

*2nd AIAA Tactical Interceptor Technology Symposium,
Huntsville, Alabama*



Radar Technology

- Radar Guidance Techniques -

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Session 2 - 3 Radar Technology -
Radar Guidance Techniques

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Topics



0 Atmospheric and Weather Attenuation - Why Radar?

0 Top Level Discussion of Guidance Concepts

- Differential Command Guidance
- Beam Rider Guidance
- Semi Active Homing
- Active Homing
- Basic Radar Equations
- Optimum Tracking Accuracy

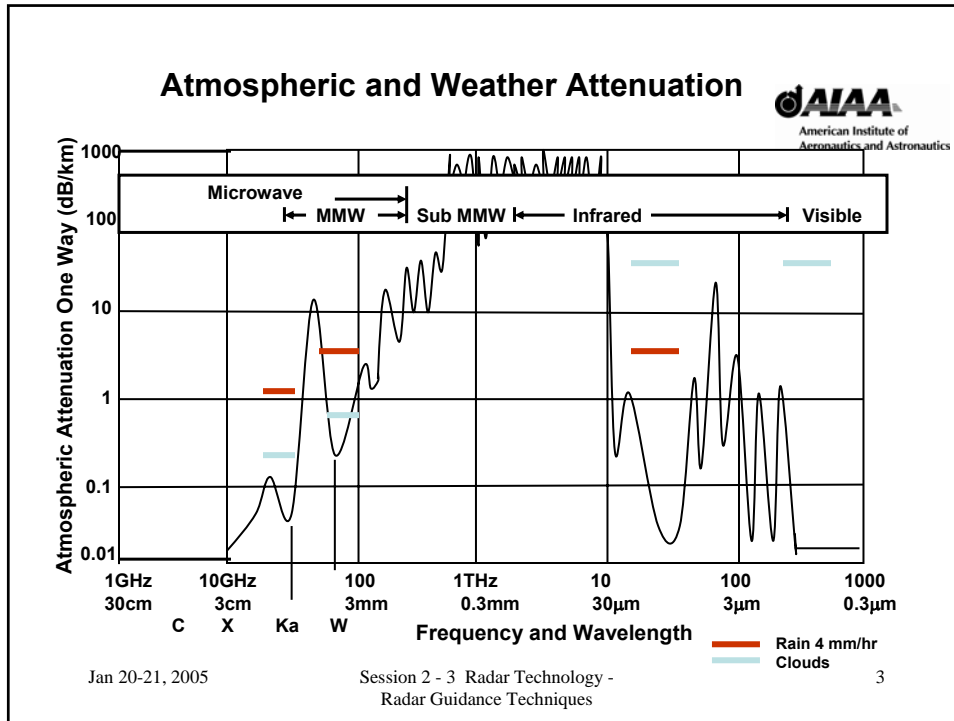
0 Timeline Considerations

0 Summary

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Example Fire Control Radar - Radar Range Equation -

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$$S_r = \frac{P_t G_t}{4\pi R^2} \times \frac{\sigma}{4\pi R^2} \times \frac{G_r \lambda^2}{4\pi} = \frac{P_t G^2 \sigma \lambda^2}{(4\pi)^3 R^4}$$


At the receiver, reflected energy competes with the receiver noise, $N = k T_0 B F_N$

$$\frac{S}{N} = \frac{P_t G^2 \sigma \lambda^2 I}{(4\pi)^3 R^4 k T_0 B F_N L}$$

k = Boltzman's Constant 1.38×10^{-23} (W/Hz K)
 T_0 = 290 K
 B = Bandwidth (Hz)
 F_N = Noise Figure
 I = Integration Gain
 L = Losses
 $G_t = G_r = G$

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Common Symbols and Relationships




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<p> P_t = Transmitted Power (W) D = Antenna Diameter A = Antenna Aperture Area G = Antenna Gain (dB) G_t = Transmit Antenna Gain (dB) G_r = Receive Antenna Gain (dB) ϵ = Antenna Efficiency Θ = Antenna Beamwidth σ = Target Radar Cross Section (RCS) f_o = Radar Operating Frequency (Hz) λ = Wavelength of Operating Frequency (m) k = Boltzman Constant (W/Hz K) T_0 = Reference Temperature = 290K B = Radar Bandwidth (Hz) F_N = Receiver Noise Figure (dB) N = Receiver Noise Power (W) I = Integration Gain (dB) L = Losses (dB) R = Range (m) c = Speed of Light (3×10^8 m/s) </p>	<p> Operating frequency and wavelength relationship $\lambda f_o = c$ Antenna Beamwidth $\Theta = \lambda / D$ Antenna Gain vs Diameter and Operating Wavelength $G = 4 \pi A / \lambda^2$ Angle Tracking Error due to noise K a constant $\sigma_{Angle} = \Theta / K \sqrt{2 SNR}$ </p>
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Example Fire Control Radar Ka Band - Blake Chart -



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$$\frac{S}{N} = \frac{P_t G_t G_r \sigma \lambda^2 I}{(4\pi)^3 R^4 k T_0 B F_N L}$$

	Value	dB	dB
P_t	2000W	33	dBW
<i>(A = 0.8m², D = 1m, ϵ = 50%)</i>			
G_t	49×10^3	47	+ 81
G_r	49×10^3	47	
σ	0.03 m ²	- 15	- 97
λ^2	(0.01m) ²	- 40	
I	8	9	
$(4\pi)^3$	(12.56) ³	33	
R^4		40	
k	1.38×10^{-23}	-228.6	
T_0	290 K	24.6	
B	1MHz	60	
F_N		6	
L		8	

dB = 10 log₁₀ (Ratio)

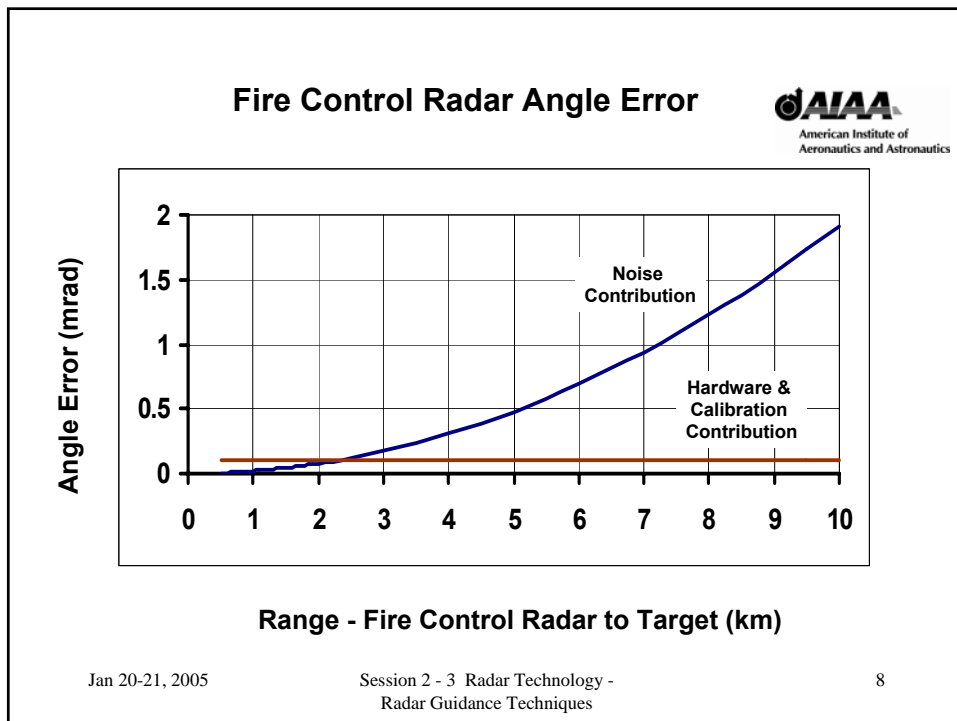
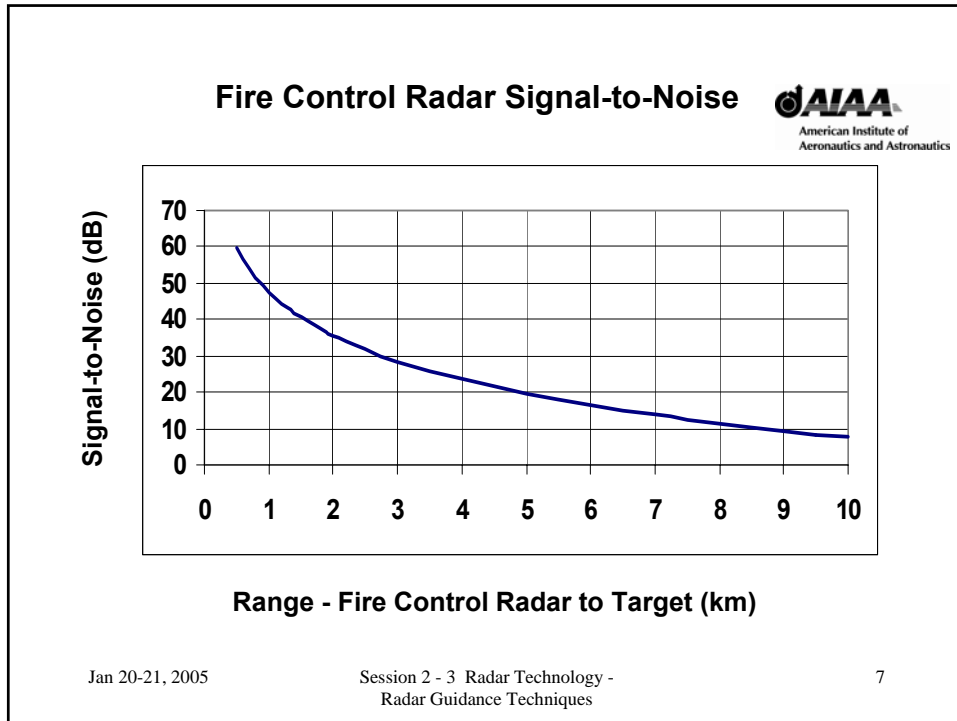
log (xy) = log x + log y

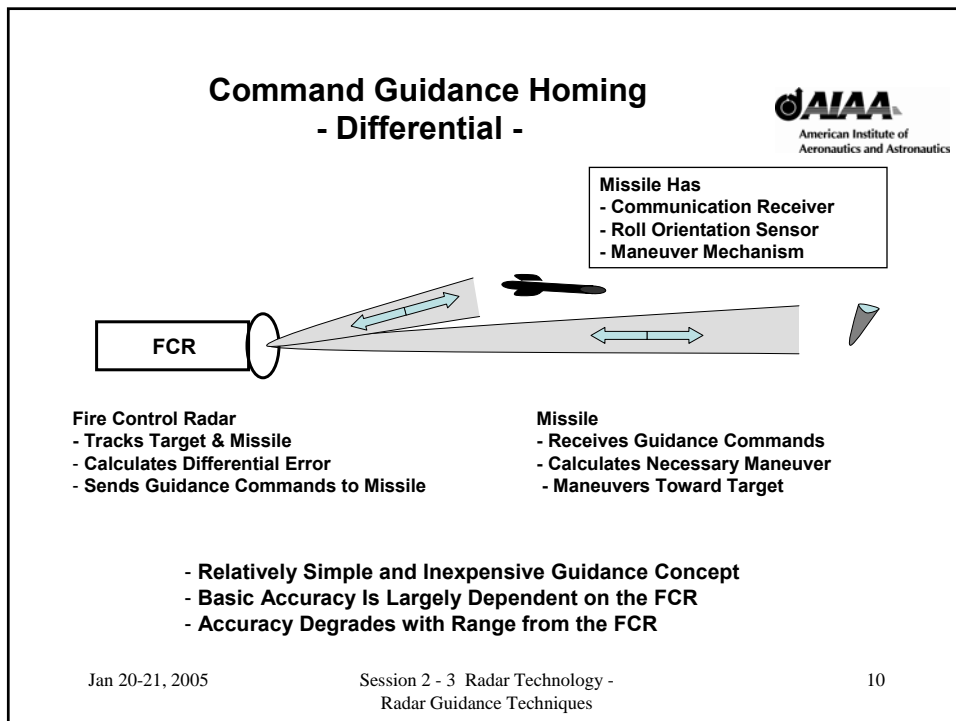
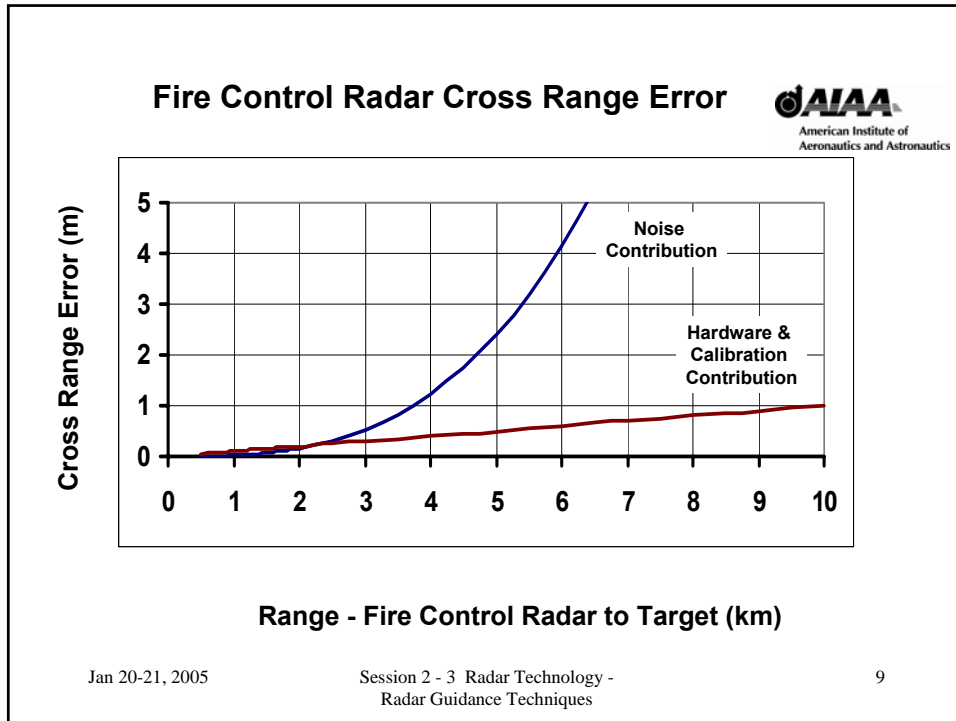
log (x/y) = log x - log y

SNR = 81 - (- 97) - 40 log₁₀ R

= 178 - 40 log₁₀ R

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Beamrider Homing

Fire Control Radar

- Tracks Target
- Provides a Missile Capture Beam
- Codes Beam to Aid Missile Guidance

$A_r = \frac{G_r \lambda^2}{4\pi}$

$N = kT_0 B F_N$

$SNR = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 R_{RM}^2 kT_0 B F_N L}$

Missile Has

- Rear Mounted Receiving Antenna
- RF Receiver at FCR Frequency
- Error Measurement Circuits
- Roll Orientation Sensor
- Maneuver Mechanism

- Uses FCR Transmitter as Illuminator
- Missile Implementation is more complex and expensive than Command Guidance
- Accuracy Depends upon both the FCR and Missile Error Resolving
- Missile should receive high energy from FCR illuminator
- Accuracy degrades with FCR to Target range, i.e. with long range engagements
- Likely requires dedicated illuminator during engagement
- Difficult to support true simultaneous engagements

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Example Beamrider Homing - Wide Beam Antenna - Ka Band

	Value	dB
P_t	2000	33
G_t	49×10^3	47
G_r	3	5
λ^2	$(0.01m)^2$	- 40
$(4\pi)^2$	$(12.56)^2$	22
R_{RM}^2	1.38×10^{-23}	$20 \log R_{RM}$
k	290 K	24.6
T_0	1MHz	60
B	6	6
F_N	8	8
L		

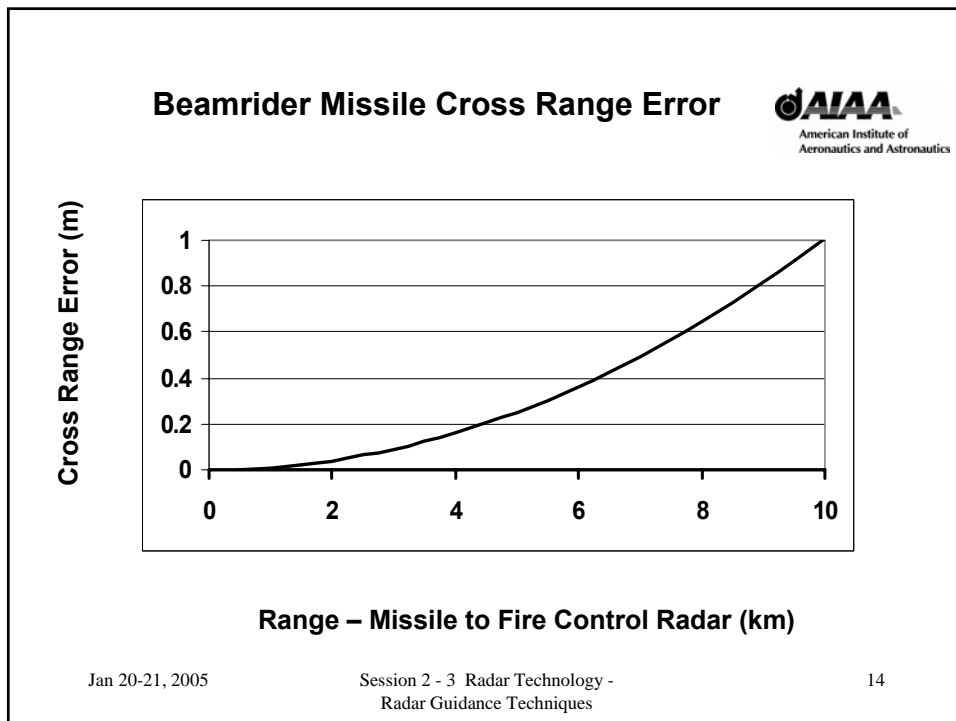
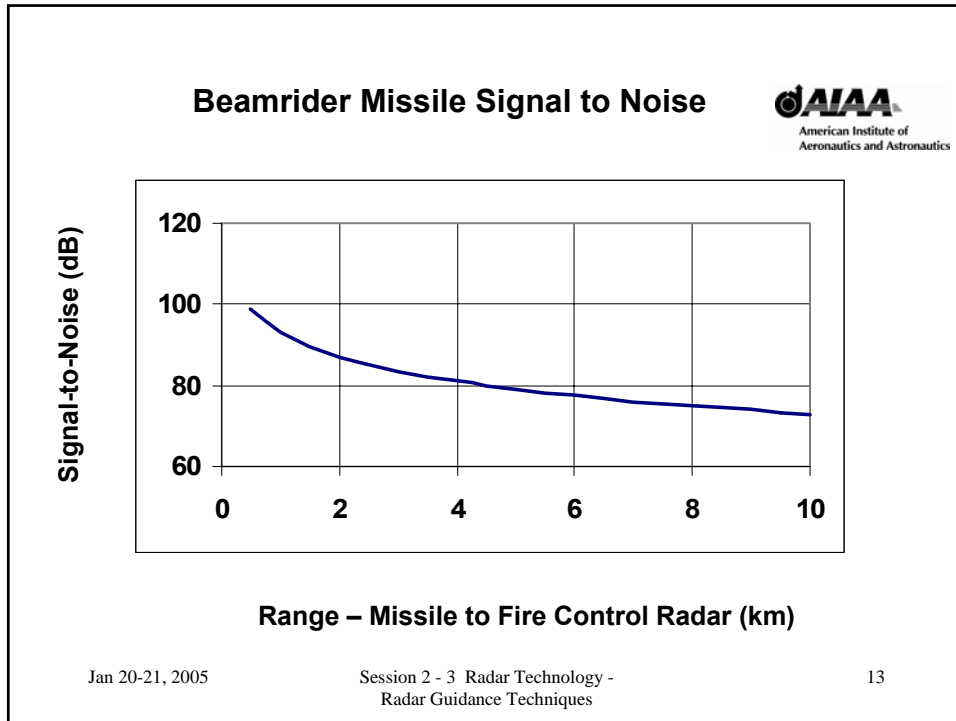
$SNR = \frac{P_t G_t G_r \lambda^2}{(4\pi)^3 R_{RM}^2 kT_0 B F_N L}$

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- 108

$SNR = 153 - 20 \log R_{RM}$

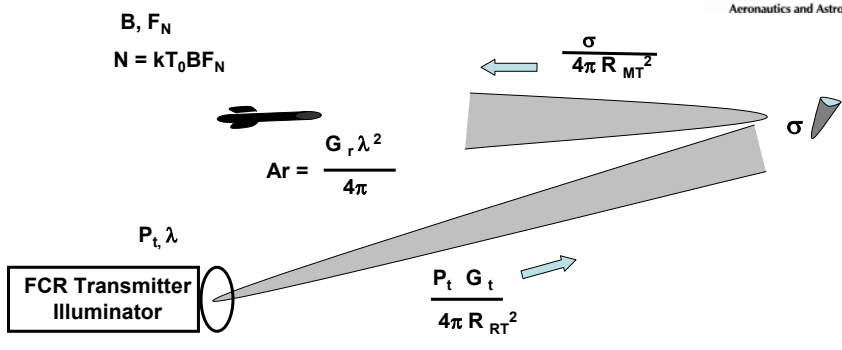
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Semi Active Homing



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B, F_N
 $N = kT_0 B F_N$

$A_r = \frac{G_r \lambda^2}{4\pi}$

$\frac{\sigma}{4\pi R_{MT}^2}$


$\frac{P_t G_t}{4\pi R_{RT}^2}$

$SNR = \frac{P_t G_t G_r \lambda^2 \sigma I}{(4\pi)^3 R_{RT}^2 R_{MT}^2 kT_0 B F_N L}$

Missile Has
 - Front Mounted Antenna w/angle measurement capability
 - RF Receiver at FCR Frequency
 - Maneuver Mechanism

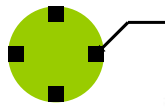
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Semi Active Homing

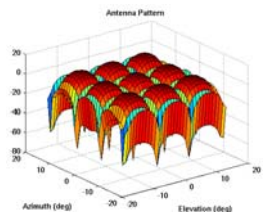


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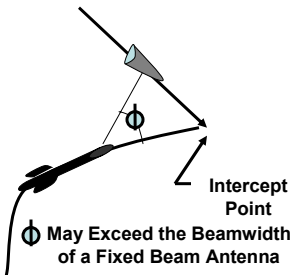
- FCR tracks target and Missile homes on FCR energy reflected from Target
- Accuracy depends upon the Missile ability to track Target
- Missile Implementation is more complex and expensive than Beam Rider Guidance
- Energy received by the Missile is a major consideration
- A simple missile antenna is desired but antenna gain must be considered
- Engagement geometry may require missile to have a steering antenna
- Given sufficient FCR energy long range engagements may be possible
- Missile will likely require a dedicated target illumination during engagement endgame



Antenna Elements



Antenna Pattern




Intercept Point

May Exceed the Beamwidth of a Fixed Beam Antenna

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Example Semi Active Homing 2.65 inch Aperture Ka Band



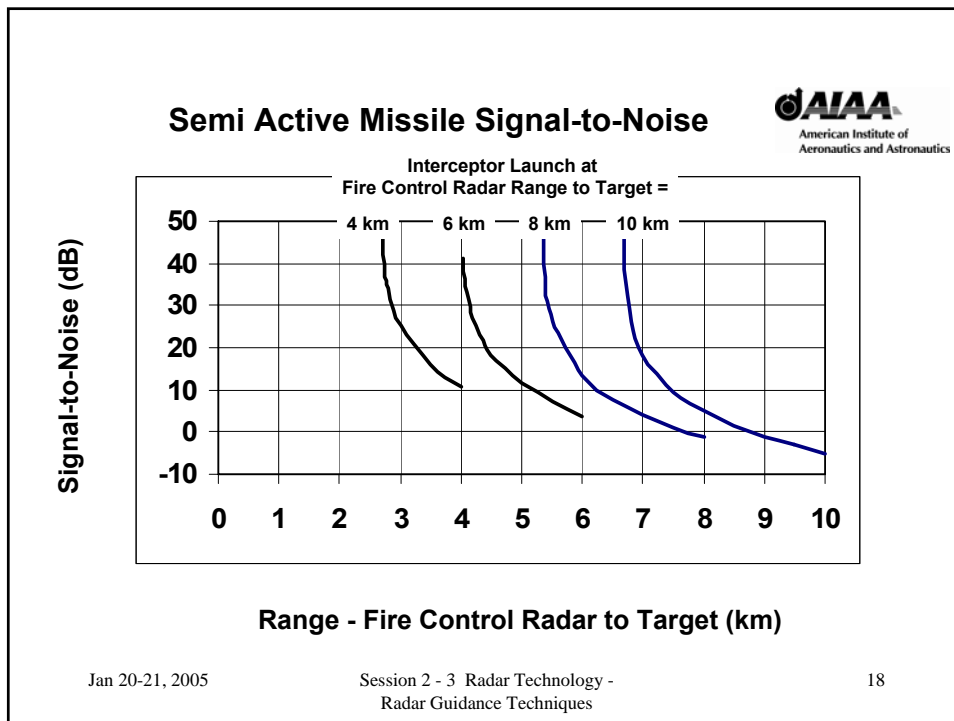
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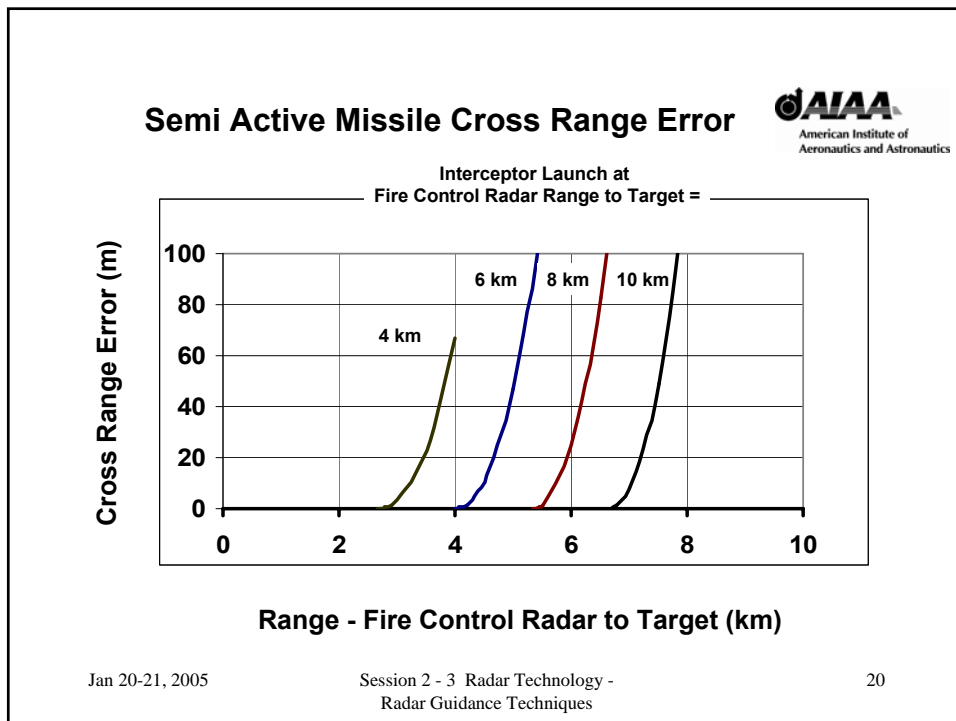
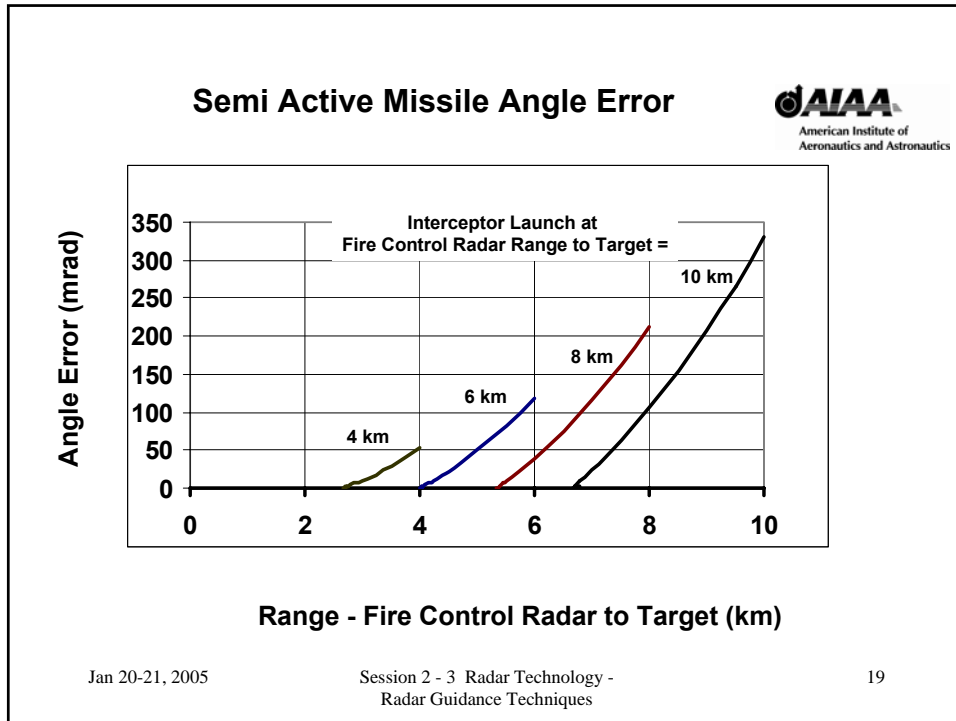
	Value	dB	
P_t	2000W	33	+ 58
G_t	49×10^3	47	
G_r	300	24	
σ	0.03 m^2	- 15	
λ^2	$(0.01\text{m})^2$	- 40	
L	8	9	
$(4\pi)^3$	$(12.56)^3$	33	- 97
R_{RT}^2		$20 \log R_{rt}$	
R_{MT}^2		$20 \log R_{rt}$	
k	1.38×10^{-23}	-228.6	
T_0	290 K	24.6	
B	1MHz	60	
F_N		6	
L		8	

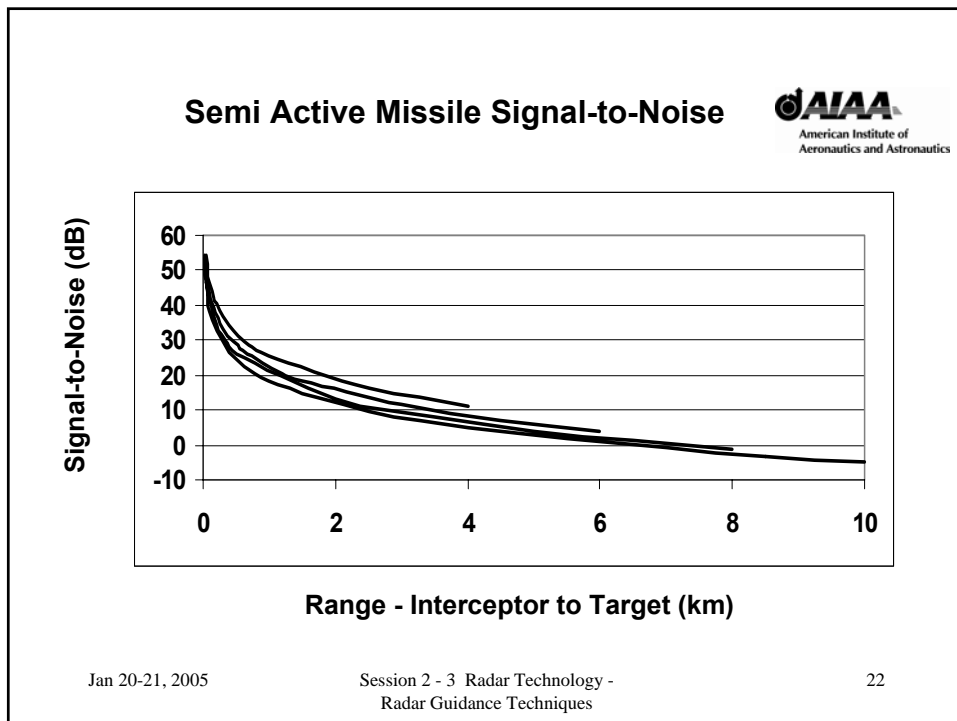
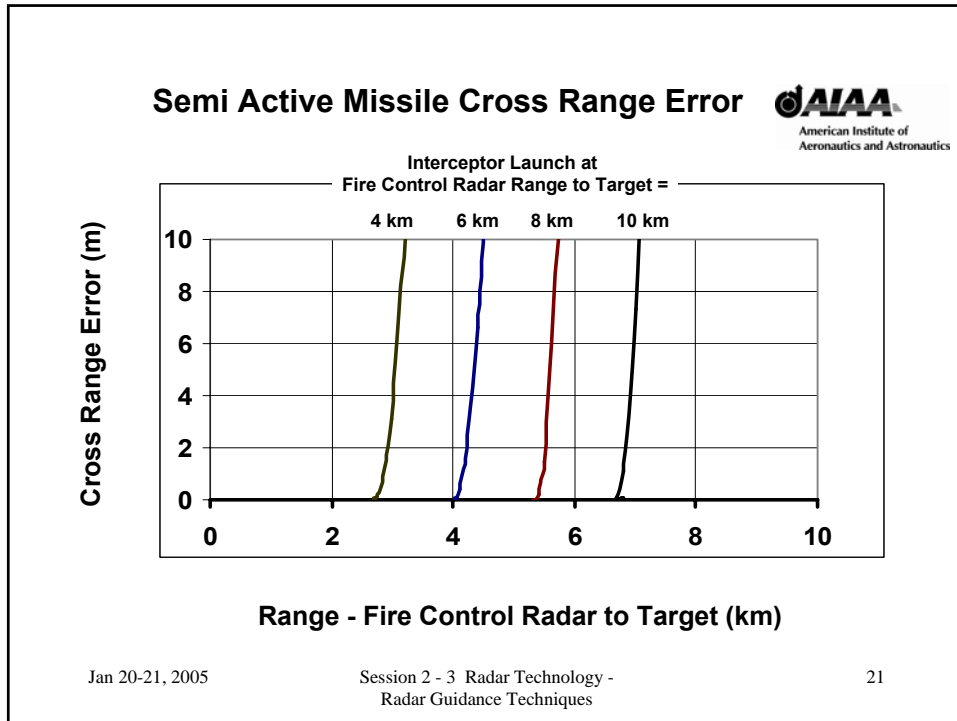
$$SNR = \frac{P_t G_t G_r \lambda^2 \sigma L}{(4\pi)^3 R_{RT}^2 R_{MT}^2 k T_0 B F_N L}$$

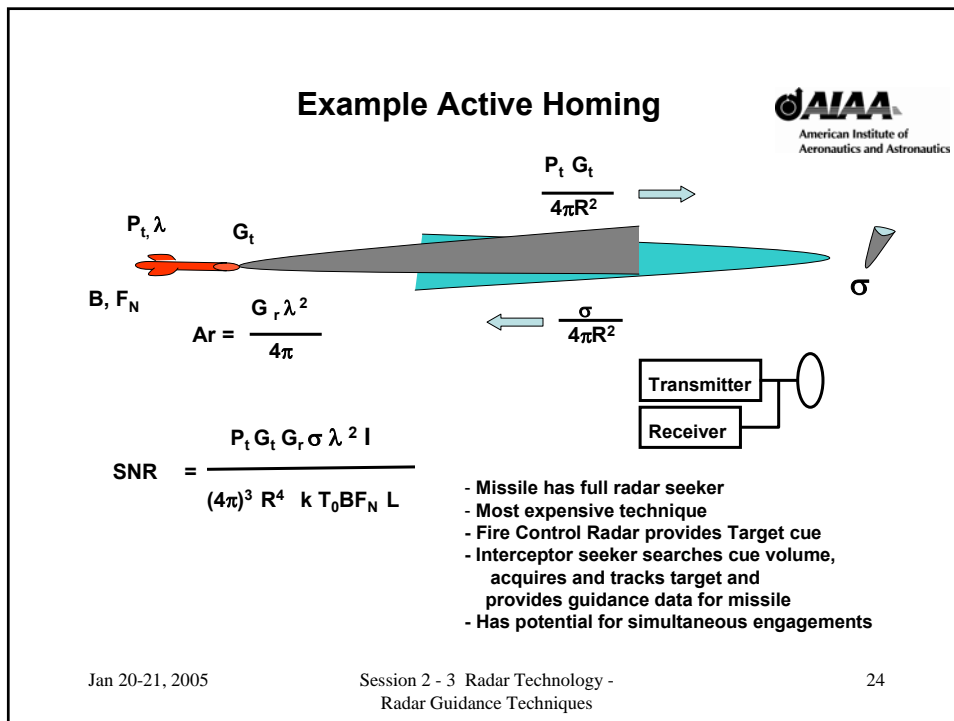
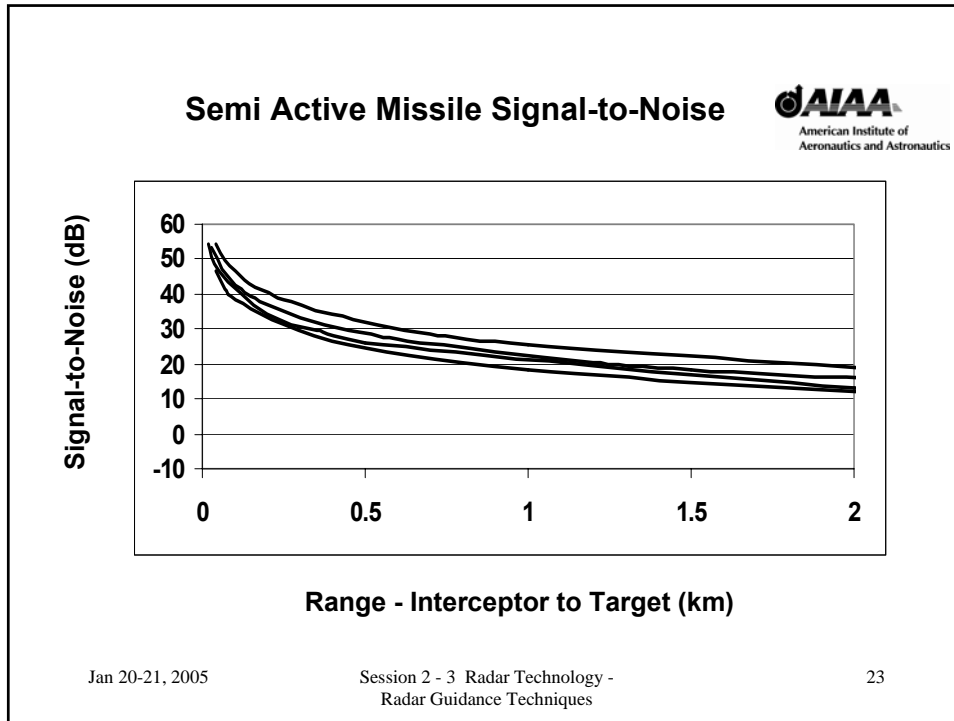
$SNR = 58 - (-97)$
 $- 20 \log R_{RT} - 20 \log R_{RM}$
 $SNR = 155 - 20 \log R_{RT} - 20 \log R_{RT}$

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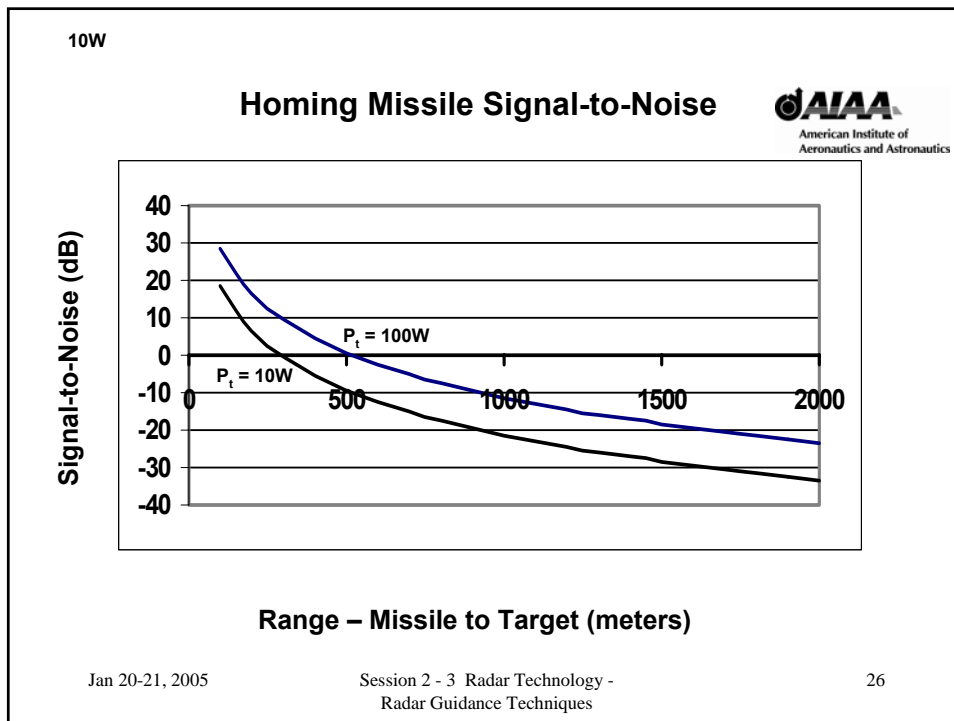
Example Active Homing 2.65 inch Aperture Ka Band

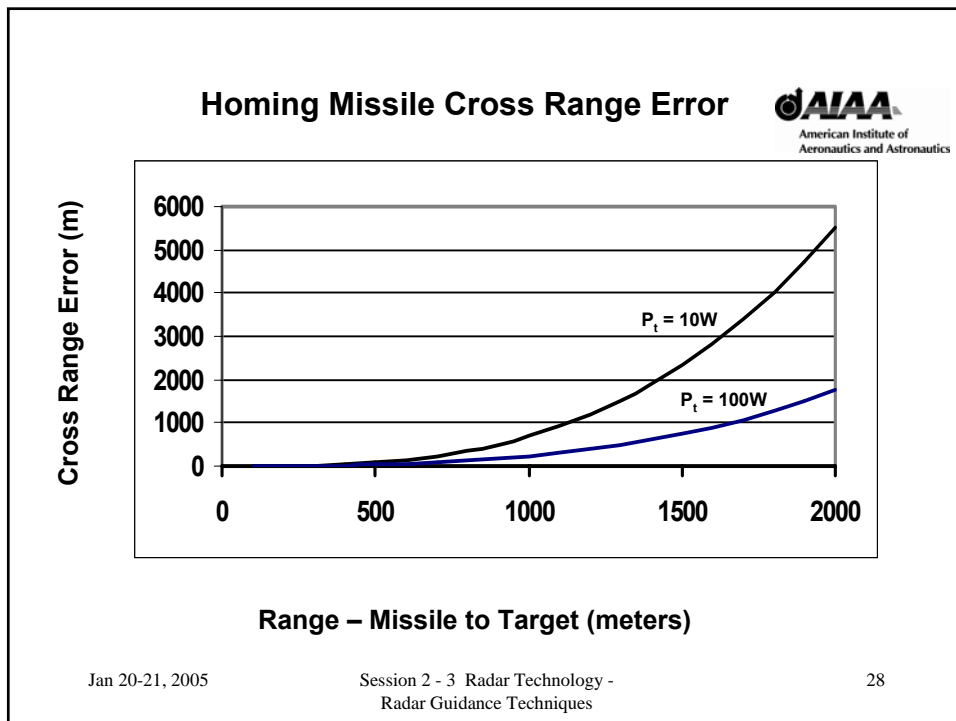
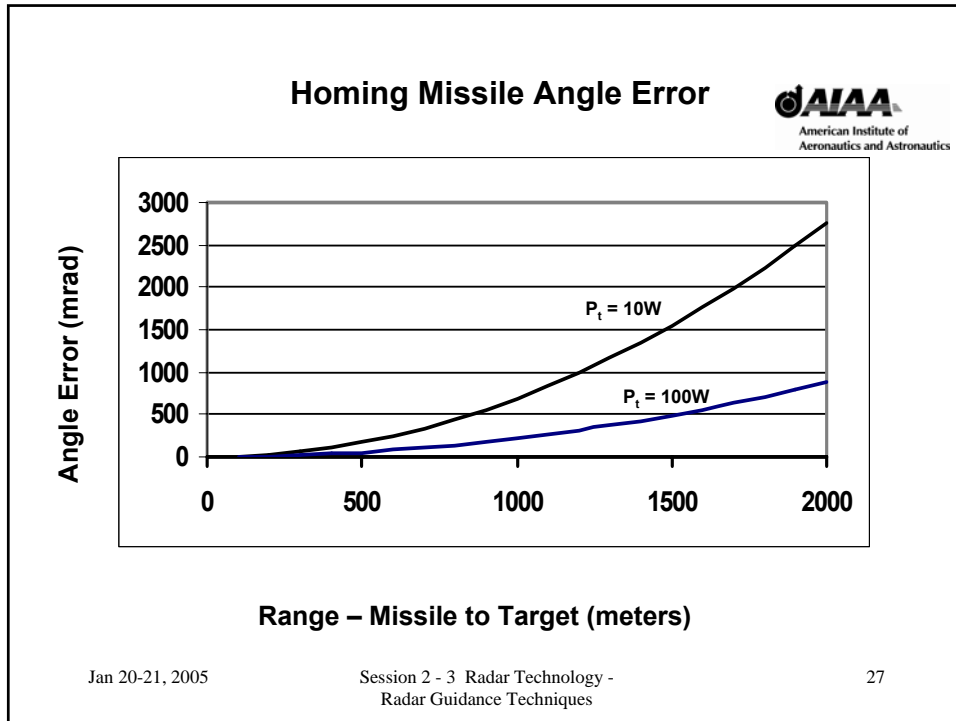


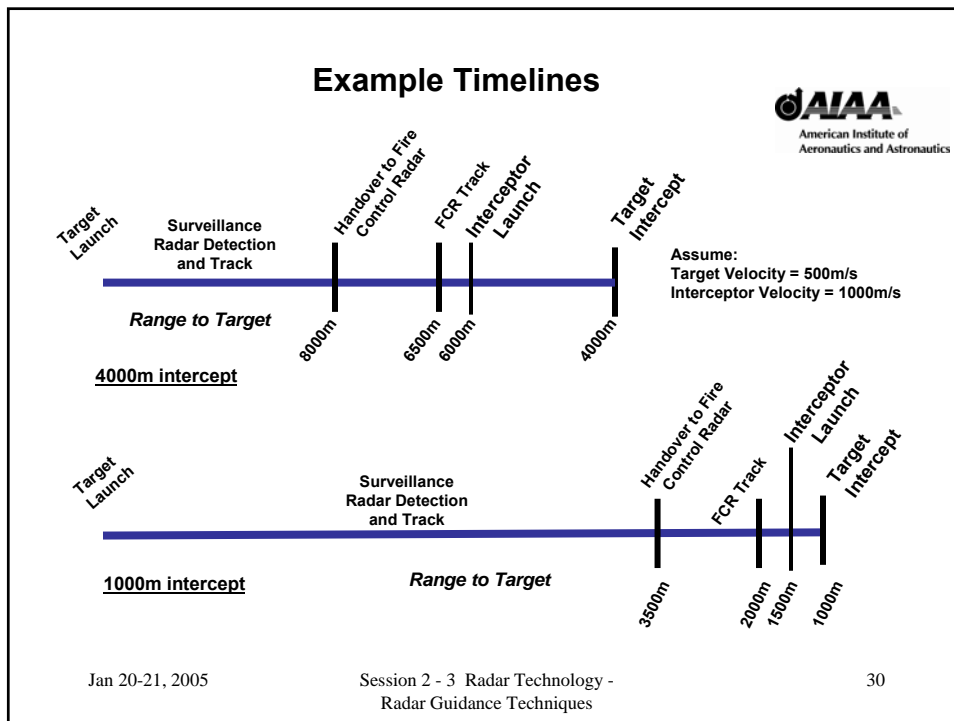
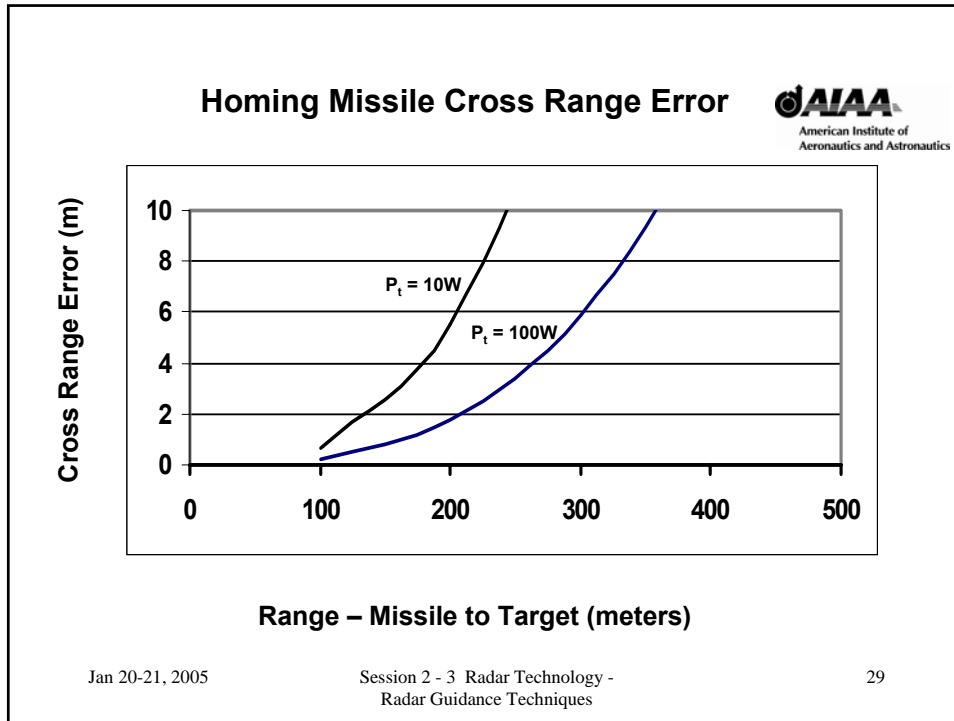
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	Value	dB		SNR =	$\frac{P_t G_t G_r \lambda^2 \sigma I}{(4\pi)^3 R^4 k T_0 B F_N L}$
P_t	10W & 100W	10 & 20			
G_t	300	24			
G_r	300	24			
σ	0.03 m ²	- 15	+ 12		
λ^2	(0.01m) ²	- 40	&		
I	8	9	+22		
$(4\pi)^3$	(12.56) ³	33			
R^4		40 log R	- 87		
k	1.38x10 ⁻²³	-228.6			
T_0	290 K	24.6		SNR = 99 - 40 log R	10W
B	10MHz	70		SNR = 109 - 40 log R	100W
F_N		6			
L		8			

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Summary



- 0 Guidance concepts from least to most expensive are**
 - Command, Beamrider, Semi Active and Active Homing

- 0 Command and Beamrider Guidance depend on the tracking accuracy of the Fire Control Radar**
 - Long range intercepts require a large, powerful expensive FCR

- 0 Semi Active Guidance can support longer range engagements**
 - Depends on the FCR capability and Interceptor accuracy

- 0 Beam Rider and Semi Active Homing require a dedicated illuminator during engagements**

- 0 Active Homing places less requirements on the FCR and has the potential to support simultaneous engagements**

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