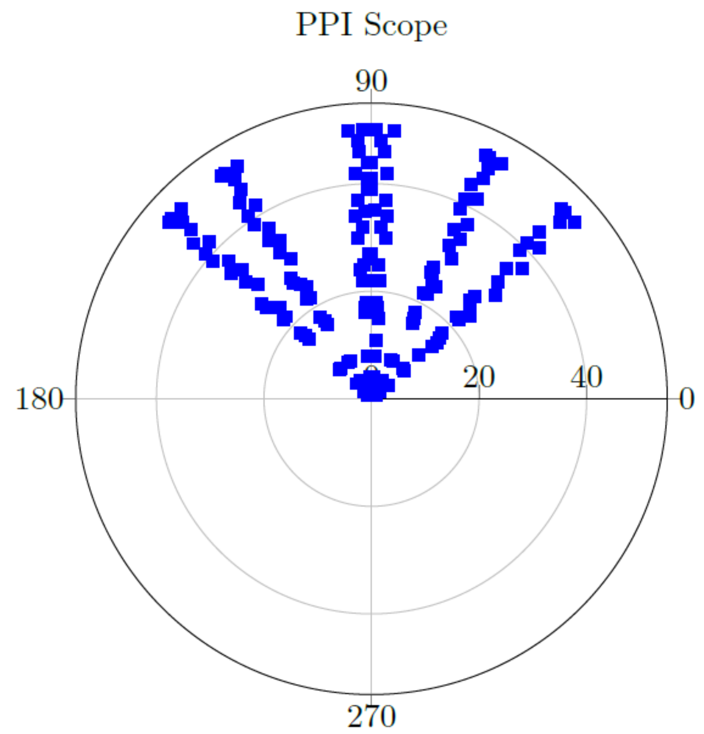


Figure 3: *The effects of broad band noise jamming against a search radar.*

Effects of Frequency Hopping

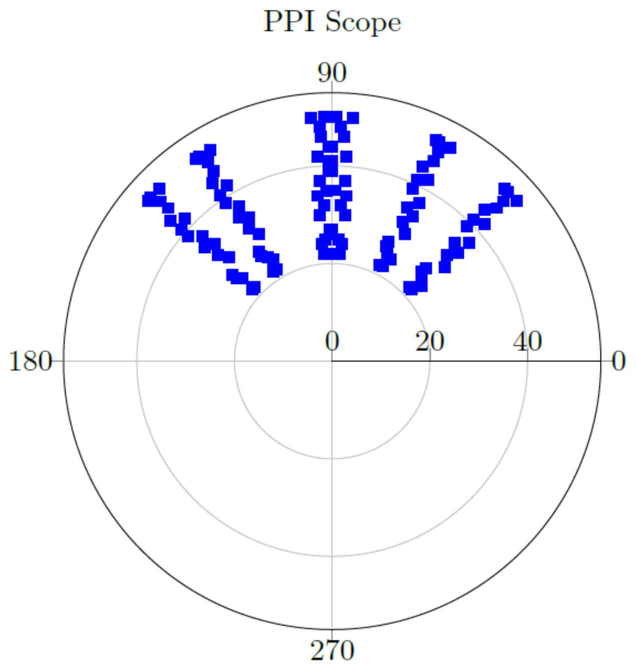


Figure 4: *The effects of noise jamming on a frequency agile radar, with the target located at 22 km.*

Inverse Power Jamming

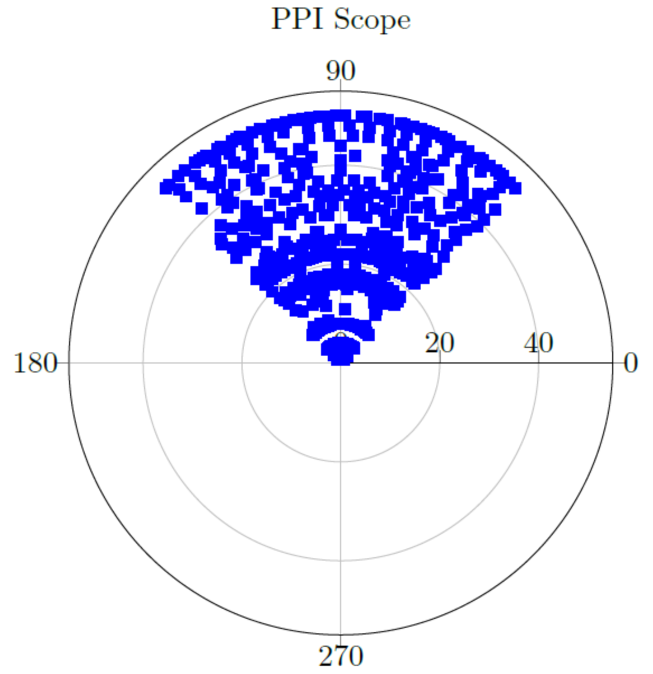


Figure 5: *The effects of noise jamming combined with inverse power gain against a search radar.*

Jammer Scenario

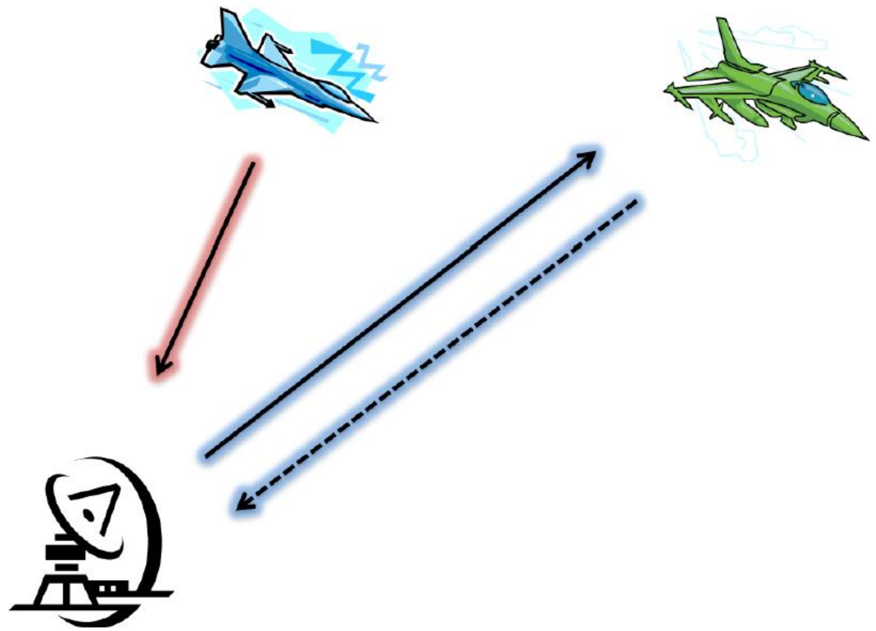


Figure 7: *A typical monostatic radar jamming scenario, shown for a separate escort jammer and radar target.*

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

$$\frac{J}{S} = \frac{P_j G_j}{P_t G_t} \frac{4\pi R^2}{\sigma}$$

The Bistatic Case

- Fro 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:

$$\frac{J}{S} = \frac{P_j G_j G_{r_j}}{P_t G_t G_r} \frac{4\pi R_t^2 R_r^2}{R_j \sigma_{bistatic}}$$

Probability of Detection

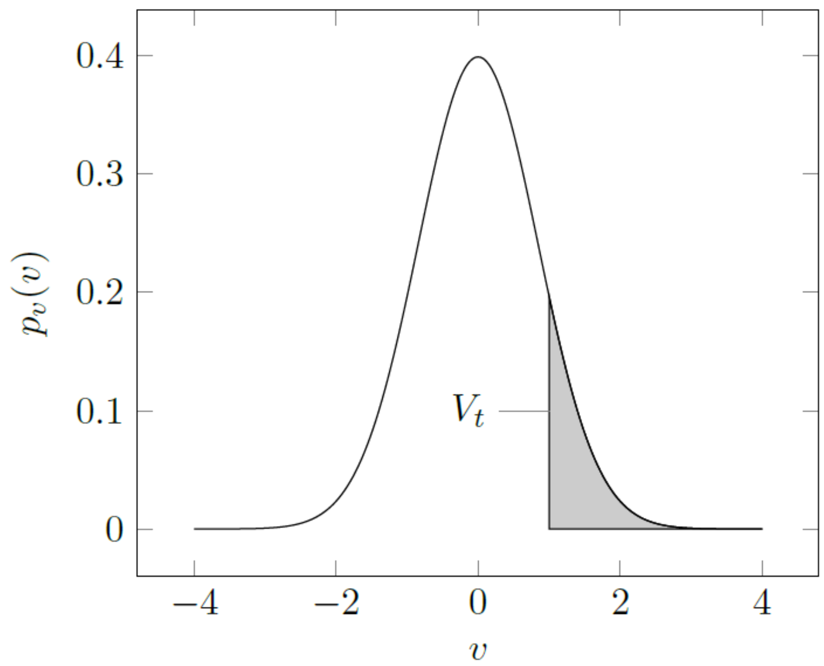


Figure 8: *The probability density function of noise voltage, $p_v(v)$, with the probability of $v > V_t$ represented by the shaded region.*

Choosing a Threshold

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

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

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],

$$P_{FA}(n) = [P_{FA}(1)]^n \qquad (32)$$

where n is the number of pulses.

Distribution Curve

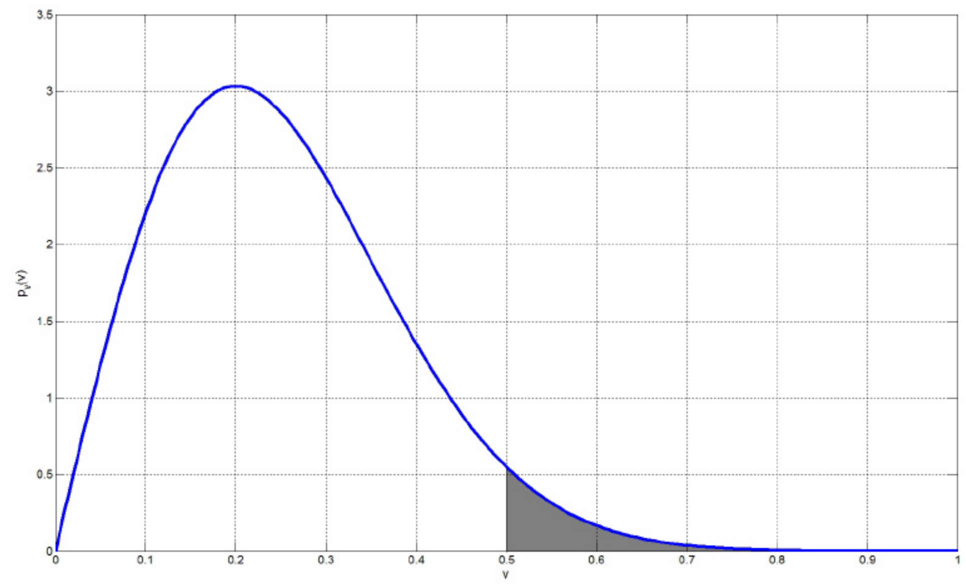


Figure 9: *The Rayleigh distribution of $p_v(v)$, with a noise power of $\sigma_n^2 = 0.1$ Watts, and the shaded area representing the probability of a false alarm for $V_t > 0.5$ V.*

Signal and Jamming Distributions

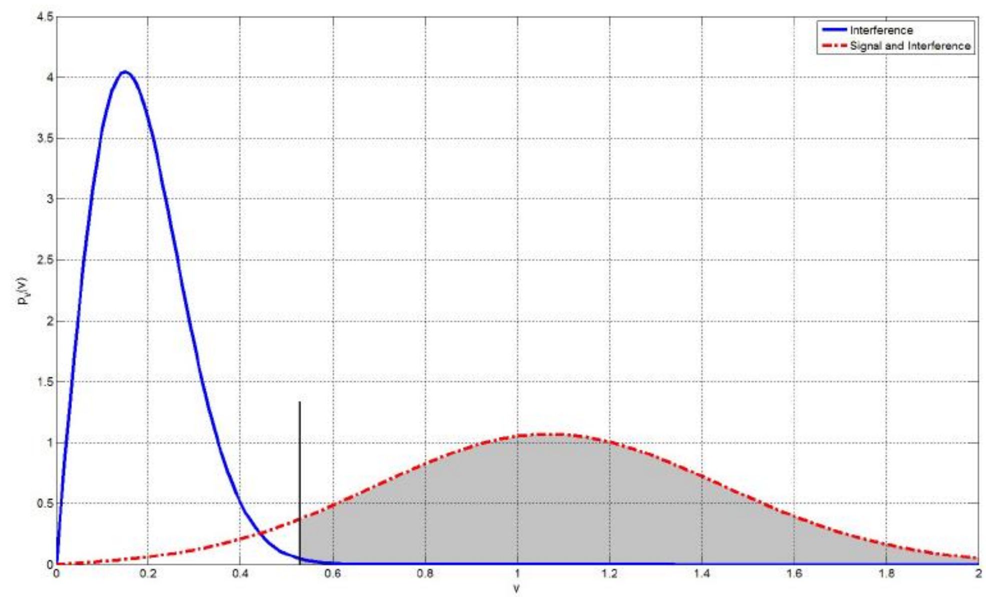


Figure 10: *The Gaussian PDF of the noise, at the left, and the Rician PDF of the signal pluse noise. The threshold level is indicated by the vertical black line, with the area representing detected targets shaded in grey.*

What is the effect?

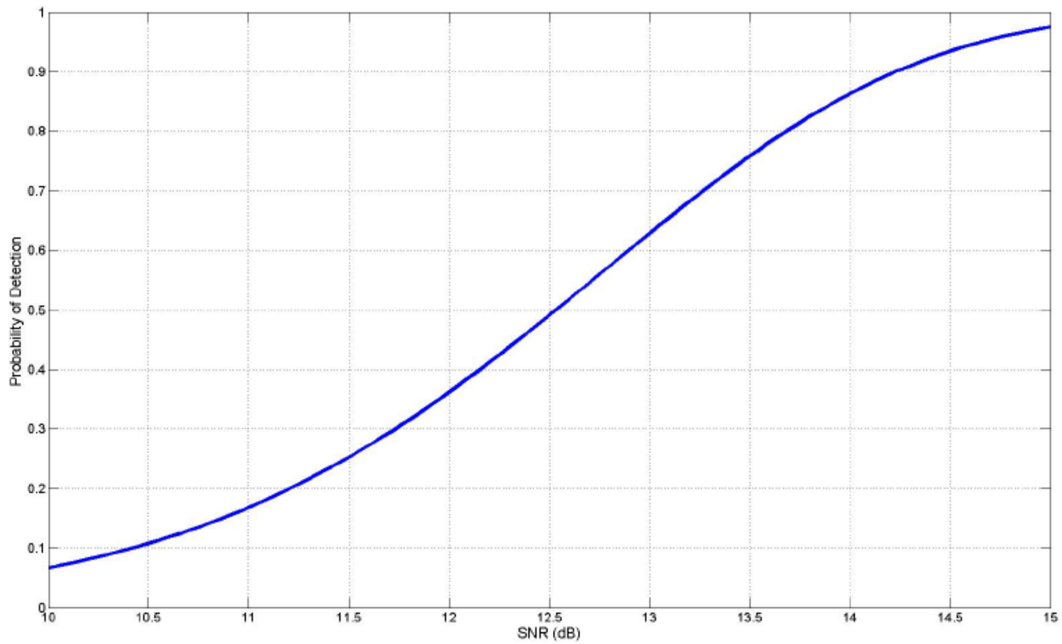


Figure 11: *The probability of detection for a non-fluctuating target with a* $P_{FA} = 10^{-8}$

Receiver Operating Curve

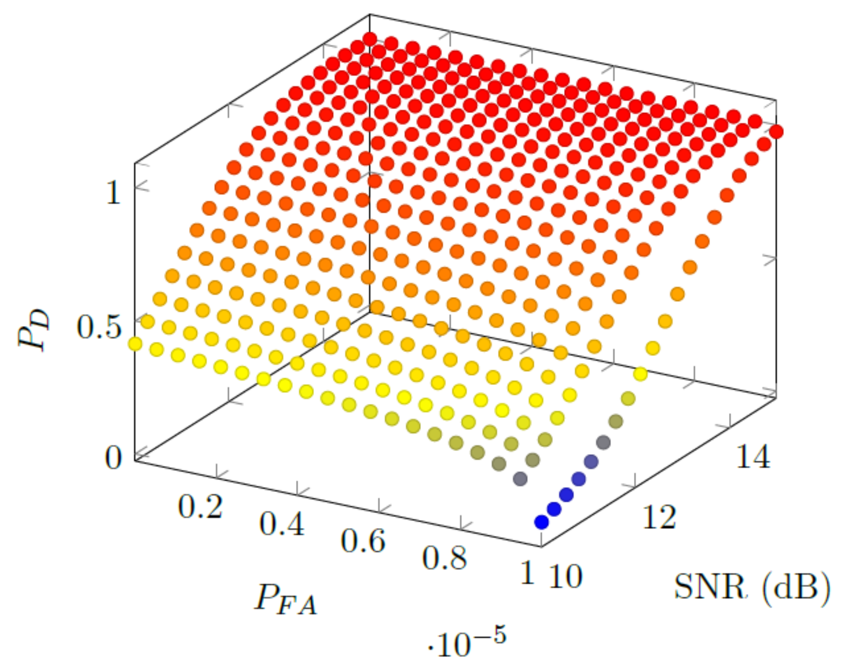


Figure 12: *The probability of detection plotted against the false alarm rate, and the signal-to-noise ratio.*

Range Deception

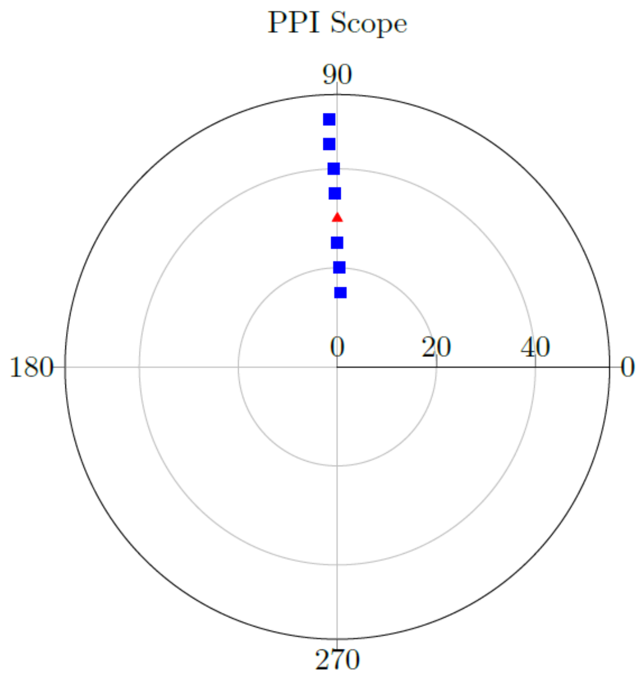


Figure 14: *The effects of deception ECM against a pulse doppler radar, where the red triangle indicates the true target.*

Deception and Frequency Hopping

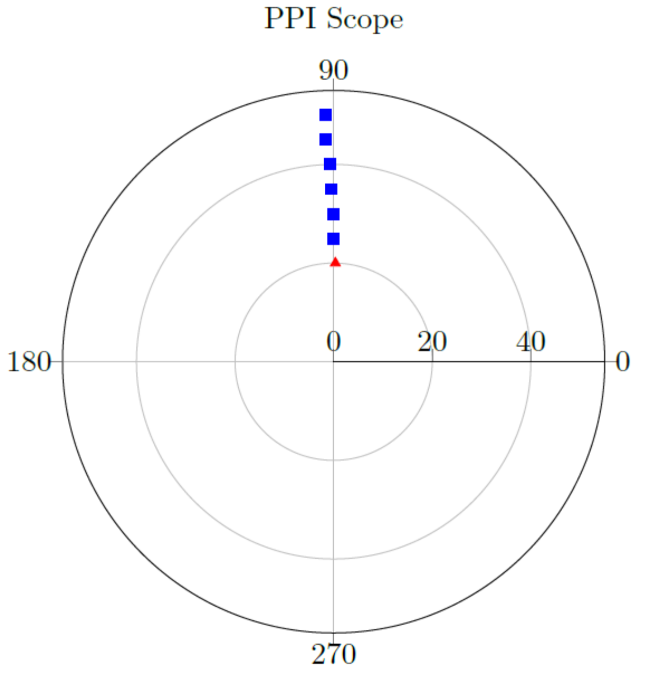


Figure 13: *The effects of deception ECM against a convetional pulsed radar with frequency agility, where the red triangle indicates the true target.*

Towed Decoys

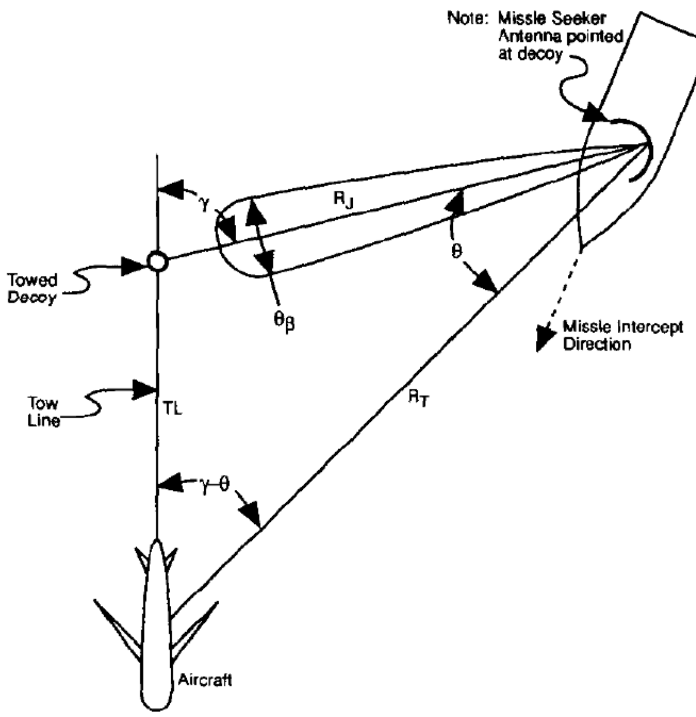


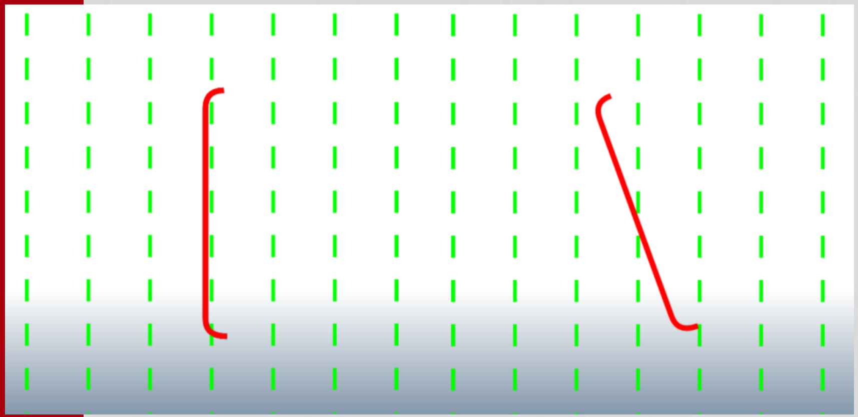
Figure 15: *Spatial geometery of a aircraft, towed decoy, and missile attempting to be jammed [25].*

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