HQ U.S. Air Force Academy

ECE 215
Objective 3.10
Electronic Warfare

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Objective 3.10

I can analyze jamming scenarios using the Friis equation, RADAR equation, and SNR.

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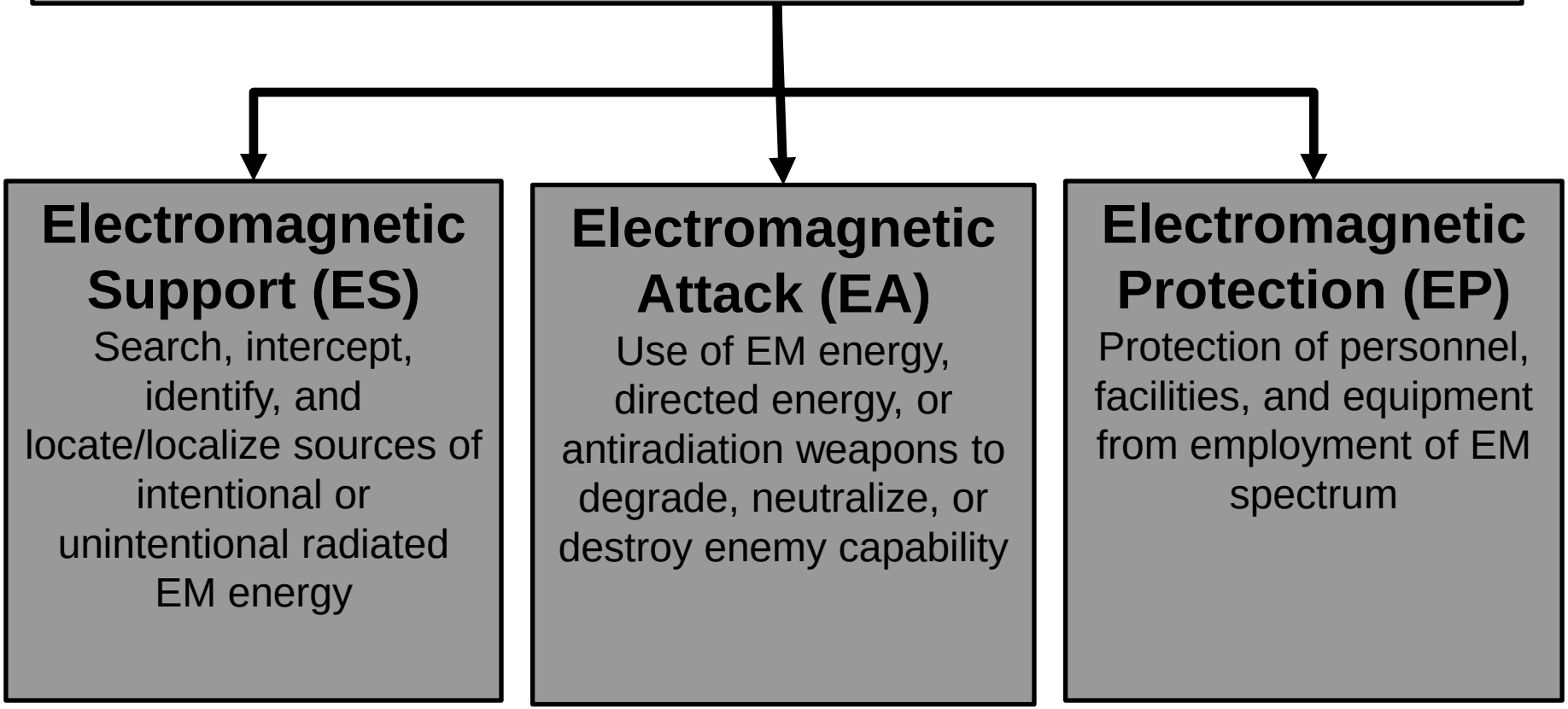
Definitions

Electromagnetic Warfare (EW)

Military action involving the use of electromagnetic (EM) and directed energy to control the EM spectrum or to attack the enemy.



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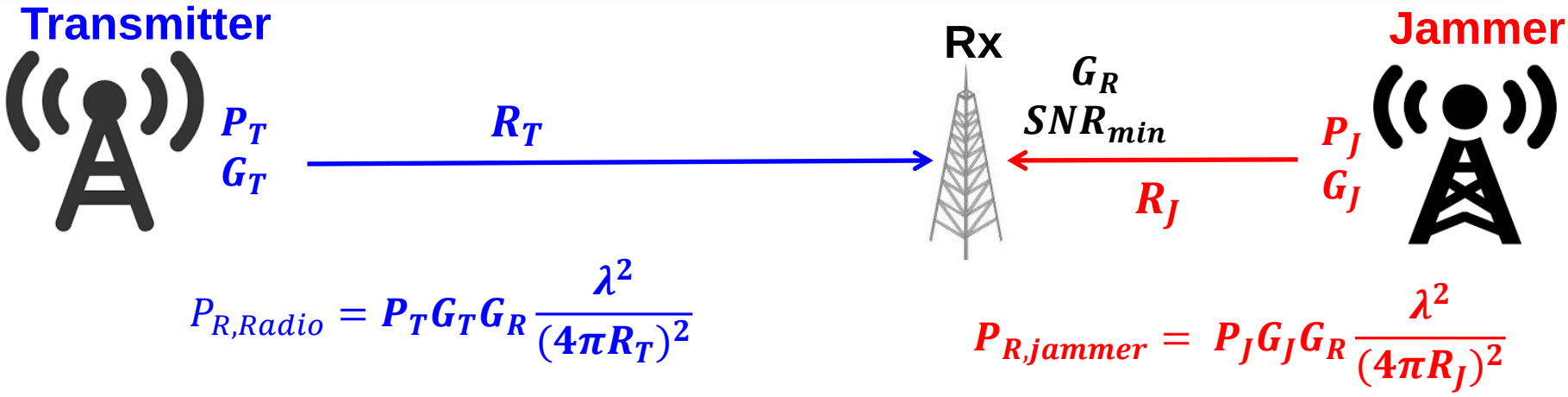
Communications Jamming



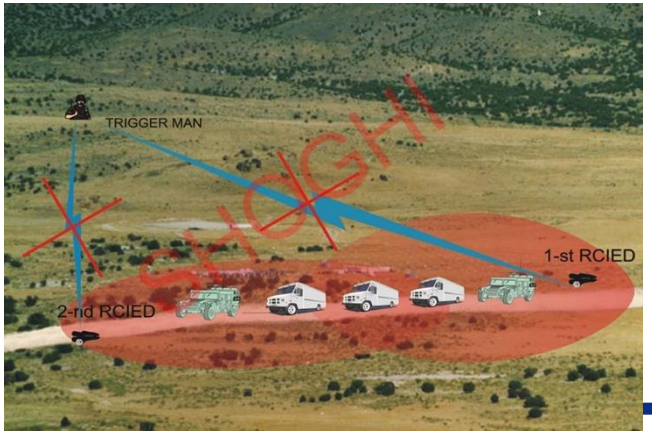
$$P_{R,Radio} = P_T G_T G_R \frac{\lambda^2}{(4\pi R_T)^2}$$

$$P_{R,jammer} = P_J G_J G_R \frac{\lambda^2}{(4\pi R_J)^2}$$

$$SNR = \frac{P_{Signal}}{P_{Noise}} = \frac{P_{R,Radio}}{P_{R,jammer}} = \frac{P_T G_T R_J^2}{P_J G_J R_T^2}$$

SNR increases - radio wins
SNR decreases - jammer wins

As the jammer gets closer to receiver, is jamming more or less effective?



Communications Jamming Example
(Example 1)

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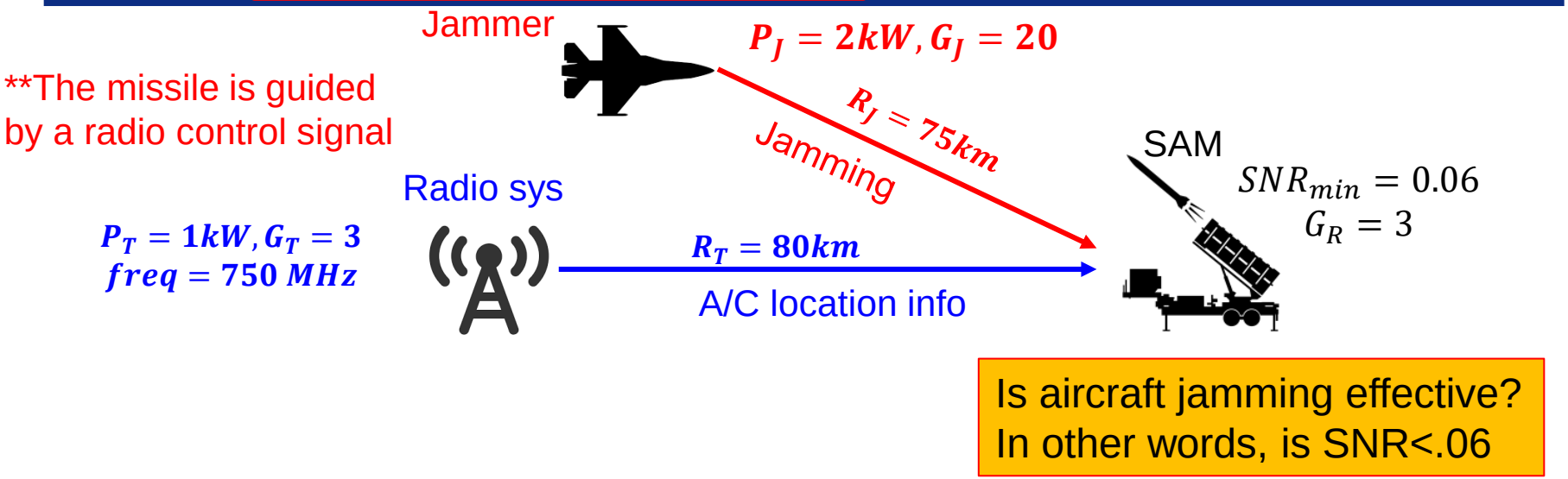
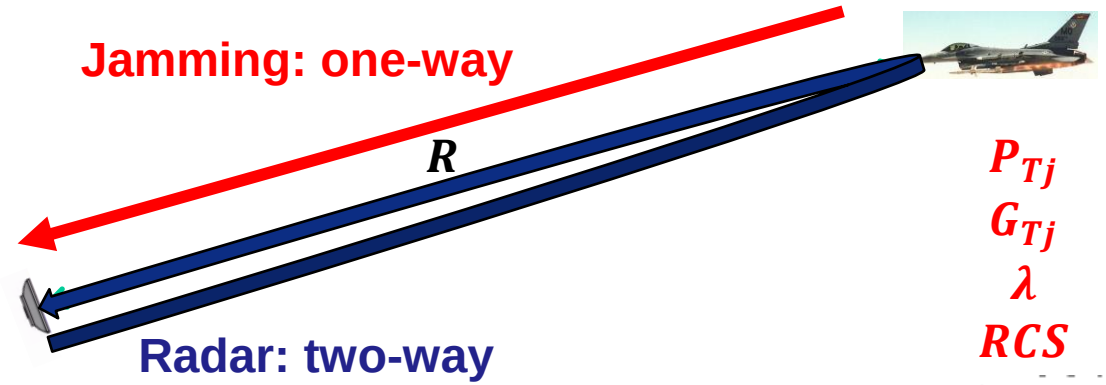
$SNR > SNR_{min}$ - radio wins
$SNR < SNR_{min}$ - jammer wins



Is aircraft jamming effective?
In other words, is SNR<.06

$$SNR = \frac{P_{R-Radio}}{P_{R-Jamming}} = \frac{P_T G_T R_J^2}{P_J G_J R_T^2}$$

Radar Jamming

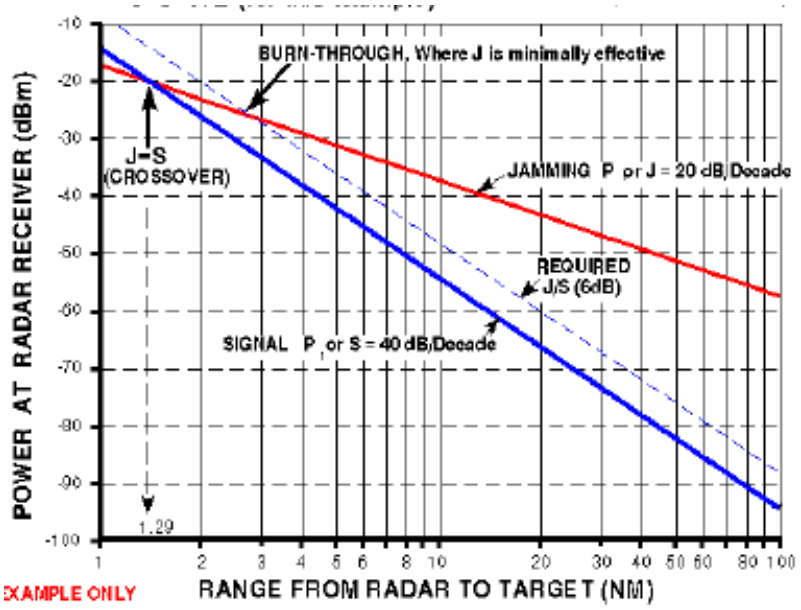


P_{Tj}
G_{Tj}
λ
RCS

Burn Through: jamming is *less* effective closer to radar

P_{Tr}
G_r
λ
SNR_{min}

$$SNR = \frac{P_{radar}}{P_{jammer}} = \frac{\frac{P_{Tr}G_r^2 RCS\lambda^2}{(4\pi)^3 R^4}}{\frac{P_{Tj}G_{Tj}G_r\lambda^2}{(4\pi R)^2}} = \frac{P_{Tr}G_r RCS}{4\pi P_{Tj}G_{Tj}R^2}$$



SNR increases - Radar wins
SNR decreases - jammer wins

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Radar Jamming Example
(Example 2)

- Given the following information about an enemy radar/SAM site and your own aircraft, what is the enemy Weapons Engagement Zone (WEZ), i.e., at what distance will the radar detect your aircraft?

Enemy Radar	**Your Aircraft Specifications**
Height = 10’ AGL	Altitude = 2,000’ AGL
Power Transmitted = 1 kW	RCS = 25 m^2
Transmit Antenna Gain = 3000	
Frequency = 7 GHz	
Min Required Power Received = 52 fW	

- You turn on your jammer pod well before this distance. What is the new WEZ, i.e., how close can you get before your jamming pod become ineffective (burn-through distance)?

Your Jamming Specifications
Jammer Power Transmitted = 20 W
Jammer Transmit Antenna Gain = 3.5
Frequency = 7 GHz
SNR_{min} = 0.02

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Jamming Summary

- **Comm Jamming**
  - **3 variables we can control**
    1. P_T **– Jammer**
    2. G_T **– Jammer**
    3. R **– (between Jammer and Radio Rcvr)**
  - **As jammer gets closer to receiver, jamming is more effective**

- **Radar Jamming**
  - **5 variables we can control**
    1. P_T **– Jammer**
    2. G_T **– Jammer**
    3. R **– (from Radar)**
    4. P_R **– Radar Power (destroy it DEAD)**
    5. **RCS (orientation and acquisition)**
  - **As jammer gets closer to radar, jamming is less effective (BURN THROUGH)**

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Jamming Countermeasures

- **Also known as Low Probability of Intercept (LPI) Signals**
  - **Chirp Signals**
  - **Frequency Hopping**
  - **Direct-sequence spread spectrum**

In order for jamming to be effective $f_{Jamming}$ must equal $f_{Transmitted}$,

Hedy Lamar

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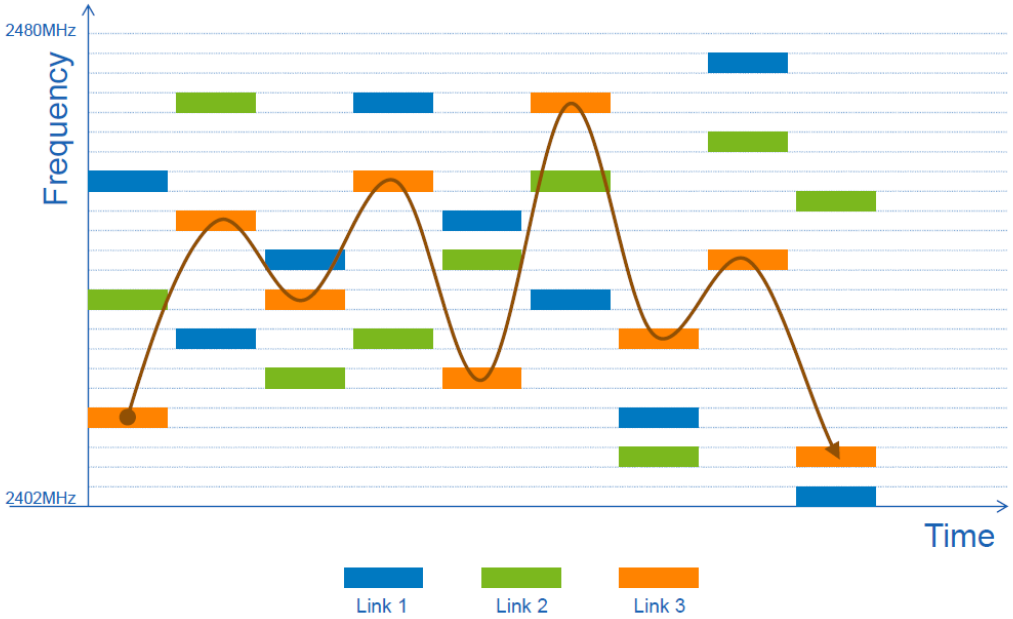
Jamming Countermeasures: Frequency Hopped Signals

Change the carrier frequency at specific points in time according to pre-established hopping sequence



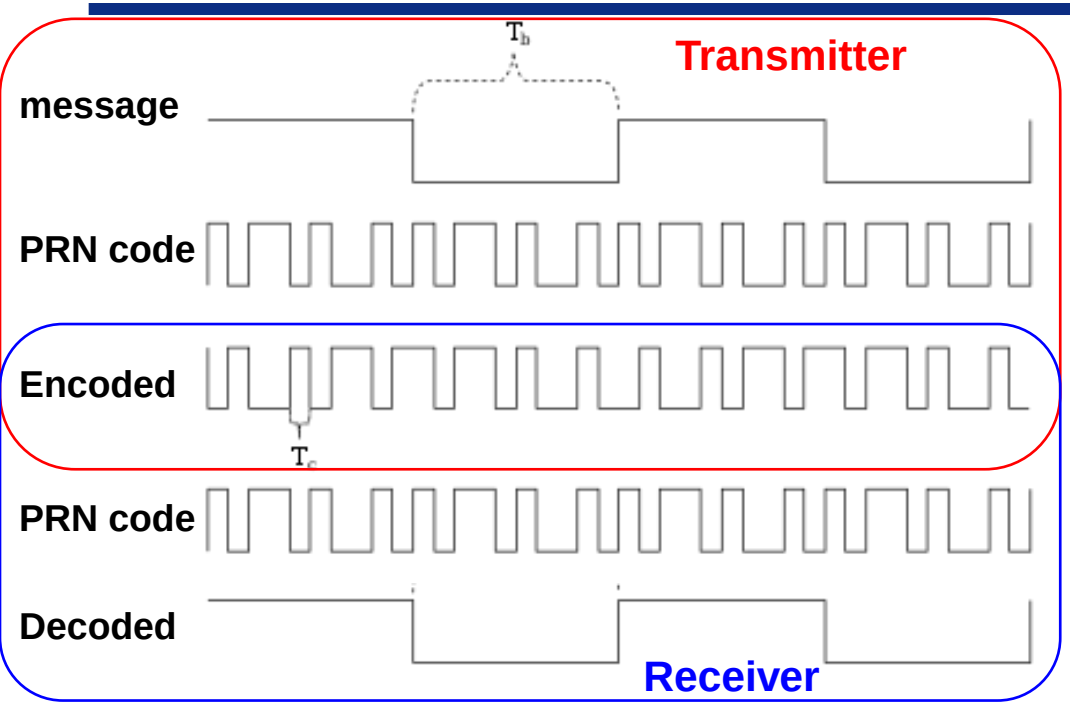
Jammer only effective for short time periods!

Examples:

- Bluetooth
- SINCGARS radios
- JTRS radios
- Link-16
- Have quick radio

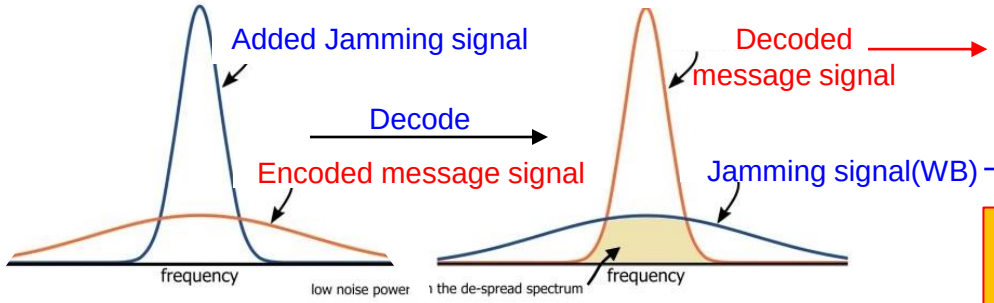
SINCGARS
Hopes 111 times/sec between 30-88 MHz

Jamming Countermeasures: Direct Sequence Spread Spectrum



Used by GPS

1. Narrow BW(NB) message signal
2. Wide BW(WB) PRN code
   *PRN: Pseudo Random Noise (crypto key)
3. WB Encoded signal
4. WB same PRN code
5. NB decoded signal(=message)



After decoding

Message signal is restored (NB, high pwr)

Jamming signal is spread (WB, low pwr)

Simply put: spread the message over a larger range of frequencies than the jammer has power/ability to jam.

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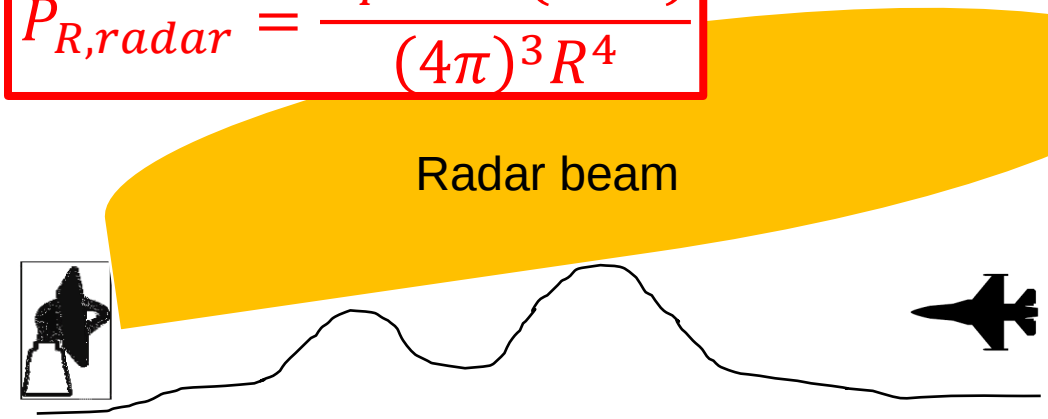
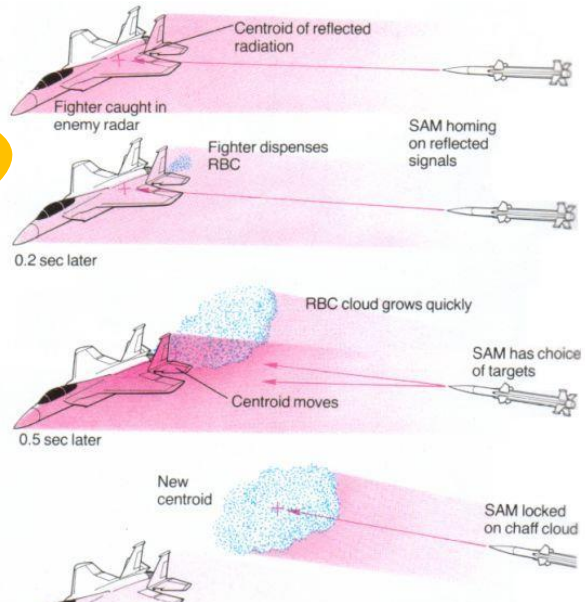
Radar Countermeasures

- **What in the radar equation can I exploit/change?**
  - **Outside R_{LOS}…fly lower… "fly under the radar"**
  - **False RCS / Decoy: chaff… release cloud of radar reflective metal**
  - **Reduce RCS: stealth**
  - **Mask/Block P_R: Radar jamming, decrease SNR**
  - **Eliminate P_T: High-speed Anti-Radiation Missiles (next slide)**
  - **Fly fast … get to target before enemy can react hypersonics**

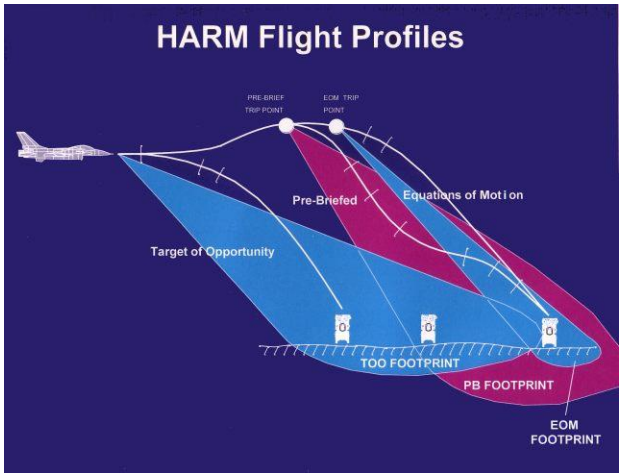
$$P_{R,radar} = \frac{P_T G^2 \lambda^2 (RCS)}{(4\pi)^3 R^4}$$





SEAD & DEAD

- **SEAD (Suppression of Enemy Air Defenses)**
  - **Taking a radar offline temporarily**
  - **Examples:**
    - **Jamming**
    - **Cyber attack**
    - **Psychological means (threat of HARMs)**
      - Radar stops transmitting to avoid HARM



- **DEAD (Destruction of Enemy Air Defenses)**
  - **Destroying enemy radar or SAM site**
  - **Examples:**
    - **Bombs**
    - **Special Forces**
    - **HARMs (High-speed Anti-Radiation Missiles)**
      - Detect radar signals and follow to origin