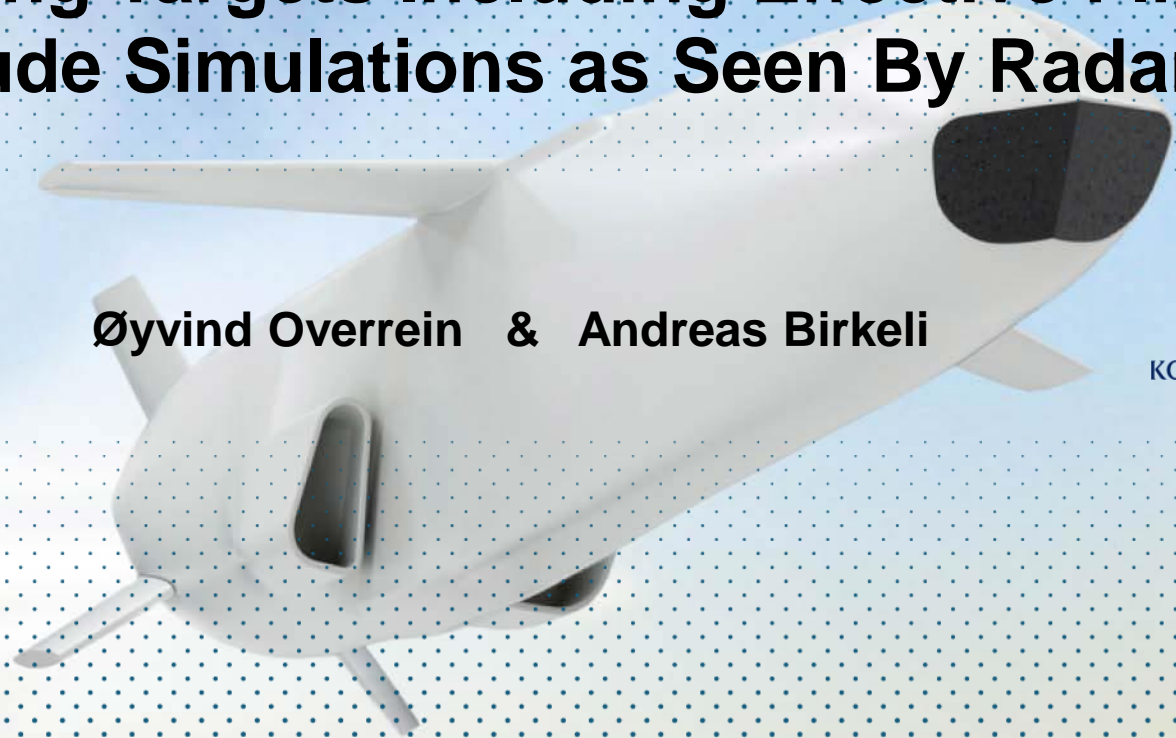


Radar Detection Evaluation Method for Sea Skimming Targets Including Effective Flight Altitude Simulations as Seen By Radar

Øyvind Overrein & Andreas Birkeli



KONGSBERG



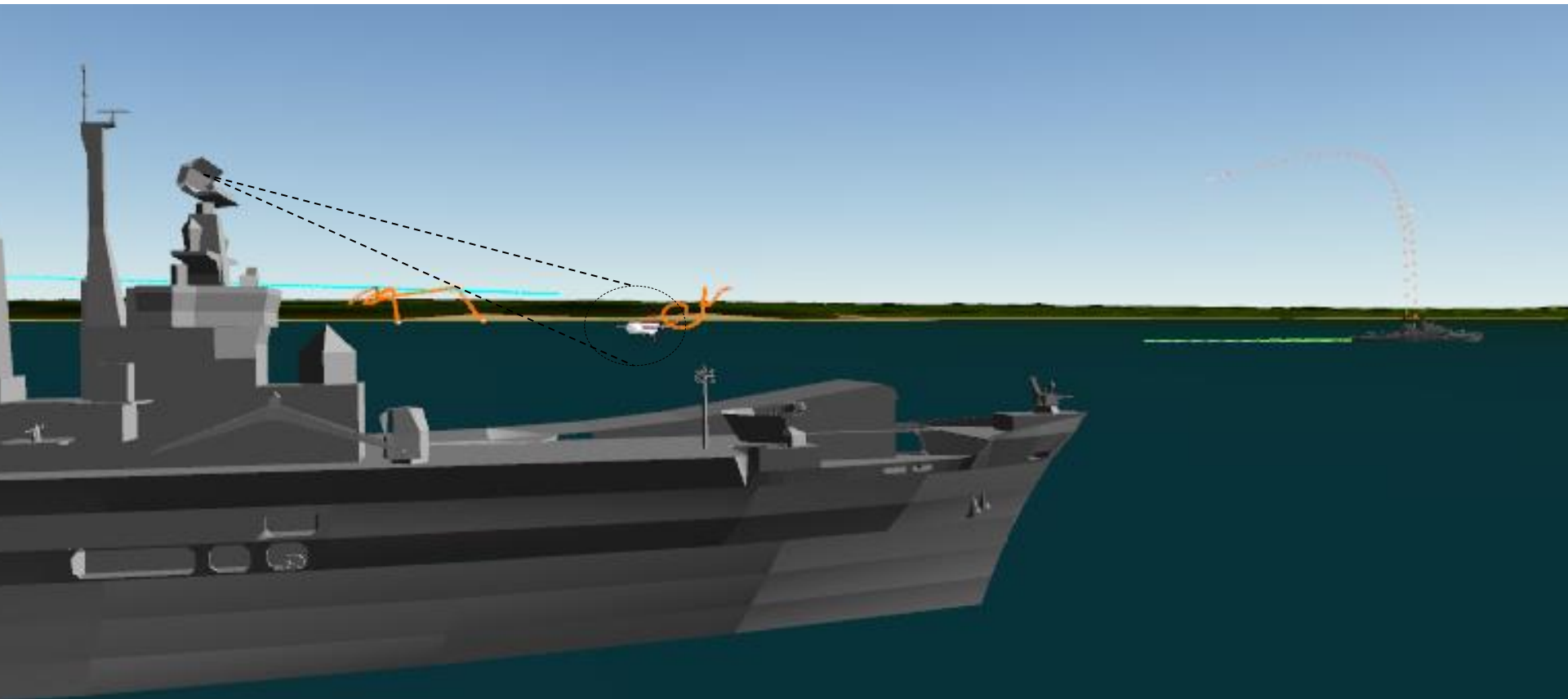
Overview

The objective of this presentation is to show a parametric study of the difference between Real Flight Altitude (RFA) and Effective Flight Altitude (EFA) above mean sea level for sea skimming targets as seen by the radar. This is carried out by:

- introducing a realistic sea surface in a commercial radar detection evaluation tool like Ship Air Defence Model (SADM).
- The radar power is adjusted so target detection takes place at a chosen range for a given RFA.
- Then the sea surface is removed and target flight altitude together with antenna height are adjusted until the same detection range is achieved. This flight altitude is then assumed to be the EFA.

Examples of how these steps are carried out are given successively. Finally EFA is estimated based upon a set of generic RFA values for ranges going from 7.5 km to 16.5 km and RFA going from 3 m to 6 m.

Problem: How to evaluate radar detection range for sea skimming targets in high sea state?





Traditional modelling

- Sea clutter model with wind speed or sea state as input
- Radar signal propagation model used over a flat surface
- Antenna height above the flat surface
- Real flight altitude of sea skimming target above the flat surface

BAE SYSTEMS

SADM

Ship Air Defence Model





Ship Air Defence Model Environment GUI

BAE SYSTEMS SADMU 5.5.0.2 in directory "C:\Program Files\BAE Systems\SADMU-AE 5.5.0.2 x64": Scenario Summary - standard

File Scenario Environment Taskgroup Ship Site Observer Aircraft ASM Background Target Options Worksheets Go To Help

UNCLASSIFIED Ship Air Defence Model

Scenario Summary

Scenario Description Summary

Scenario name	standard	Blue	Red	White
Number of Runs	1	1	0	0
No. of Monte Carlo Trials	1	0	0	0
Scenario Date (yyyy/mm/dd)	2010 06 01	0	1	0
Start Time (hh:mm)	11 : 00	0	0	0
Local Time Zone	GMT+10 (K)	0	0	0
Daylight Savings Time?	<input type="checkbox"/>	Use Hard kill? <input checked="" type="checkbox"/>		
Max Sim. Time (s)	300.00	Use Soft kill? <input type="checkbox"/>		
Ship Kill Type	Legacy			
Calculate 30° Sec. Eff?	<input type="checkbox"/>			
Run in real time?	<input type="checkbox"/>			

Update Scenario Notes

Area of Operations

N-S (km)

E-W (km)

Environment Description

Environment Summary

Sea State	0	Solar Az / El Position	14.89° / 31.45°
Abs humidity (g/m3)	7.5	Visibility (km)	20.00
Air / Surface Temp (°C)	18.0 / 18.0	Atmospheric Model	Midlatitude Summer
Rainfall Rate (mm/hr)	0.0	Sky Temp (K) / Emissivity	298.0 / 1.000
Refractivity Profile	standard	Latitude	35° 6' 0" S
Centre map on profile	<input type="checkbox"/>	Longitude	150° 45' 0" E
Sea Surface Refractivity (M-units)	339.0	Ground type	Medium dry ground
Evaporation Duct Height (m)	0.0	Terrain type	Soil and Rock
Surface-based duct ht (m)	0.0	Weibull land clutter?	<input type="radio"/> T <input checked="" type="radio"/> F
Land Clutter Coefficient (dBsm/m2)	-10.0	Use fixed shape par?	<input type="radio"/> T <input checked="" type="radio"/> F

Edit Wave Properties

Wind Data

Wind Model:	True Wind
Wind Speed (m/s)	10.00
Wind Direction (deg)	-90.0
Ang Offset wrt ASM	0.0
Speed SD (m/s)	0.0
Angle SD (deg)	0.0

Edit Wind Profile...

Use map data?

Map: None

Edit Map Data

Use PPF Switches

PPF in radar calcs?	<input checked="" type="radio"/> T <input type="radio"/> F
PPF in ESM calcs?	<input checked="" type="radio"/> T <input type="radio"/> F
PPF in ill calcs?	<input type="radio"/> T <input checked="" type="radio"/> F
PPF in ASM calcs?	<input checked="" type="radio"/> T <input type="radio"/> F
PPF in weapon calcs?	<input type="radio"/> T <input checked="" type="radio"/> F

Select Propagation Model

Ship signal calcs	APM
Aircraft signal calcs	FFACTR
ASM signal calcs	FFACTR

UNCLASSIFIED

General Taskgroup Ship Landsite Observer Aircraft ASM Background Ballistic Run



Ship Air Defence Model Radar GUI

BAE SYSTEMS SADMU 5.5.0.2 in directory "C:\Program Files\BAE Systems\SADMU-AE 5.5.0.2 x64": Shipboard Radar / Illuminator / IFF Data - standard

File Scenario Environment Taskgroup Ship Site Observer Aircraft ASM Background Target Options Worksheets Go To Help

UNCLASSIFIED Blue Ship 1 Radar / Illuminator / IFF Data

Search Radar 1 System Details

Ship: 1

Radar Name: default_radar

Radar Count: 1

3D Radar Phased Array Radar

Stab. Antenna Use Confirmation Beams?

Vector proc mode Suppress land obs?

Special Alert Mode

Spec Alert min SNR / min rdot: 20.0 / 150.0

Antenna (x,y) position on ship: 0.0 / 0.0

Test target: Red ASM 1

Buttons: Edit Radar Mode List, Update Radar Tracker Data, Update Calculation

Display mode or submode?: Current Submode

Radar Coverage Diagram

Height (m): 20 to 200

Range (km): 5 to 25

Display legend

Type: Radar Submode Characteristics

Number of Submodes: 2	Instrument/Blind range (km): 30.0 / 0.150	Pulse Compression Type: Upchirp	No. of bursts per dwell: 1
Submode No / Type: 1 / RF	Antenna Height (m): 30.0	Number of chips: 1	PRF 1 (Hz): 3750.0
Submode on?: <input checked="" type="radio"/> Yes <input type="radio"/> No	TX / RX Ant Gain (dB): 32.00 / 32.00	Uncompressed pw (us): 1.00	No. MTI/freq/PW: 15 / 5.600 / 1.00
Nominal Freq (GHz): 5.600	Az / El Beamwidths (deg): 3.00 / 5.00	Compressed pw (m): 75.00	Noise Figure / System Loss: 6.0 / 10.0
Low / High Freq (GHz): 5.600 / 5.600	Azimuth Beam Pattern: Sinc (x)	Compression gain (dB): 3.00	Dwell time / Min RCS: 0.0120 / -99.0
Waveform Type: Pulse	El Transmit Beam Pattern: Cosec^2	Max pulse eclipsing (0-1): 0.000	Set CFAR / PFA data: Edit CFAR Details
Radar Processing Mode: 3-Pulse MTI	El Receive Beam Pattern: Cosec^2	IF Bandwidth (MHz): 2.000	Track Init (m out of n): 2 / 3
Calculation Type: Smart Design...	Ant Polarisation: Horizontal	Range sidelobe (dB): -42.00	Track Confirm (m out of n): 0 / 0
STC not used: Edit STC Details	Min/Max el (deg): -10.00 / 45.00	MTI Improv factor (dB): 40.00	Burst detections (m out of n): 1 / 1
System Failure Rate: Set	Scan time / El offset: 1.50 / 0.00	Peak Xmit Power (dBW): 50.0	Track Est. Time / Rate (s): 1.50 / 1.00
		Frequency Agile Mode: None	

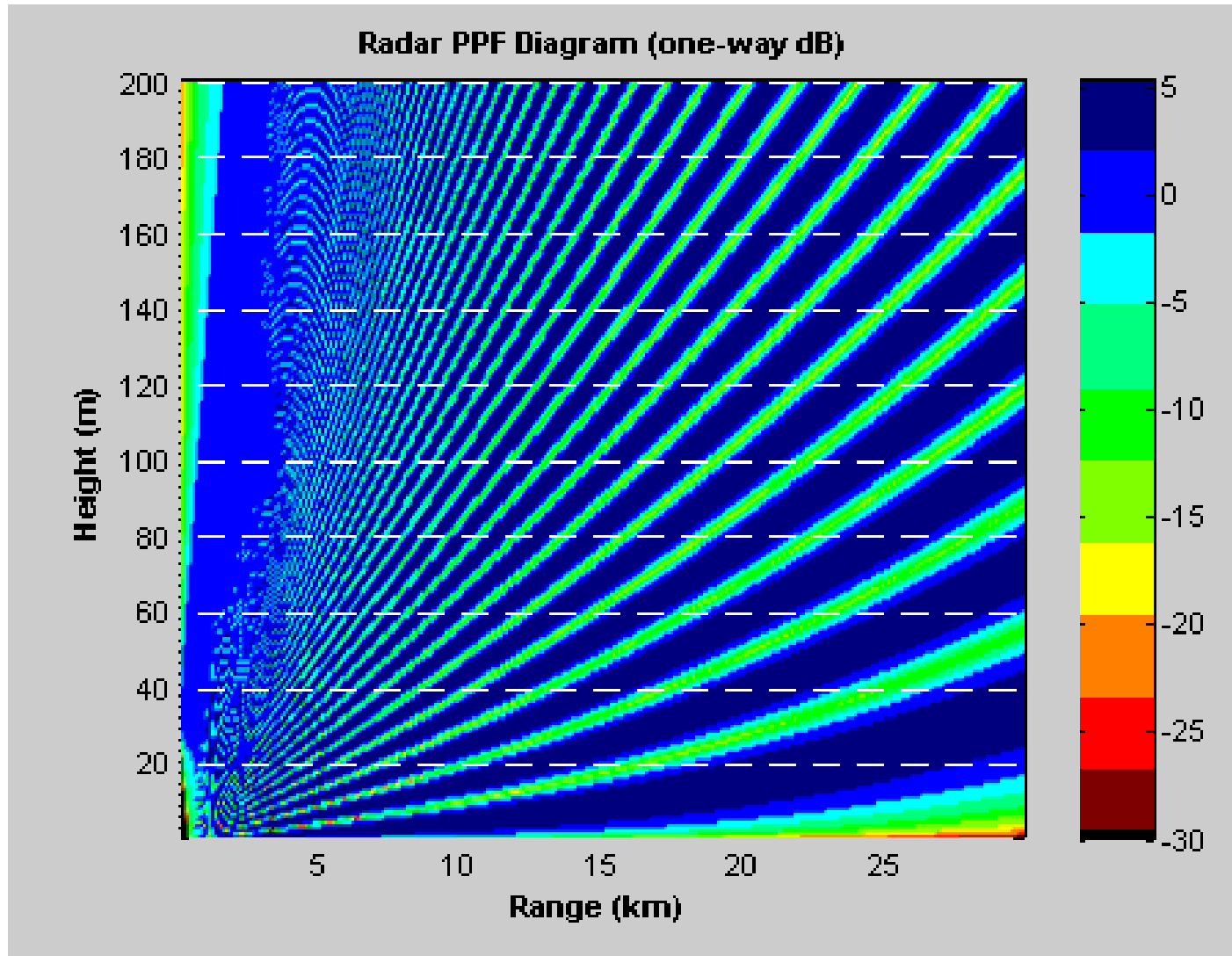
Search Radar: 1: default_radar | PAR | DIR types | 1: default_fcr | DIR/ILL channels | IFF

UNCLASSIFIED

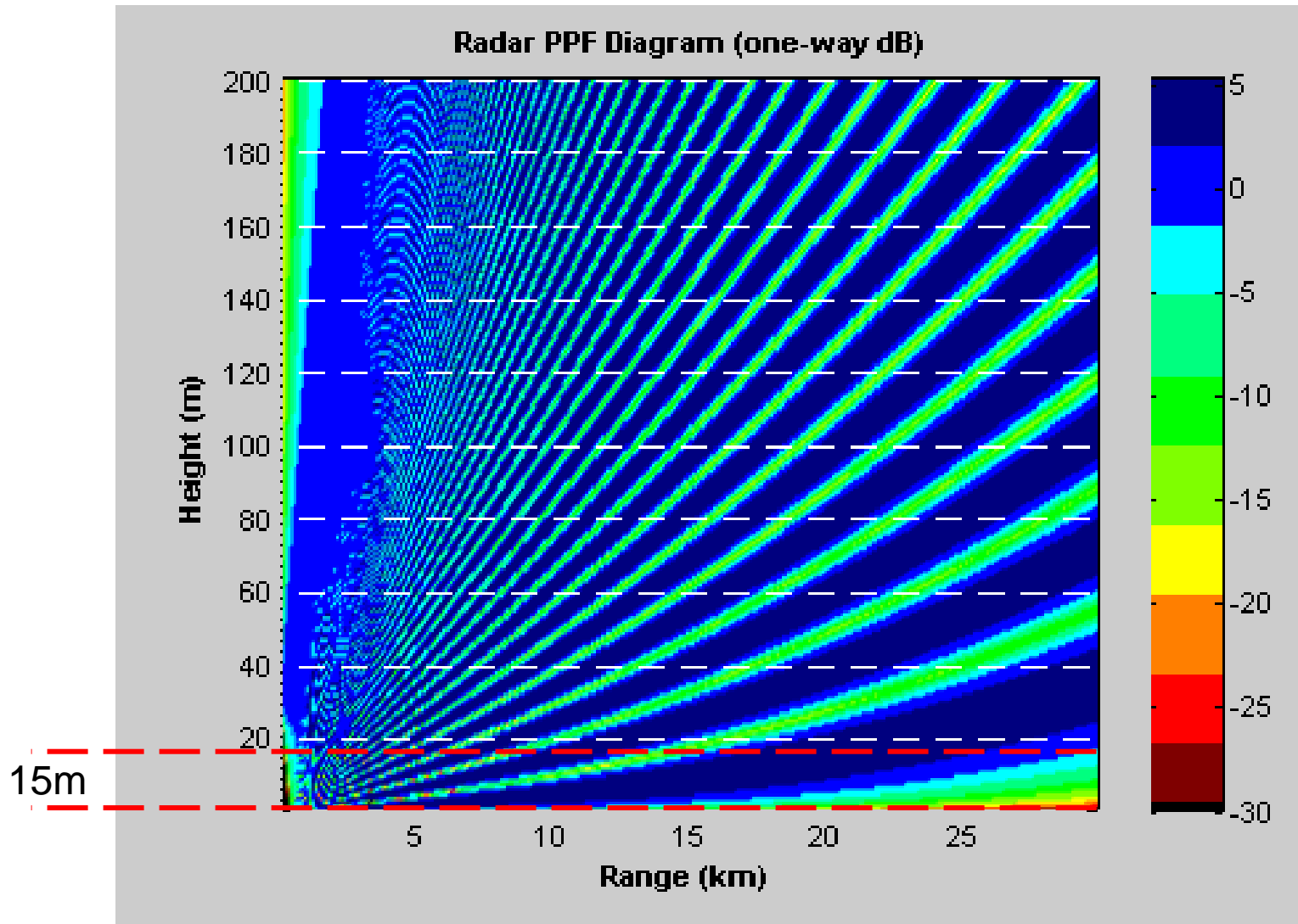
Physical
C2
ESM
EOIR
Radar
Weapon
Chaff / IR
Jammer
Decoy
Waypoint Mgmt

General
Taskgroup
Ship
Landsite
Observer
Aircraft
ASM
Background
Ballistic
Run

Advanced Propagation Model (APM) created by SPAWAR Systems Center San Diego USA

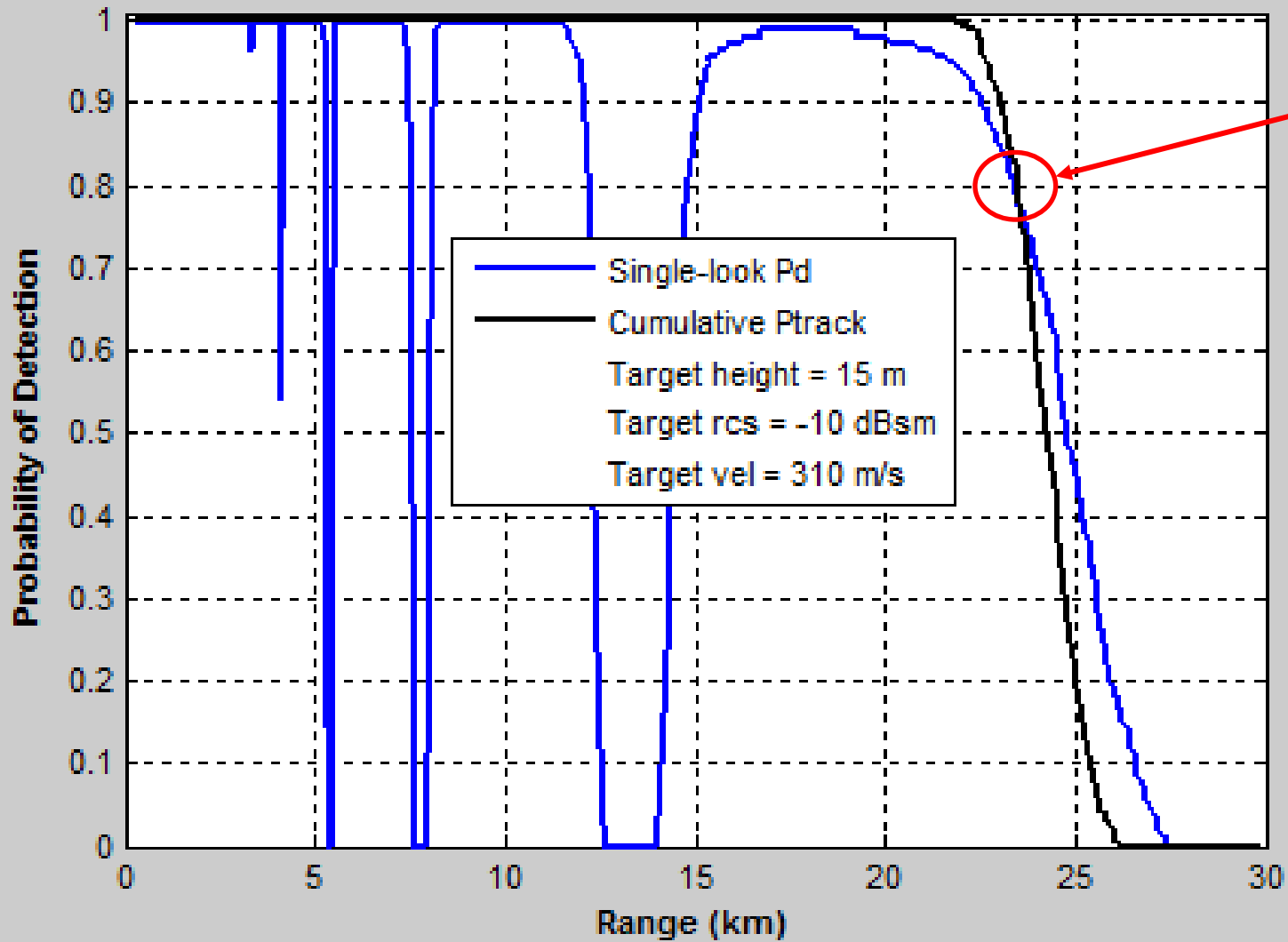


Advanced Propagation Model (APM) created by SPAWAR Systems Center San Diego USA





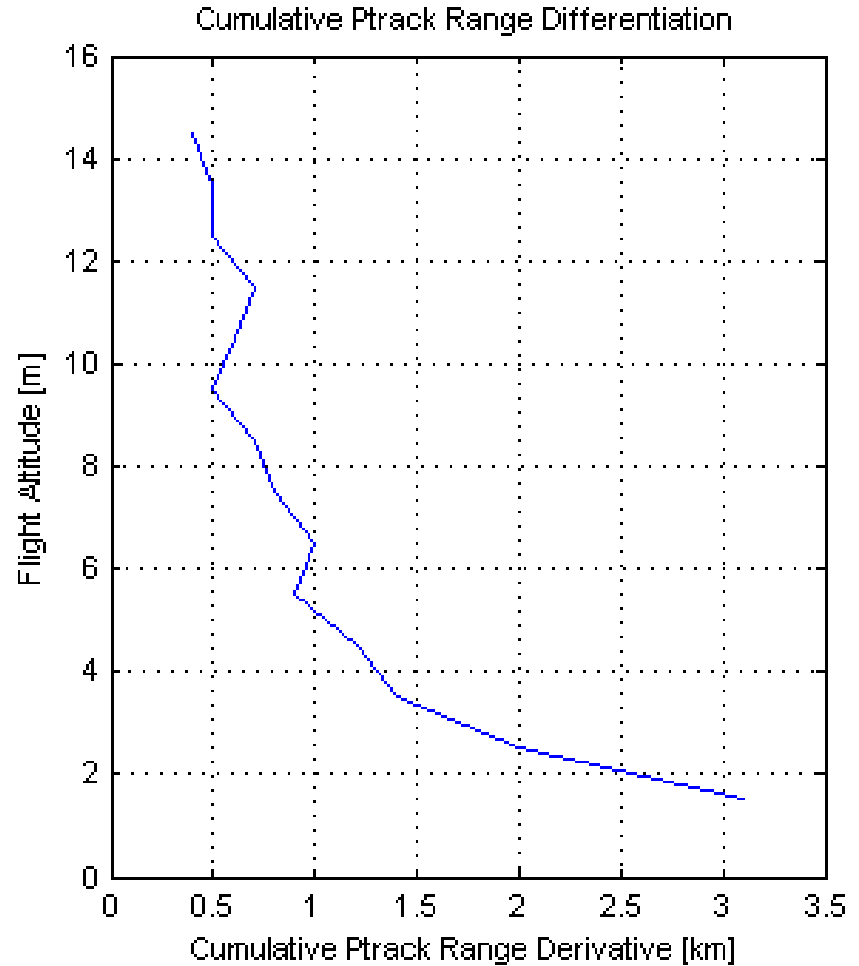
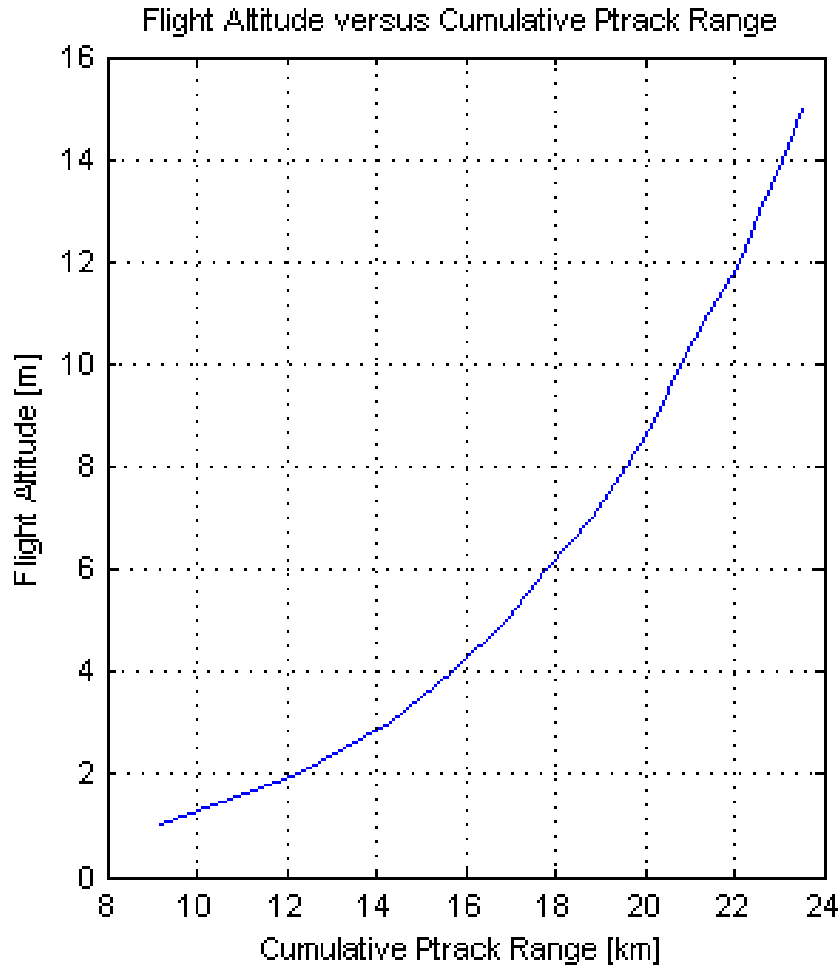
Radar Single-Look P_d and Cumulative P_{track}



2/3



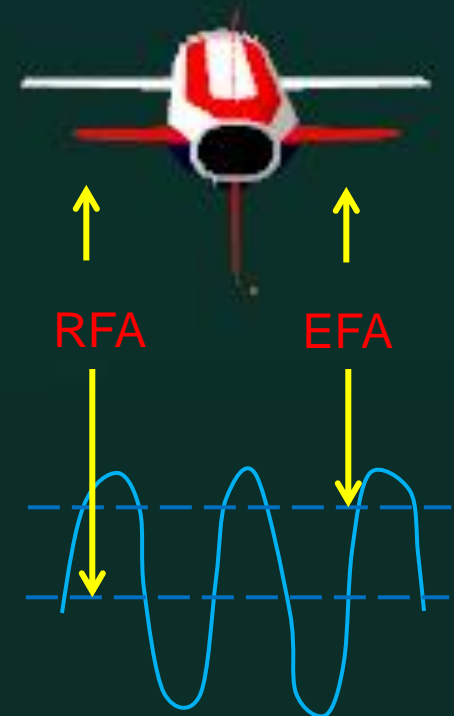
Cumulative Ptrack Range (2 detections out of 3 tries) versus flight altitude, Sea State 0



What is flight altitude for high sea state as seen by Radar? It is here called Effective Flight Altitude (EFA)

Three hypotheses have been discussed. They are that EFA is the flight altitude above:

1. Mean sea level, $EFA=RFA$ (Real Flight Altitude)
2. Significant wave height, which is the average of the upper 1/3 of all measured wave heights (peak to peak height)
3. Some maximum wave height higher than significant wave height crest based on visual impression of the sea height when viewing the horizon



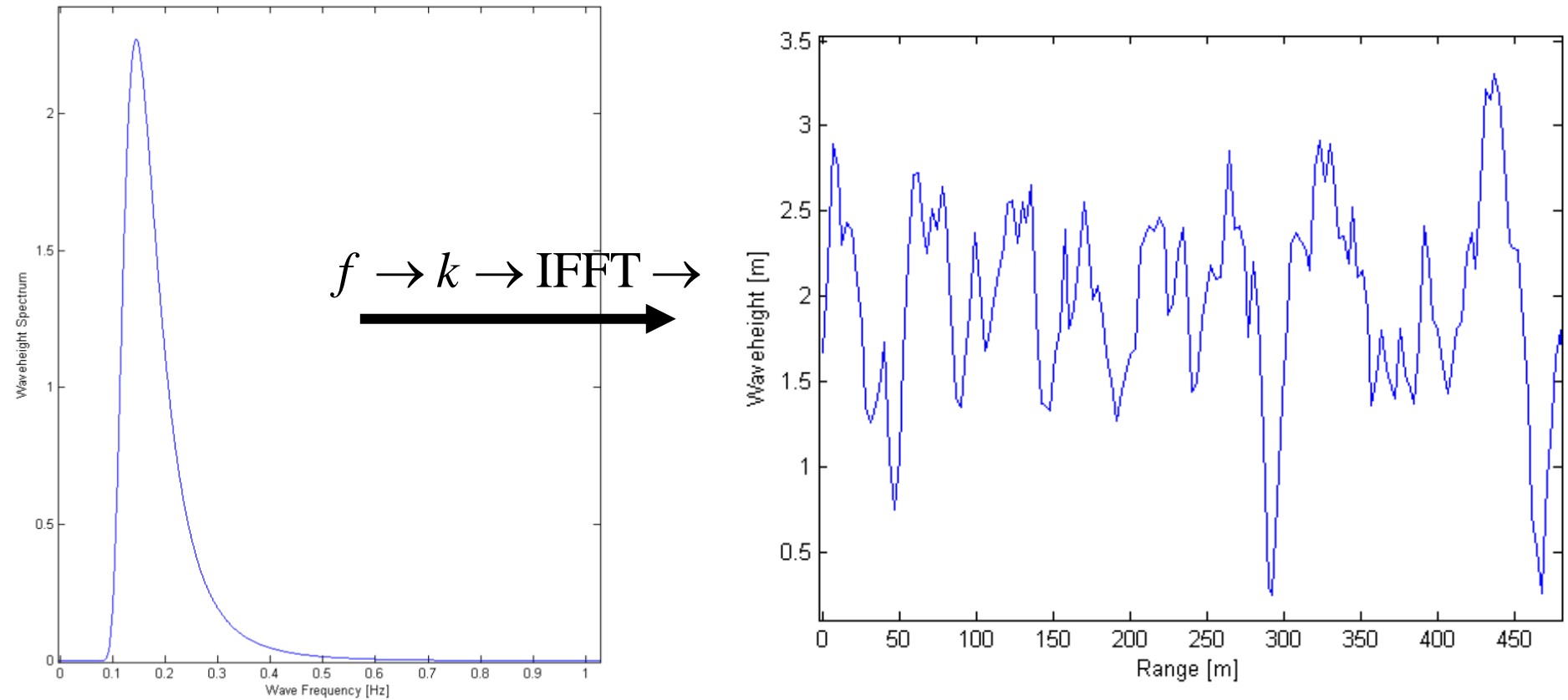


Method for solving the Effective Flight Altitude (EFA) estimation problem:

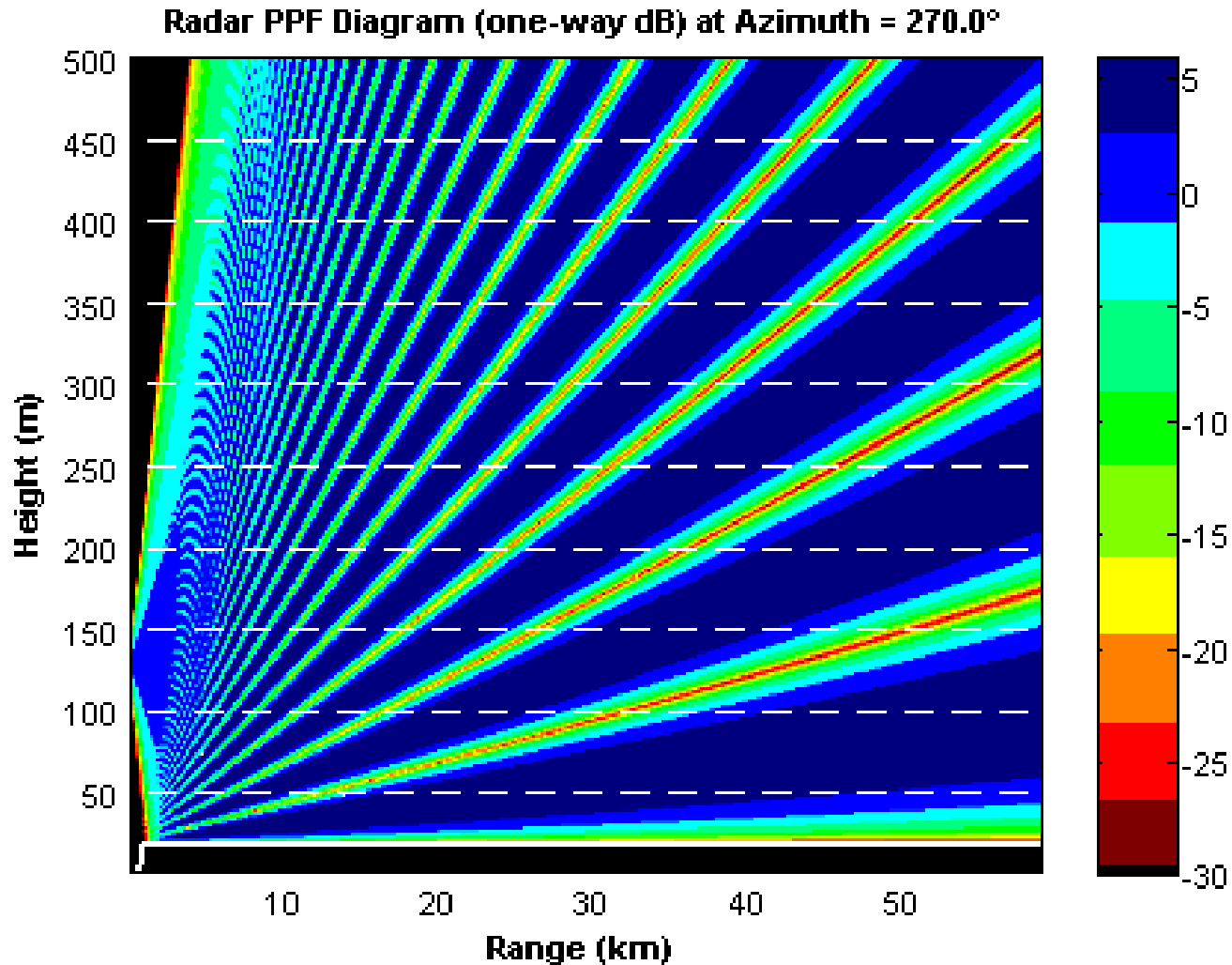
- Introduce a realistic sea surface in a commercial radar detection evaluation tool like Ship Air Defence Model (SADM).
- The radar power is adjusted so target detection takes place at a chosen range for a given Real Flight Altitude (RFA).
- Then the sea surface is removed and target flight altitude together with antenna height are adjusted until the same detection range is achieved. This flight altitude is then assumed to be the Effective Flight Altitude (EFA).



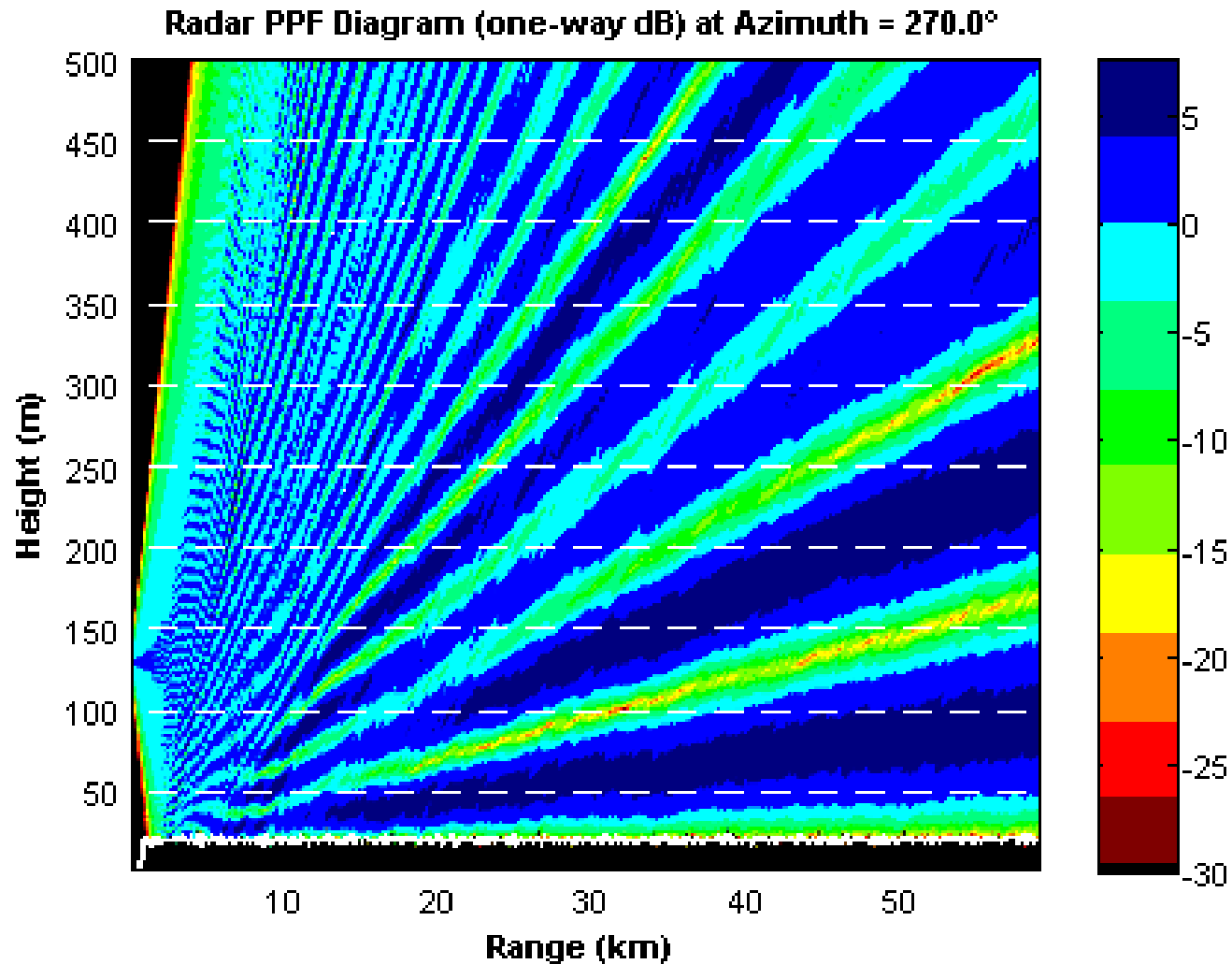
Pierson Moscowitz Sea Surface Spectrum Model converted to a range profile



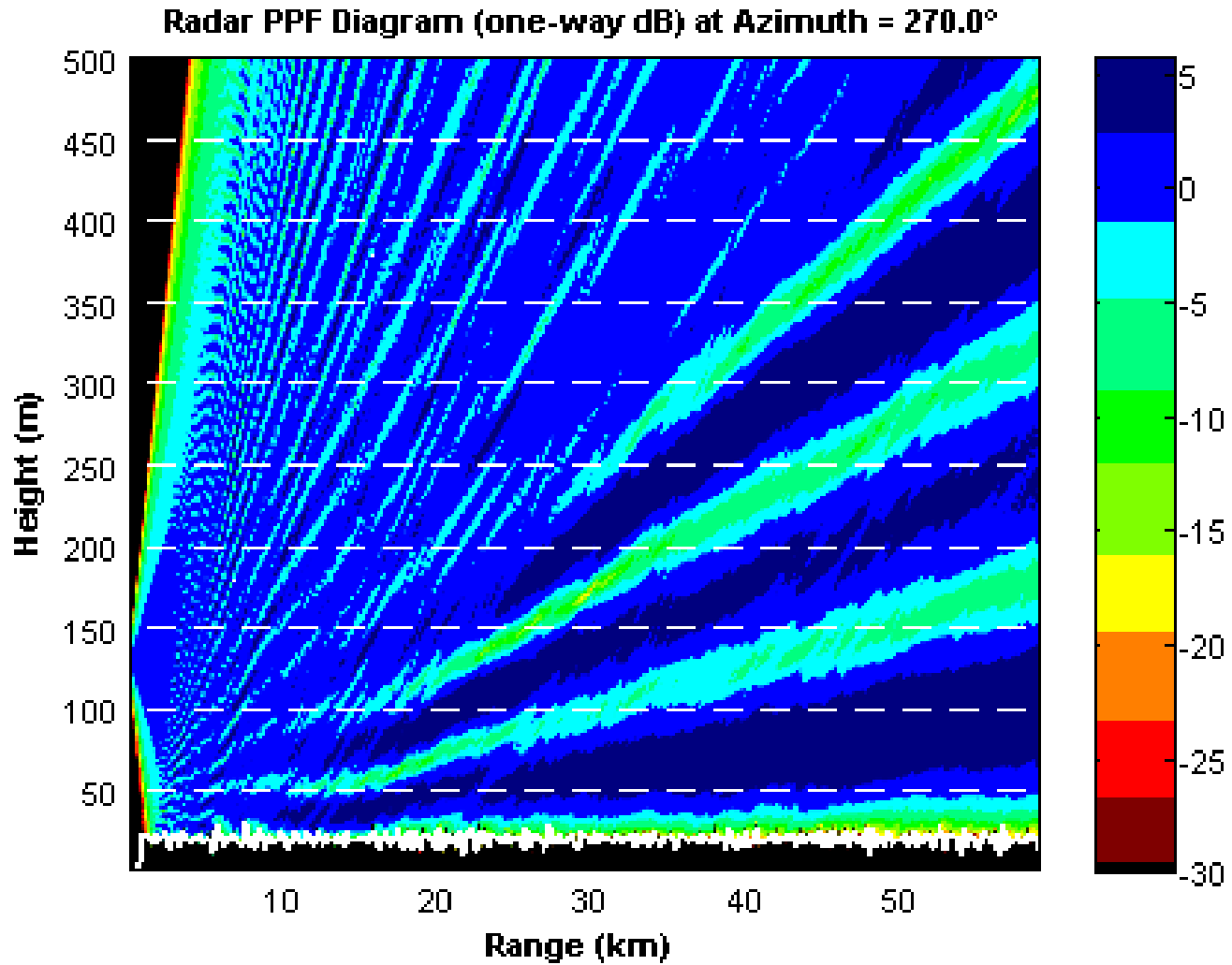
Advanced Propagation Model Sea State 0



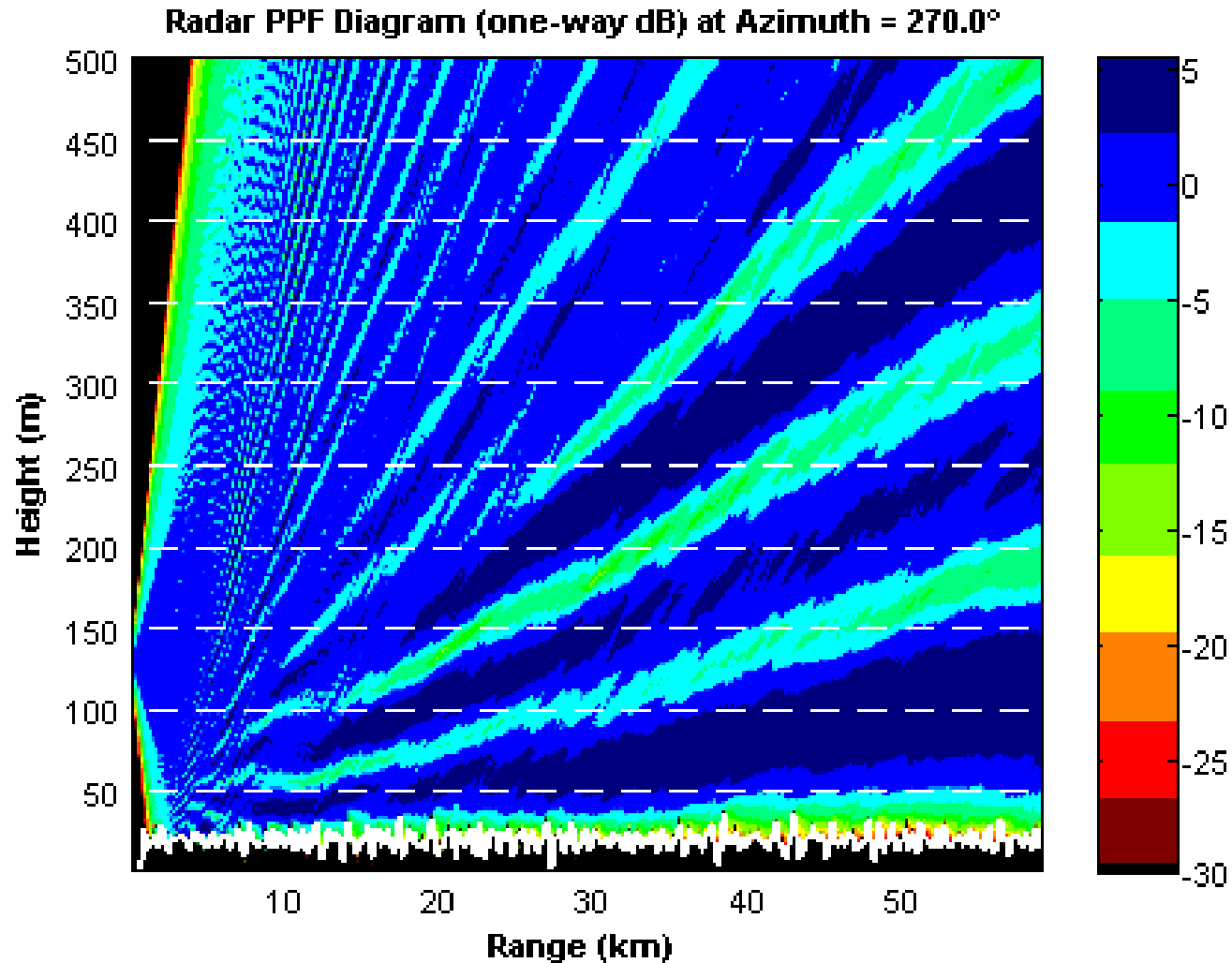
Advanced Propagation Model Sea State 3



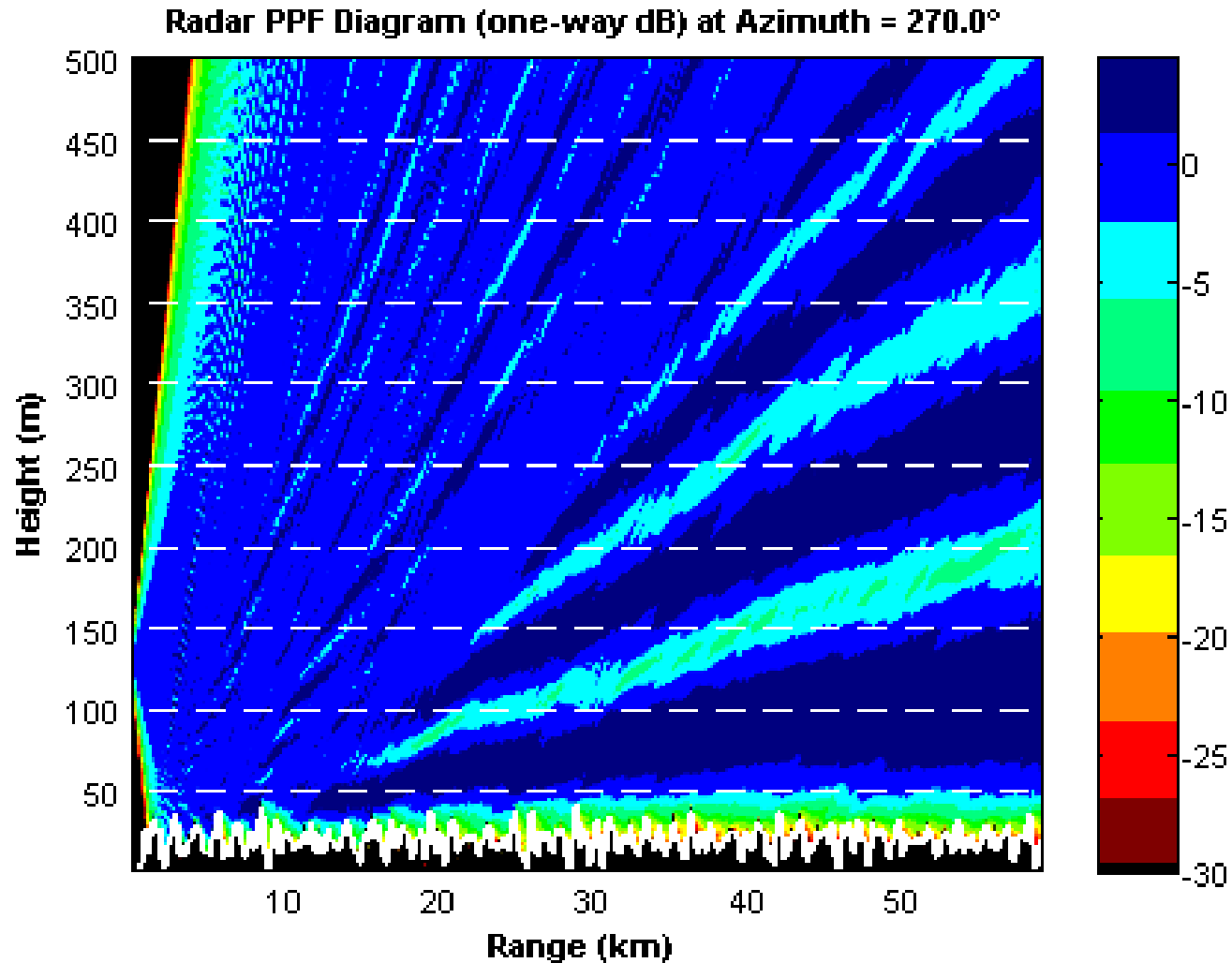
Advanced Propagation Model Sea State 4



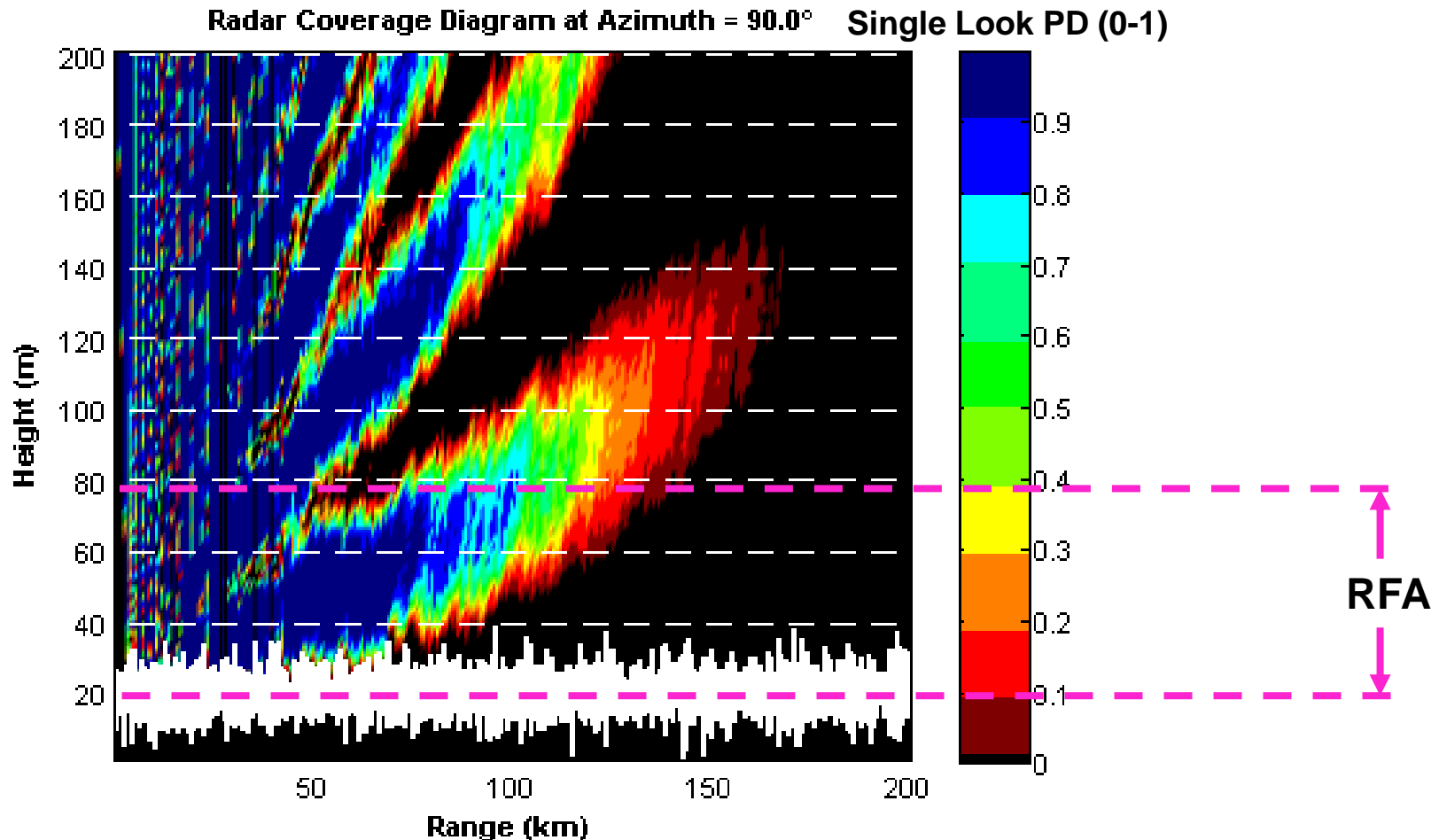
Advanced Propagation Model Sea State 5



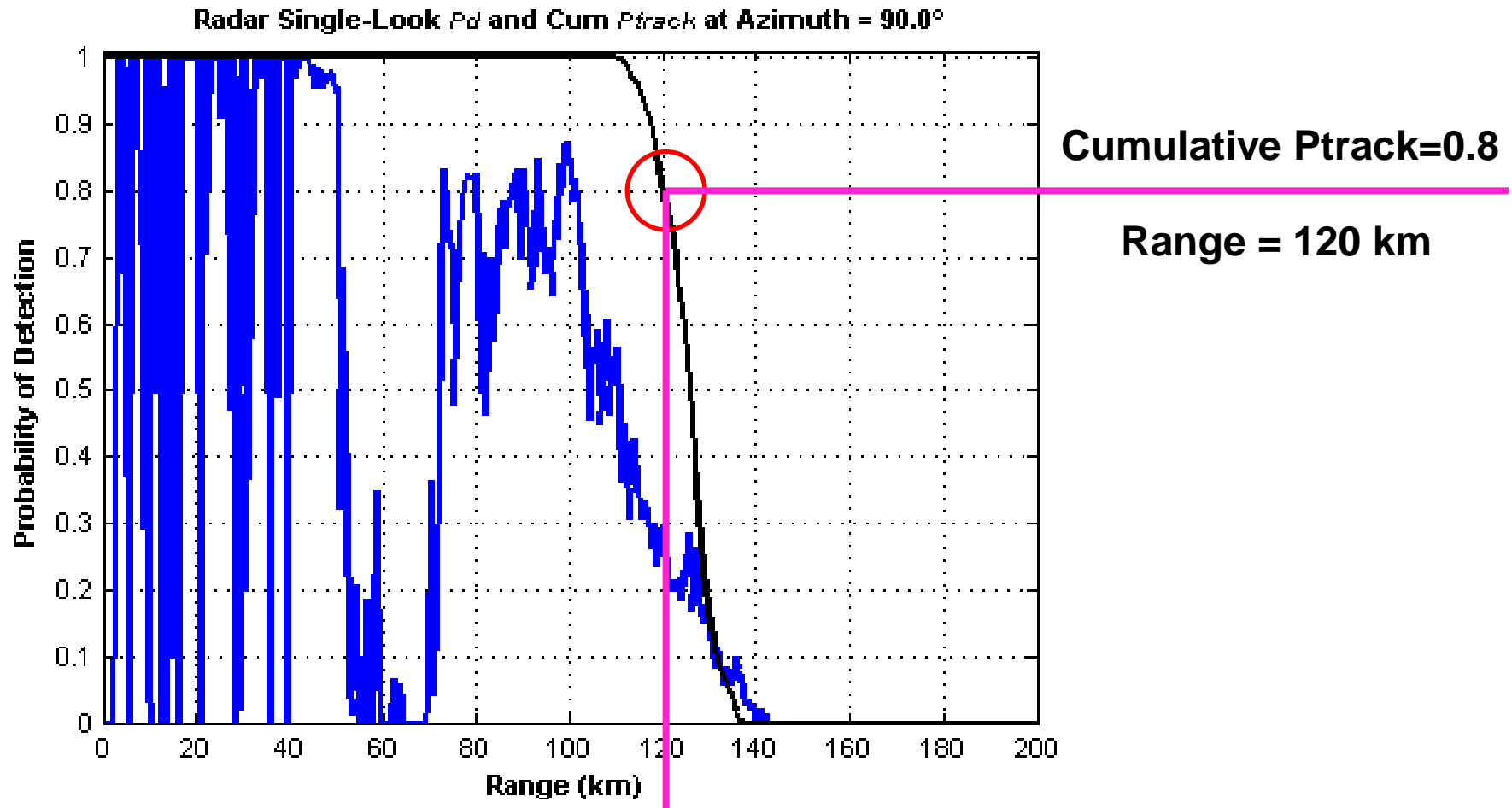
Advanced Propagation Model Sea State 6



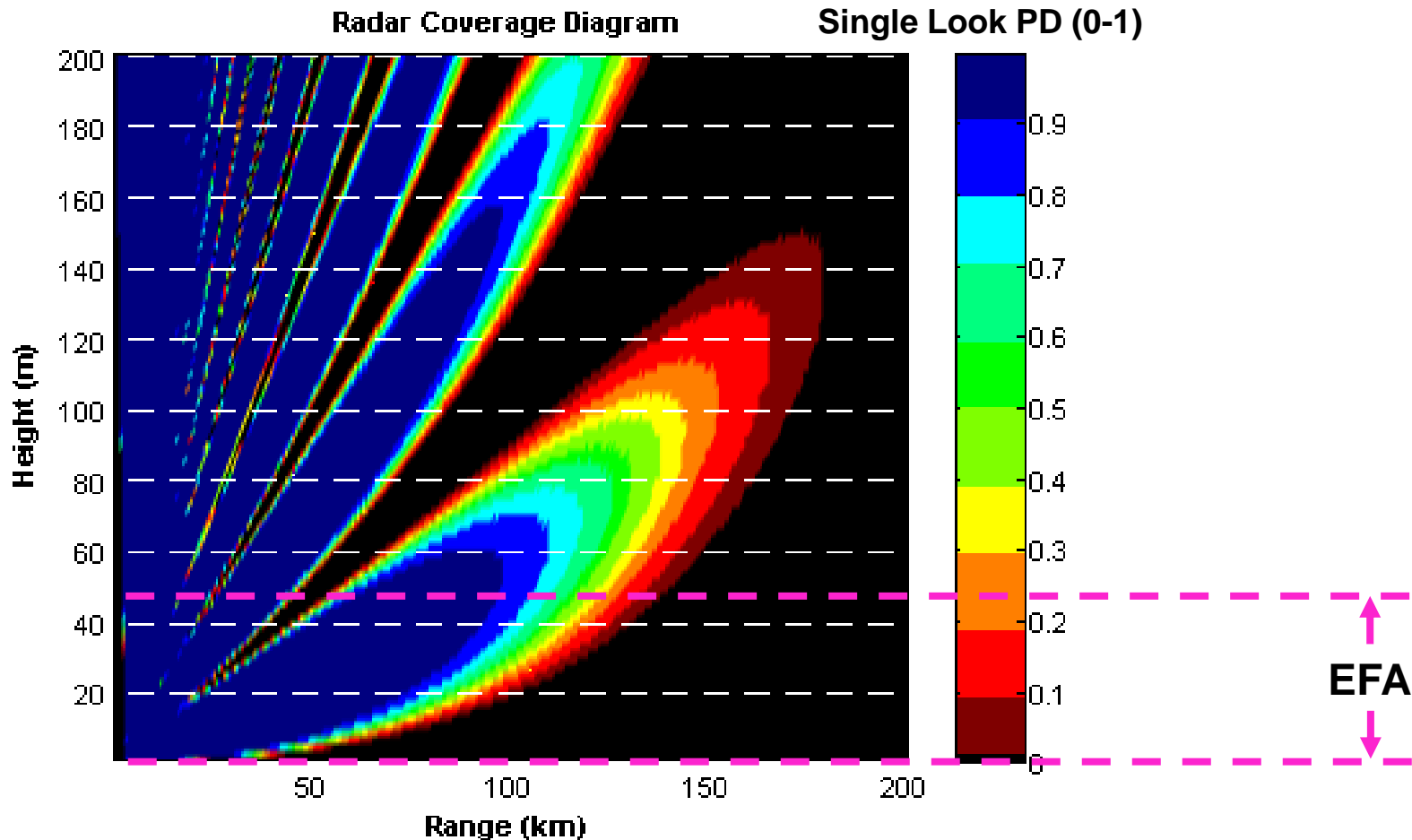
The radar power is adjusted so target detection takes place at a chosen range for a given Real Flight Altitude (RFA).



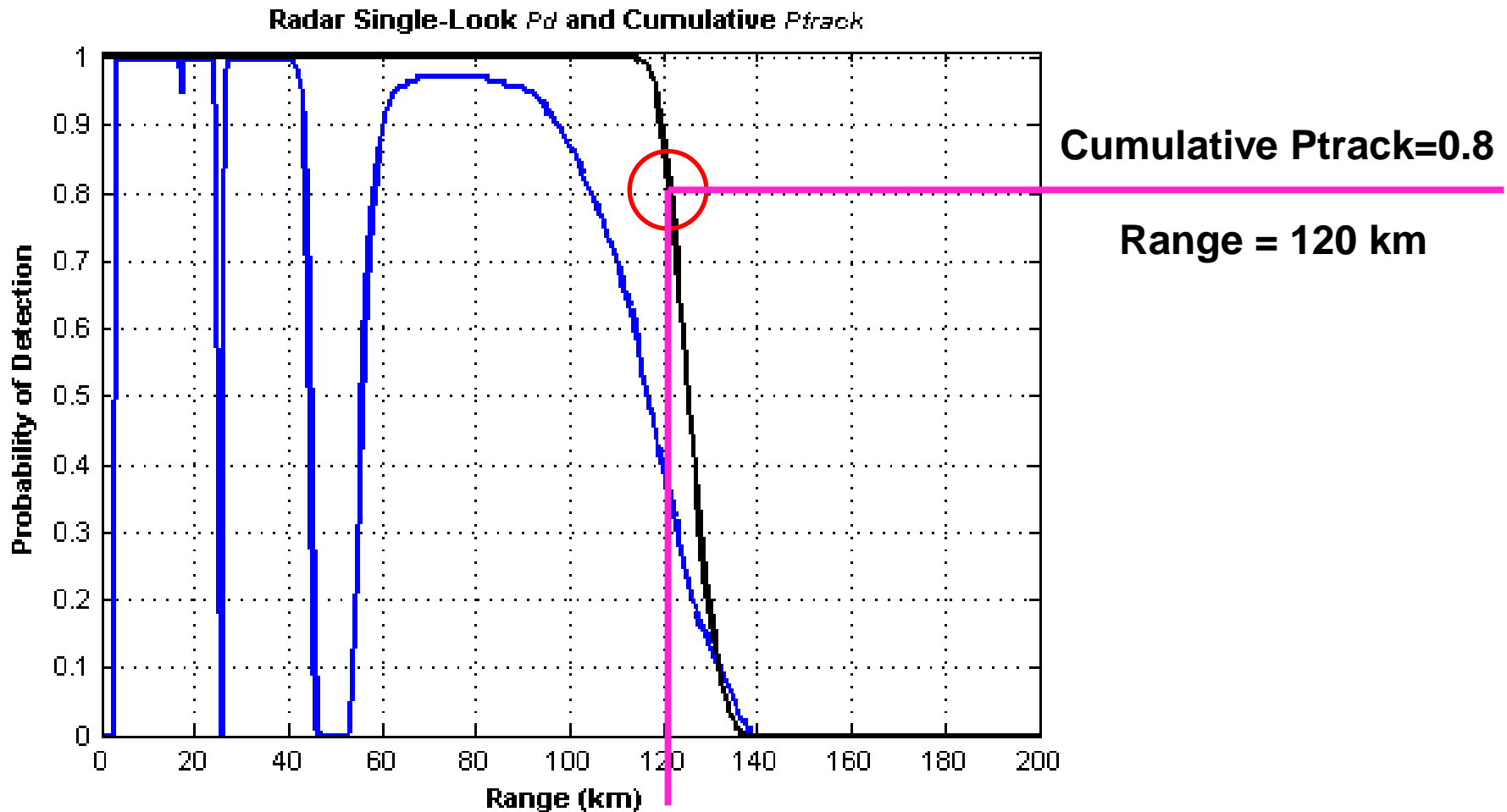
Corresponding single look probability of detection (blue curve) and cumulative probability of track (black curve)



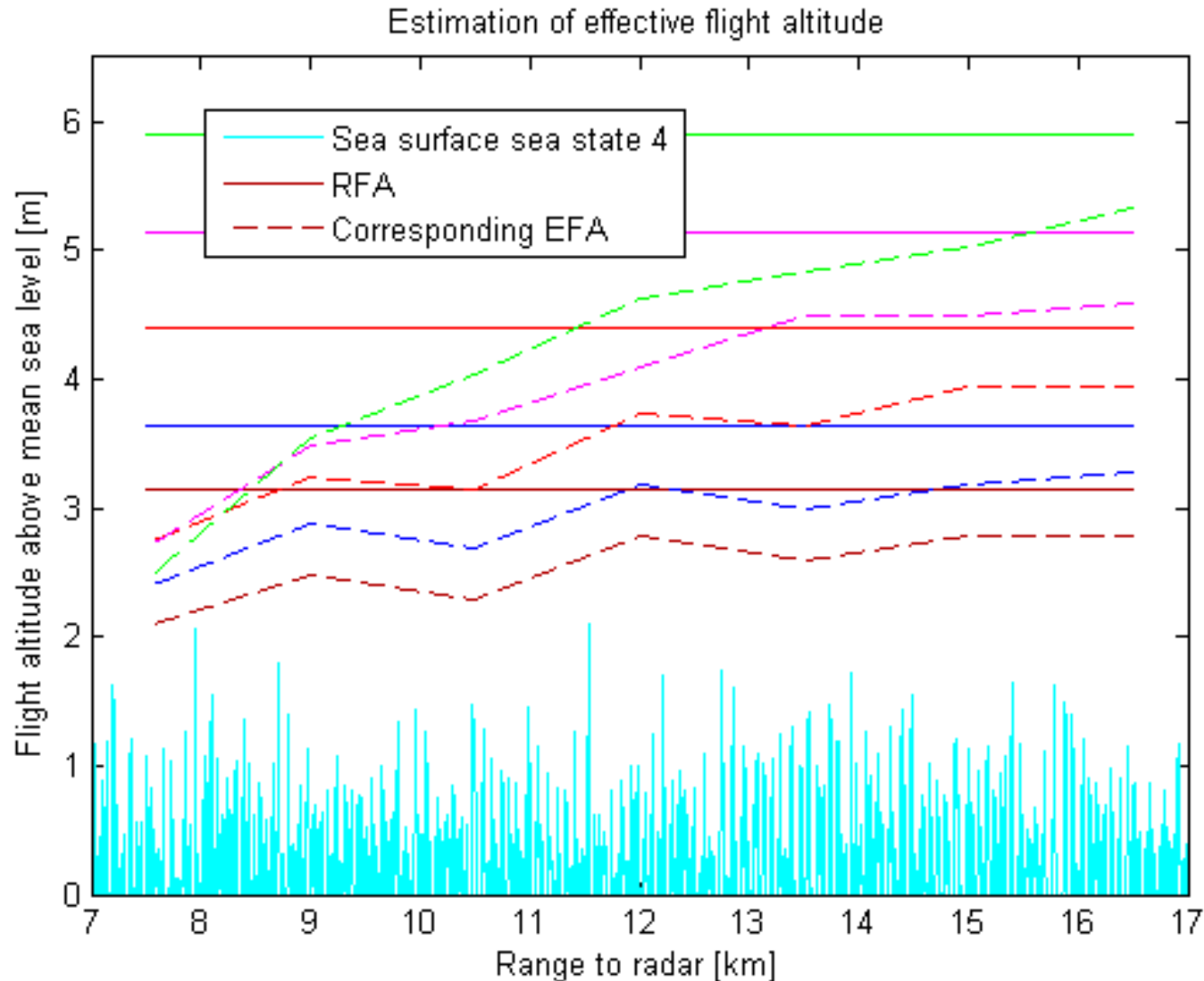
Then the sea surface is removed and target flight- and antenna altitude are adjusted until the same detection range is achieved.



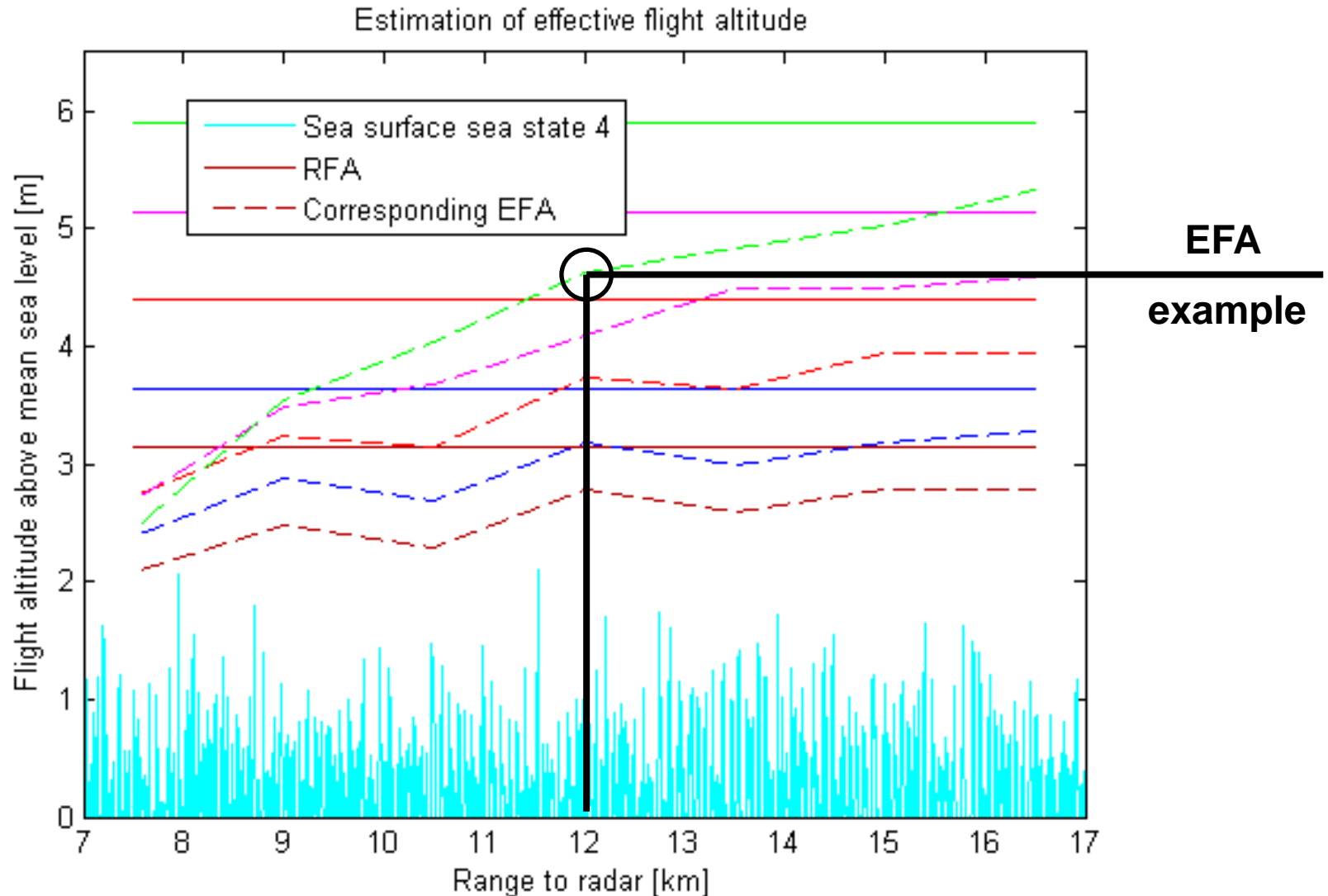
Corresponding single look probability of detection (blue curve) and cumulative probability of track (black curve)



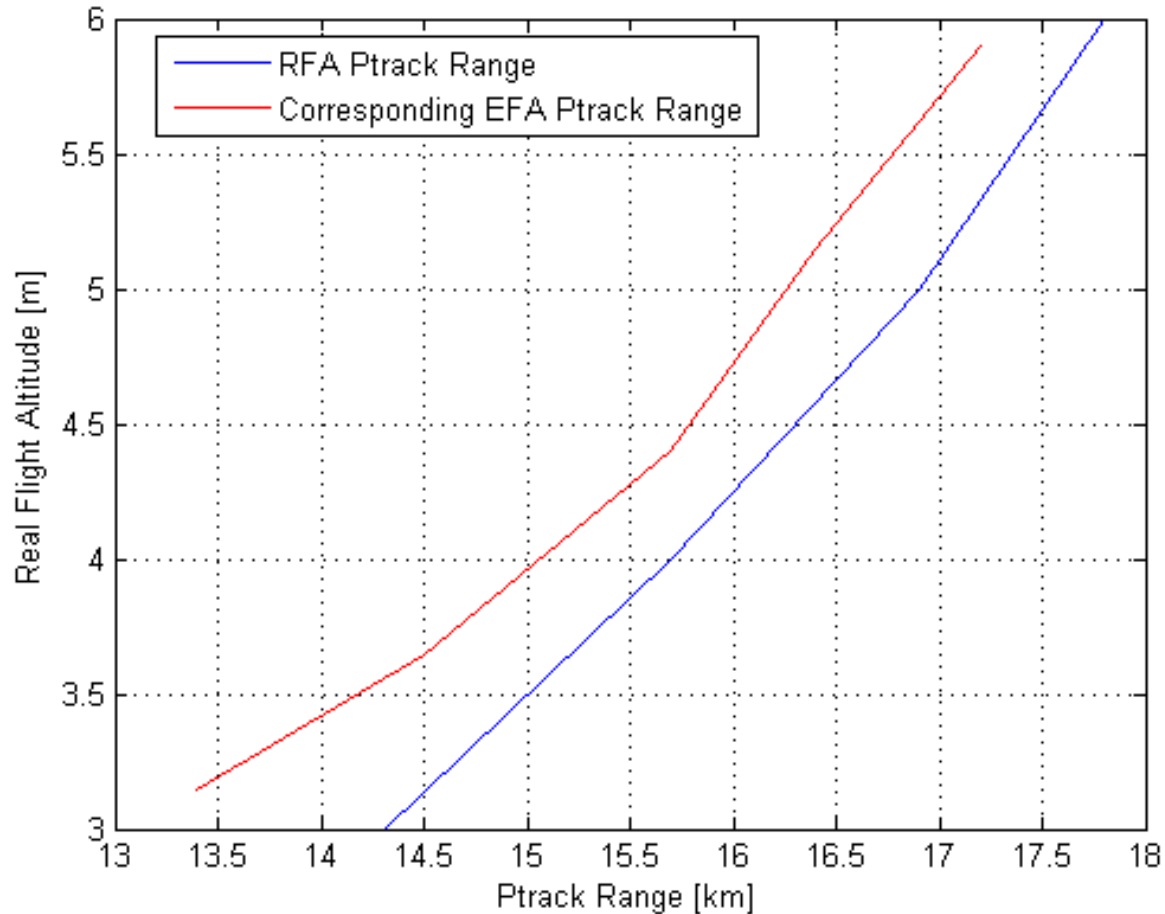
A parametric presentation of EFA and generic low RFA versus range to radar for sea state 4



A parametric presentation of EFA and generic low RFA versus range to radar for sea state 4



EFA- and RFA Ptrack range versus Real flight Altitude for SADM default radar/ASM



In this case EFA is roughly estimated to be $EFA=RFA-0.4m$.
Cumulative Ptrack range is reduced with about 0.8 km.



For high grazing angles, where the cumulative Ptrack integrates over many constructive interference lobes:

- Cumulative Ptrack is then not sensitive to changes in flight altitude to match range under test when sea surface is removed.
- For high grazing angles it may be more fruitful to talk about an Effective RCS to match range under test when sea surface is removed. Typical Effective RCS is then about 4 dB lower than Real RCS.

Conclusions

The main trend of the study shows that:

- For long ranges the EFA is close to, but slightly lower than RFA.
- For shorter ranges (increased grazing angles) the EFA becomes significantly lower than RFA.

Usage of EFA instead of RFA in radar detection evaluation is then assumed to give higher fidelity to obtained radar evaluation results for rough sea conditions.

- For high grazing angles it may be more fruitful to talk about an Effective RCS to math range under test when sea surface is removed. Typical Effective RCS is then about 4 dB lower than Real RCS.

Questions?

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