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

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# Overview

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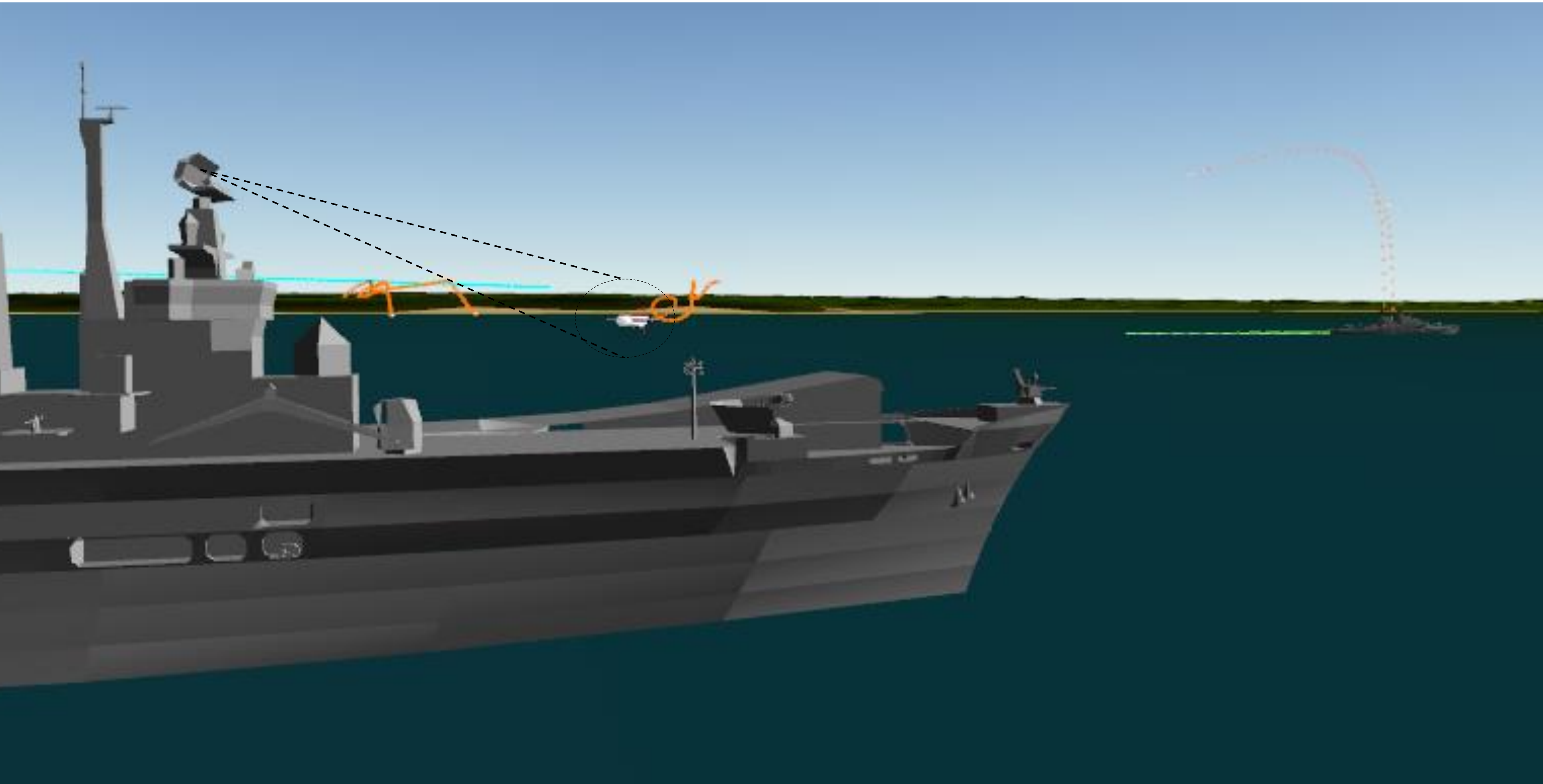
The objective of this presentation is to show a parametric study of the difference between Real Flight Altitude (RFA) and Effective Flight Altitude (EFA) above mean sea level for sea skimming targets as seen by the radar. This is carried out by:

- 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

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- 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

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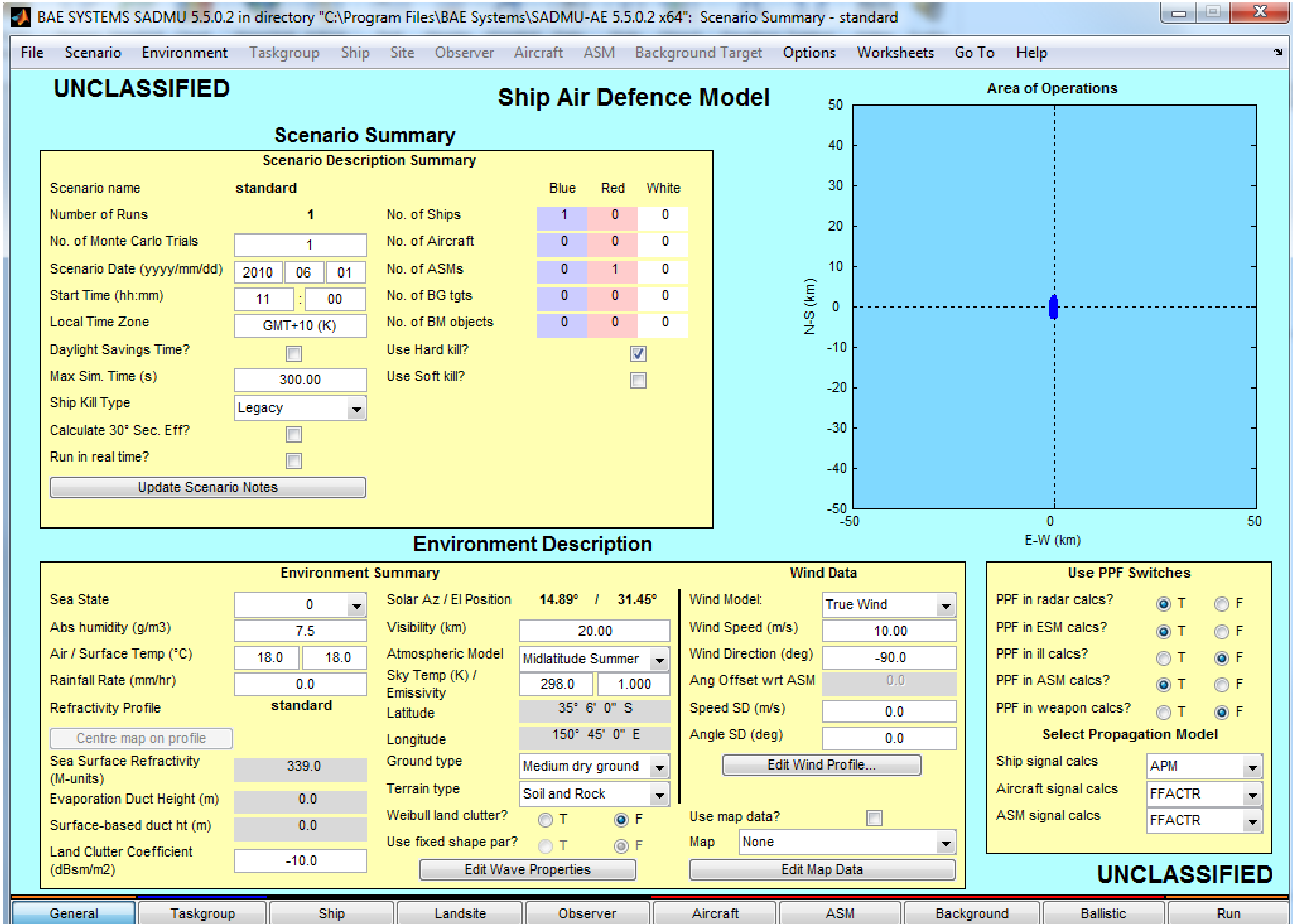

# Ship Air Defence Model Radar GUI

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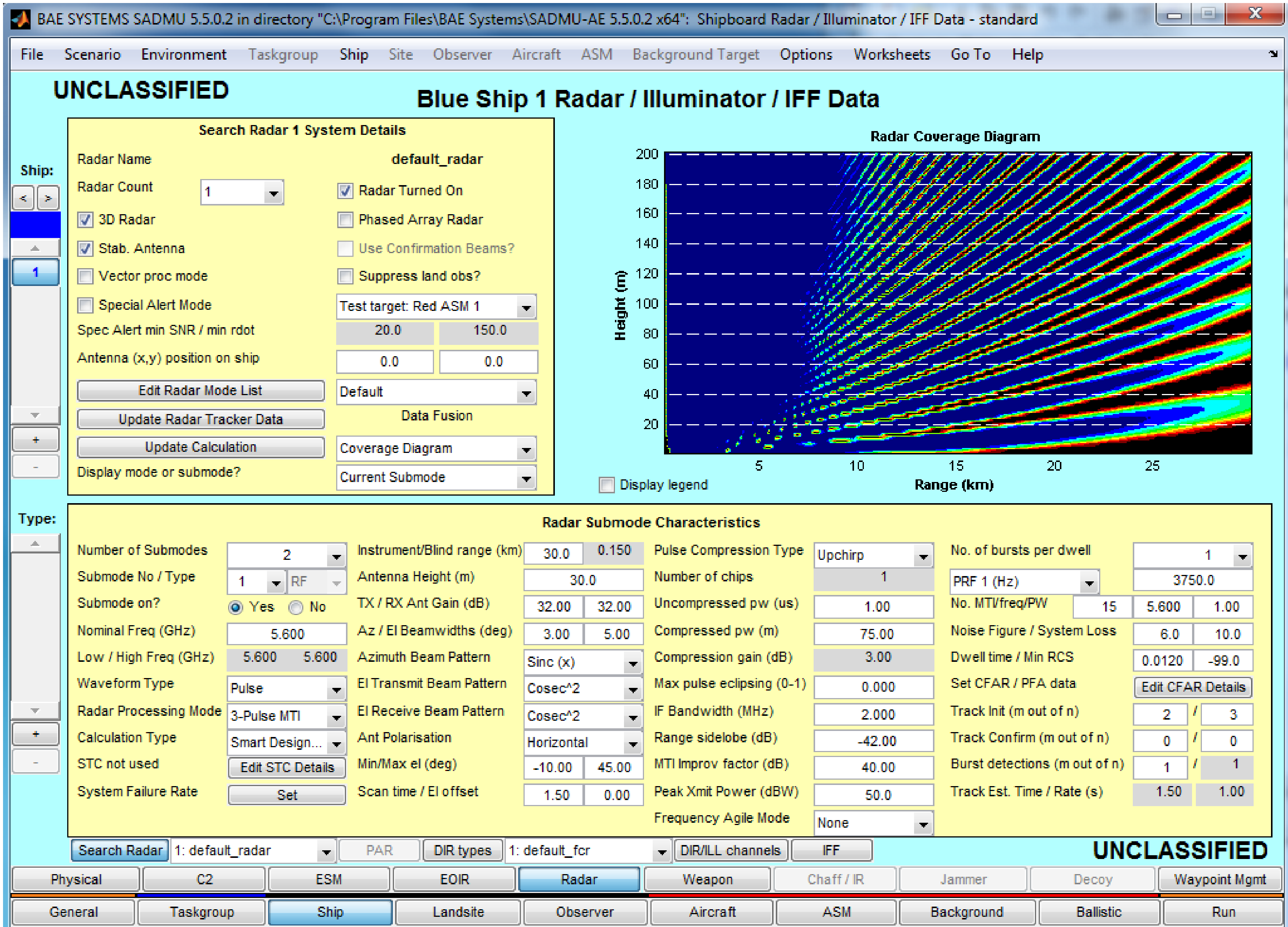
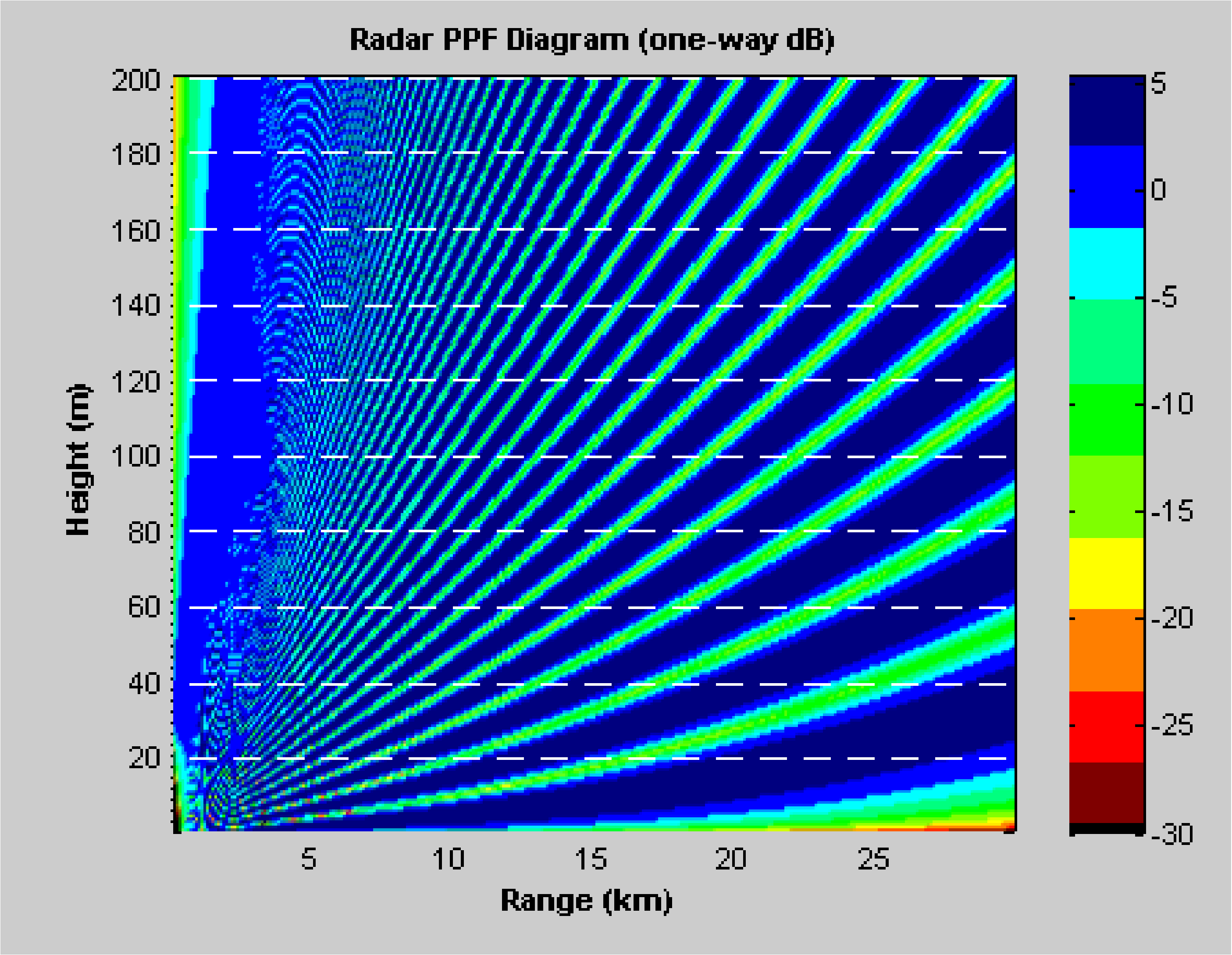


# Advanded Propagation Model (APM) created by SPAWAR Systems Center San Diego USA



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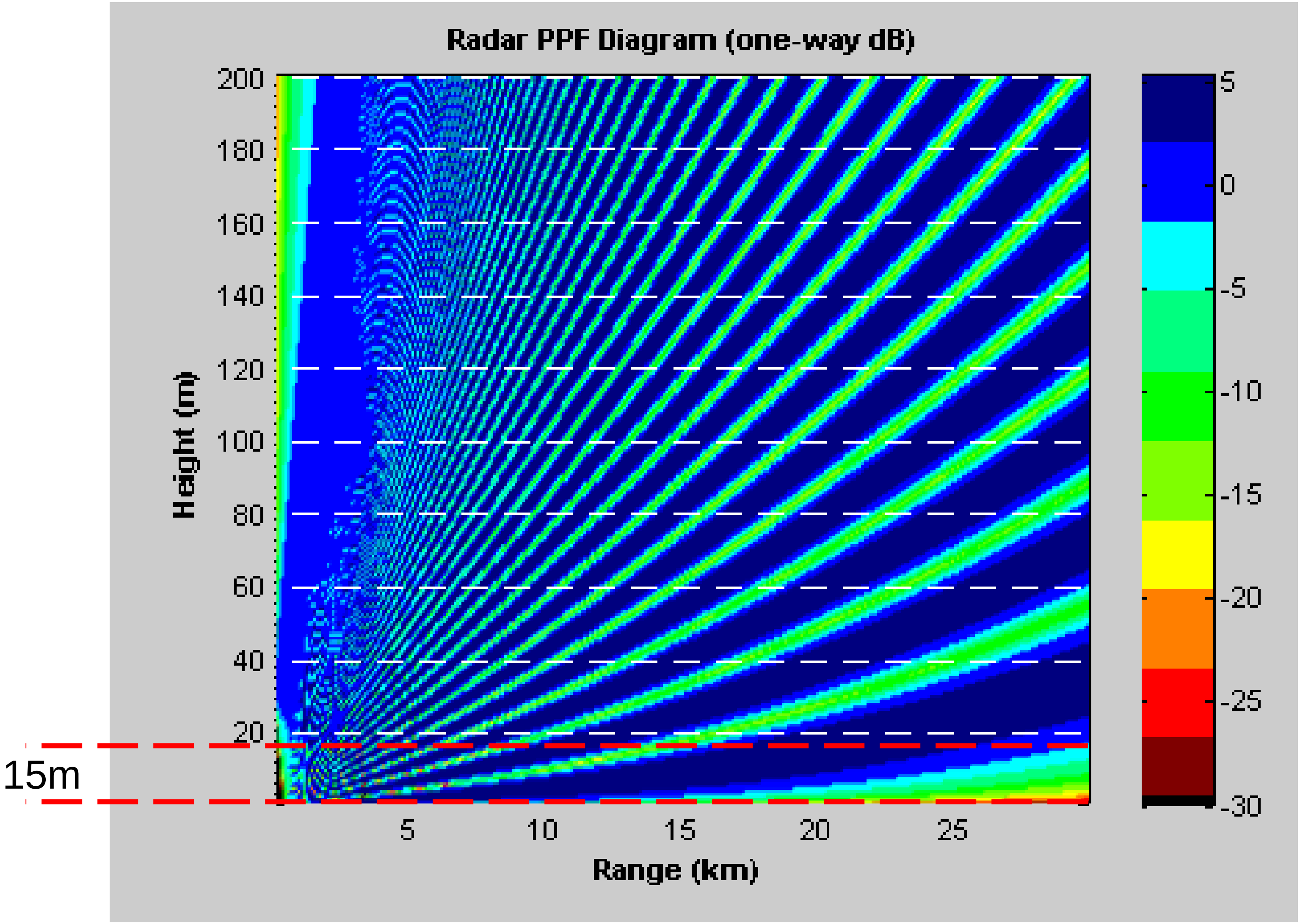
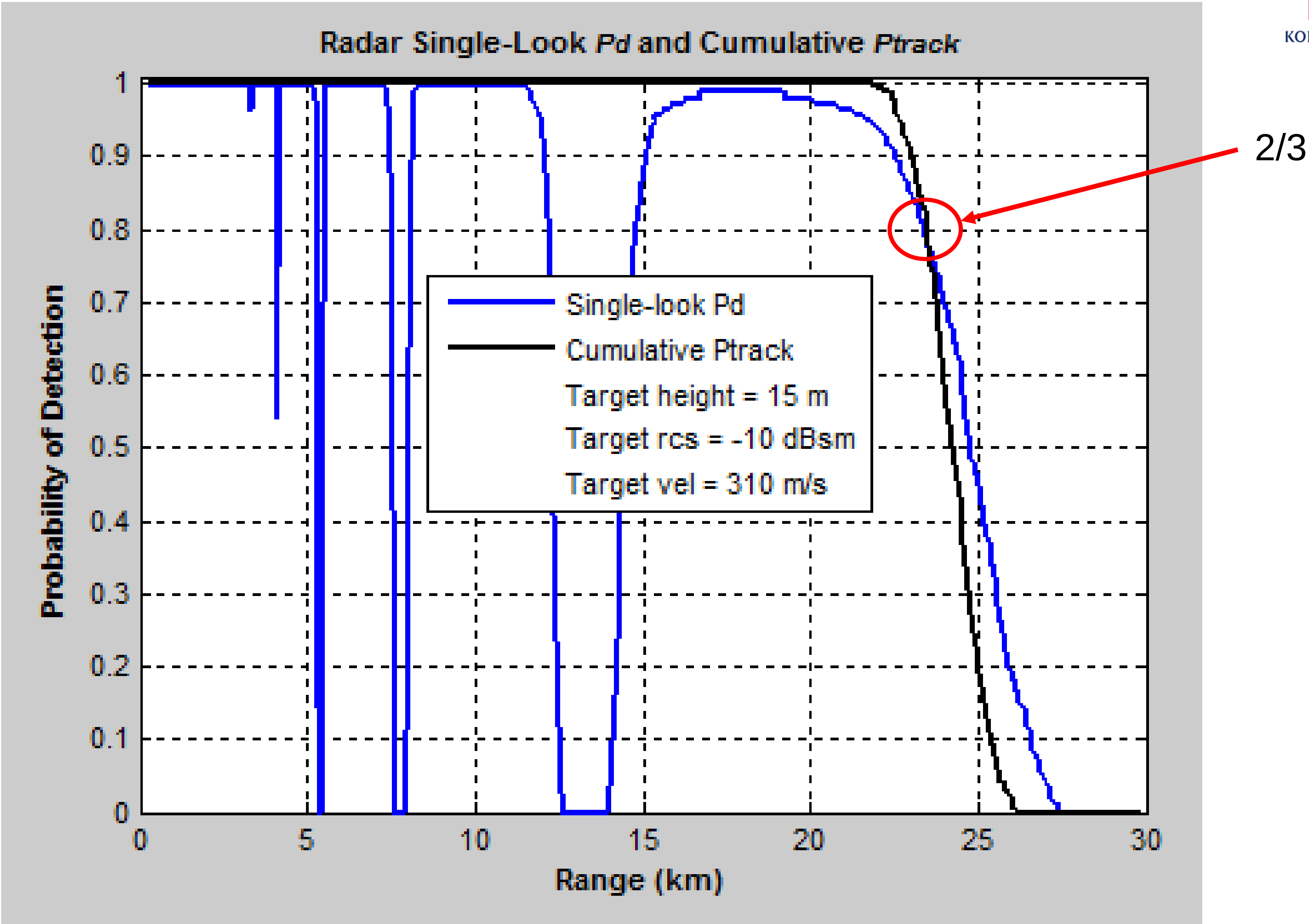
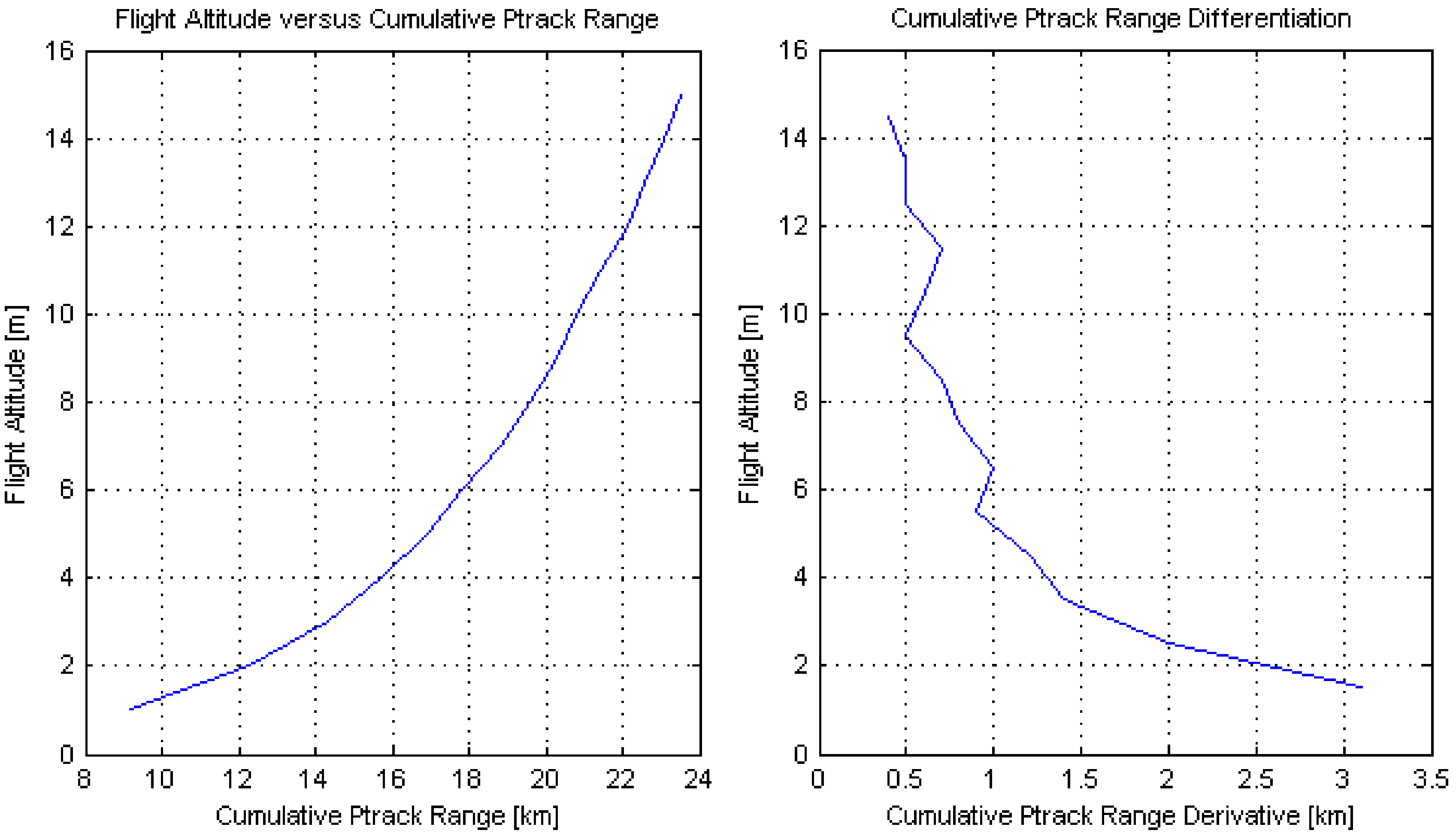



Radar Single-Look Pd and Cumulative Ptrack
Probability of Detection
Range (km)
Single-look Pd
Cumulative Ptrack
Target height = 15 m
Target rcs = -10 dBsm
Target vel = 310 m/s
2/3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30

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



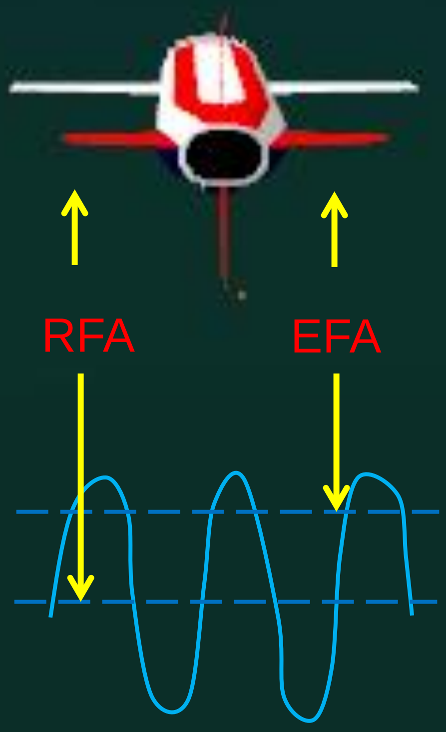
# What is flight altitude for high sea state as seen by Radar? It is here called Effective Flight Altitude (EFA)

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)

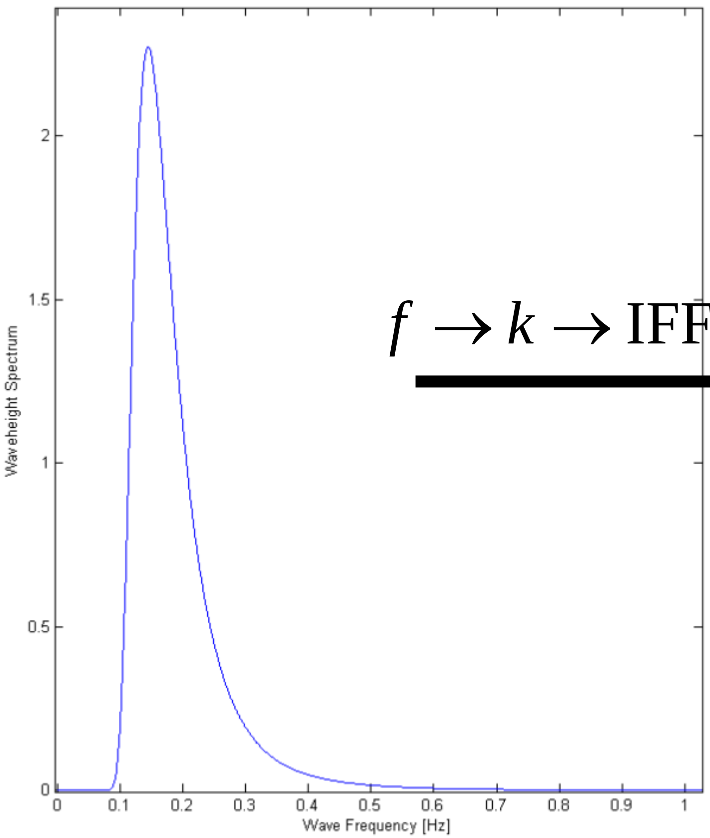
3. Some maximum wave height higher than significant wave height crest based on visual impression of the sea height when viewing the horizon



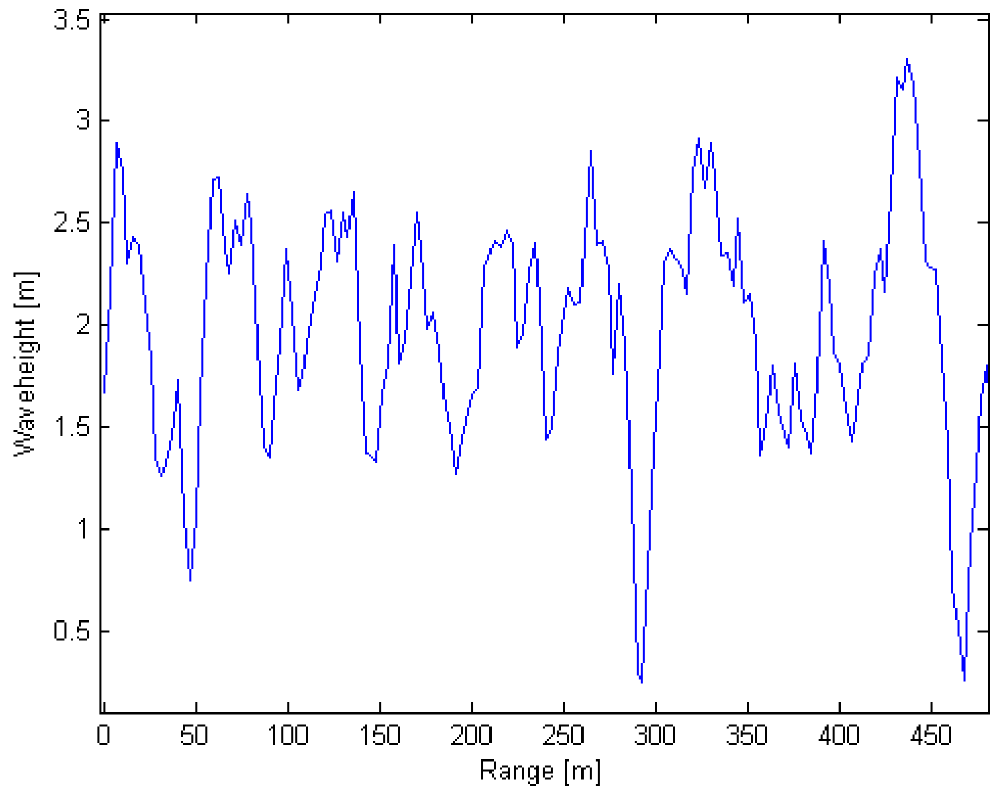
# Method for solving the Effective Flight Altitude (EFA) estimation problem:

- 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).

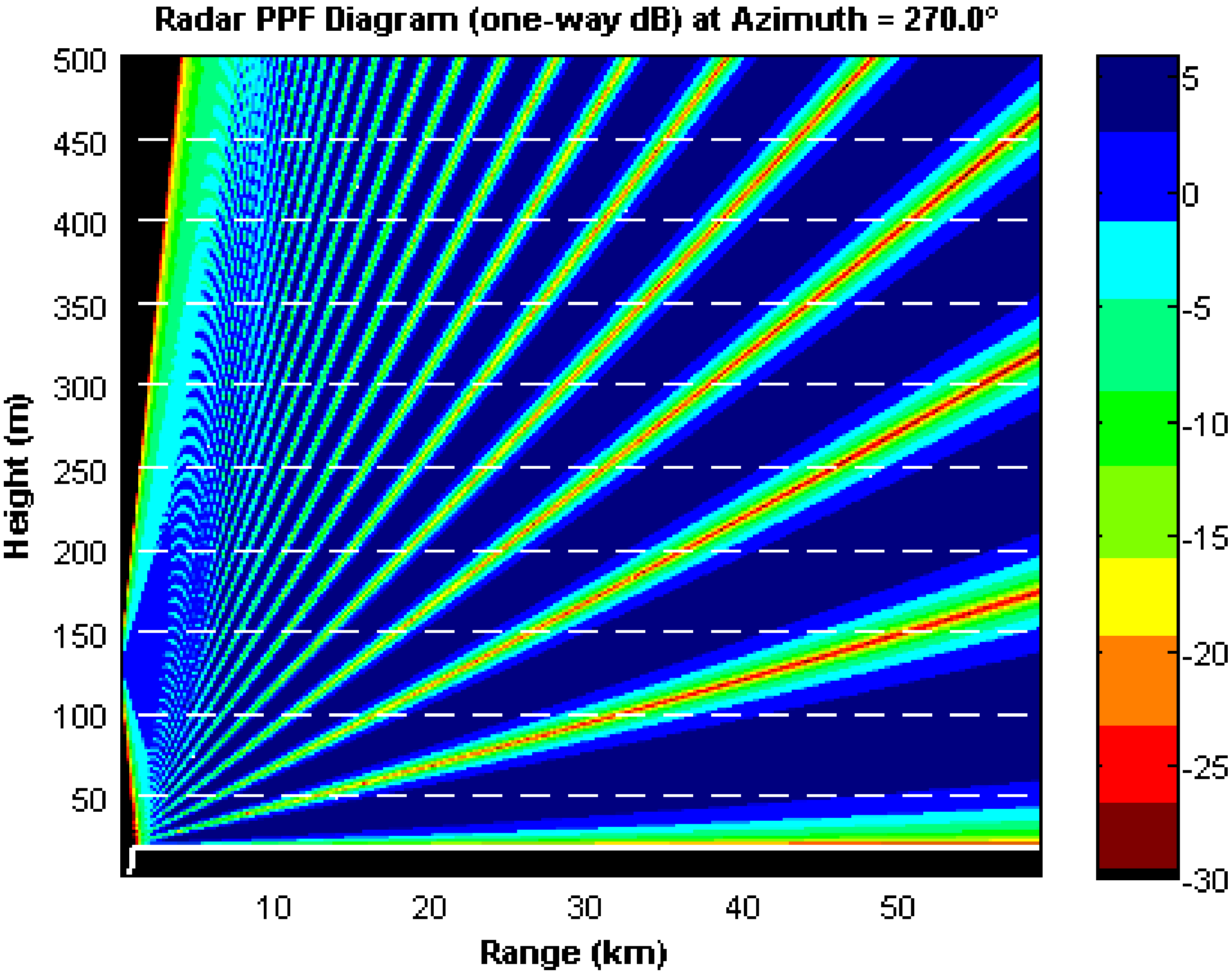
# Pierson Moscowitz Sea Surface Spectrum Model converted to a range profile



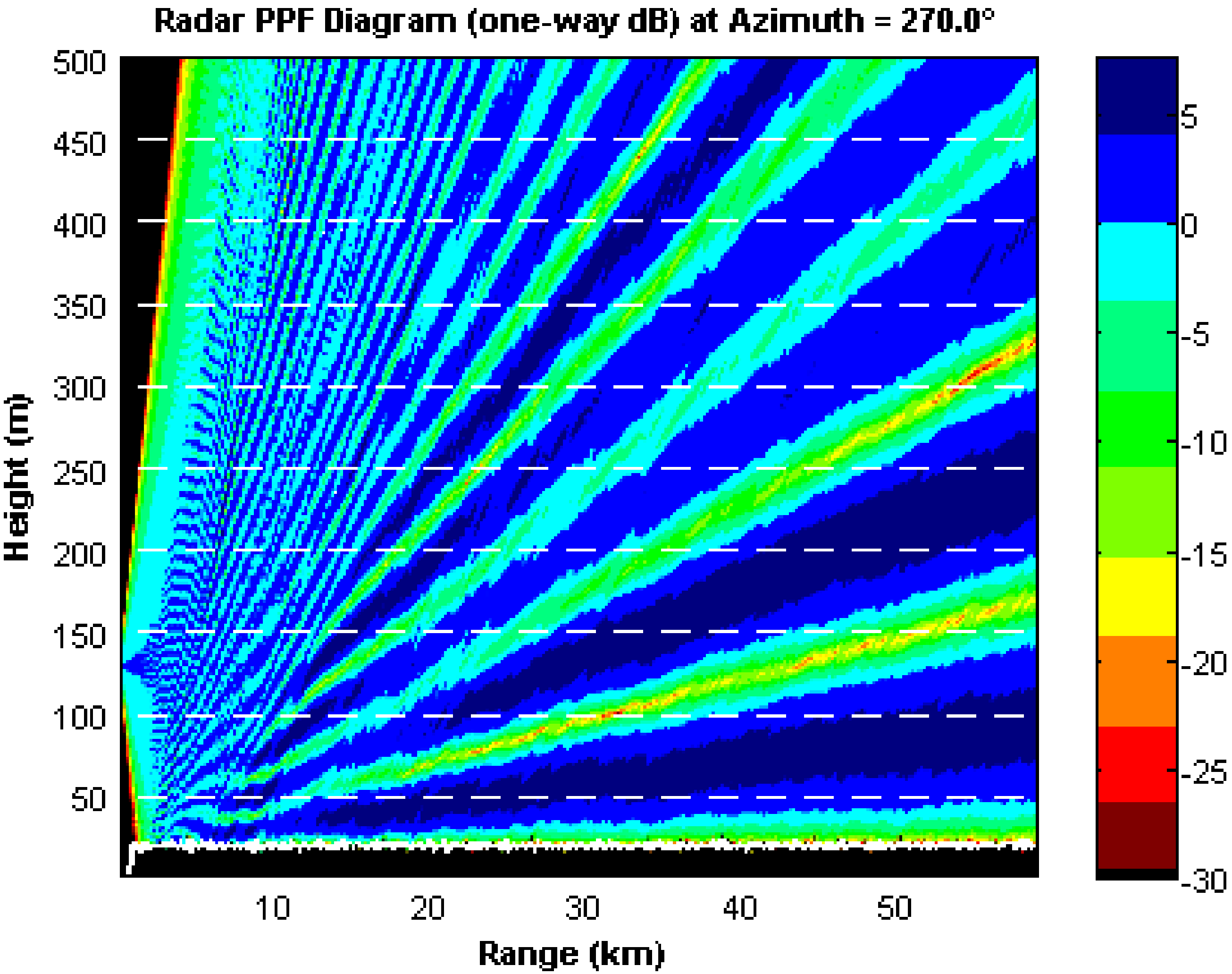

$$f \rightarrow k \rightarrow \text{IFFT} \rightarrow$$



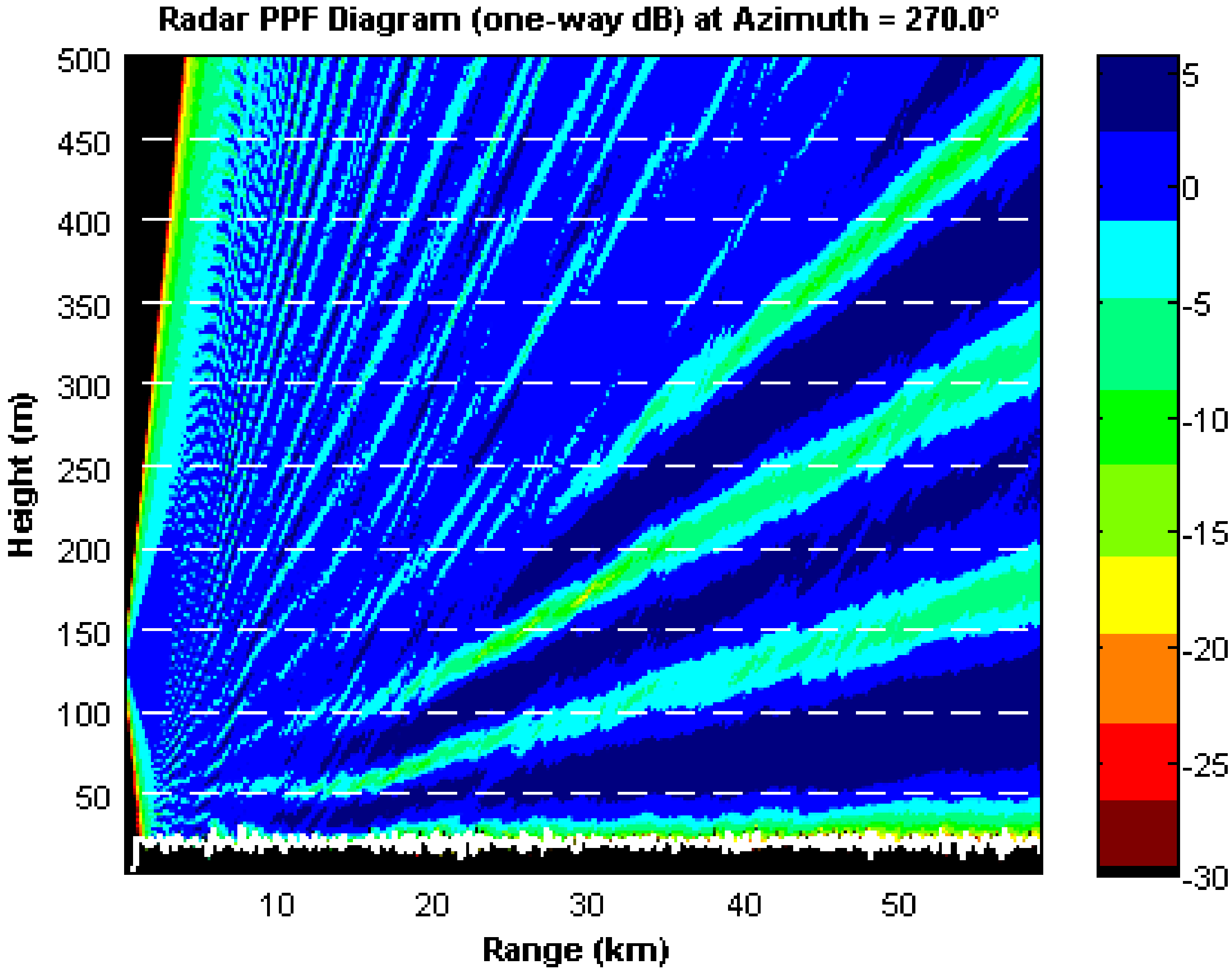
# Advanced Propagation Model Sea State 0



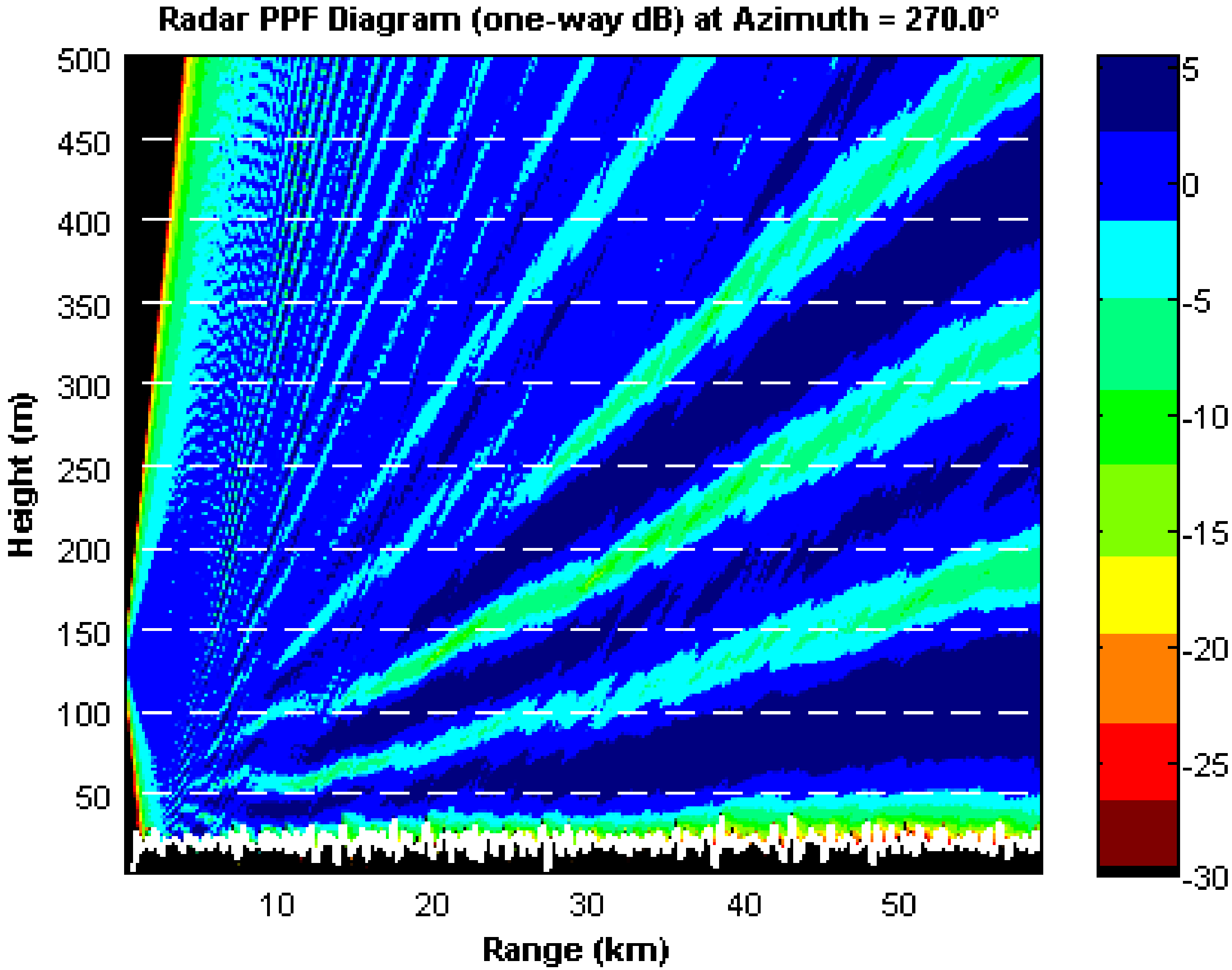
# Advanced Propagation Model Sea State 3



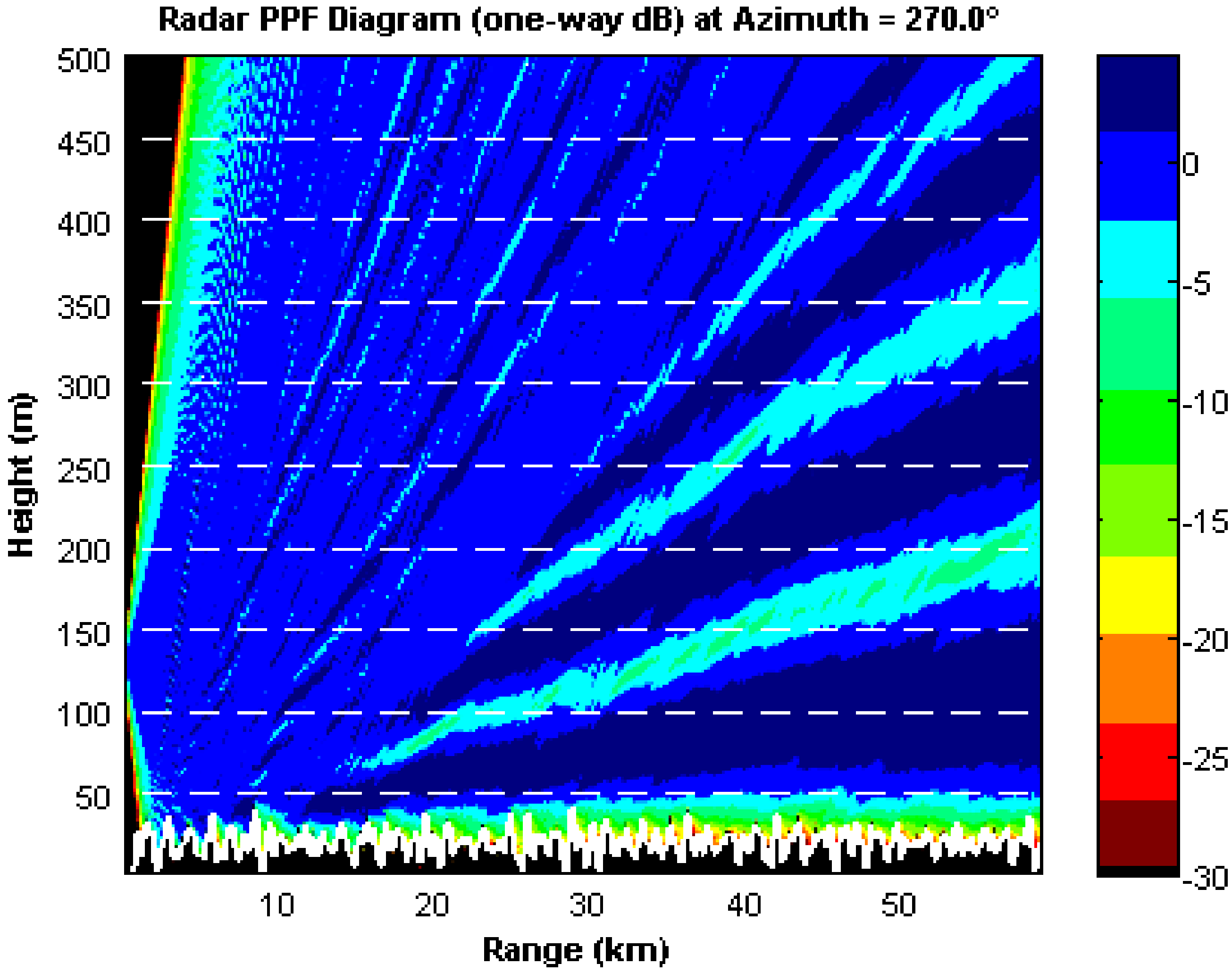
# Advanced Propagation Model Sea State 4



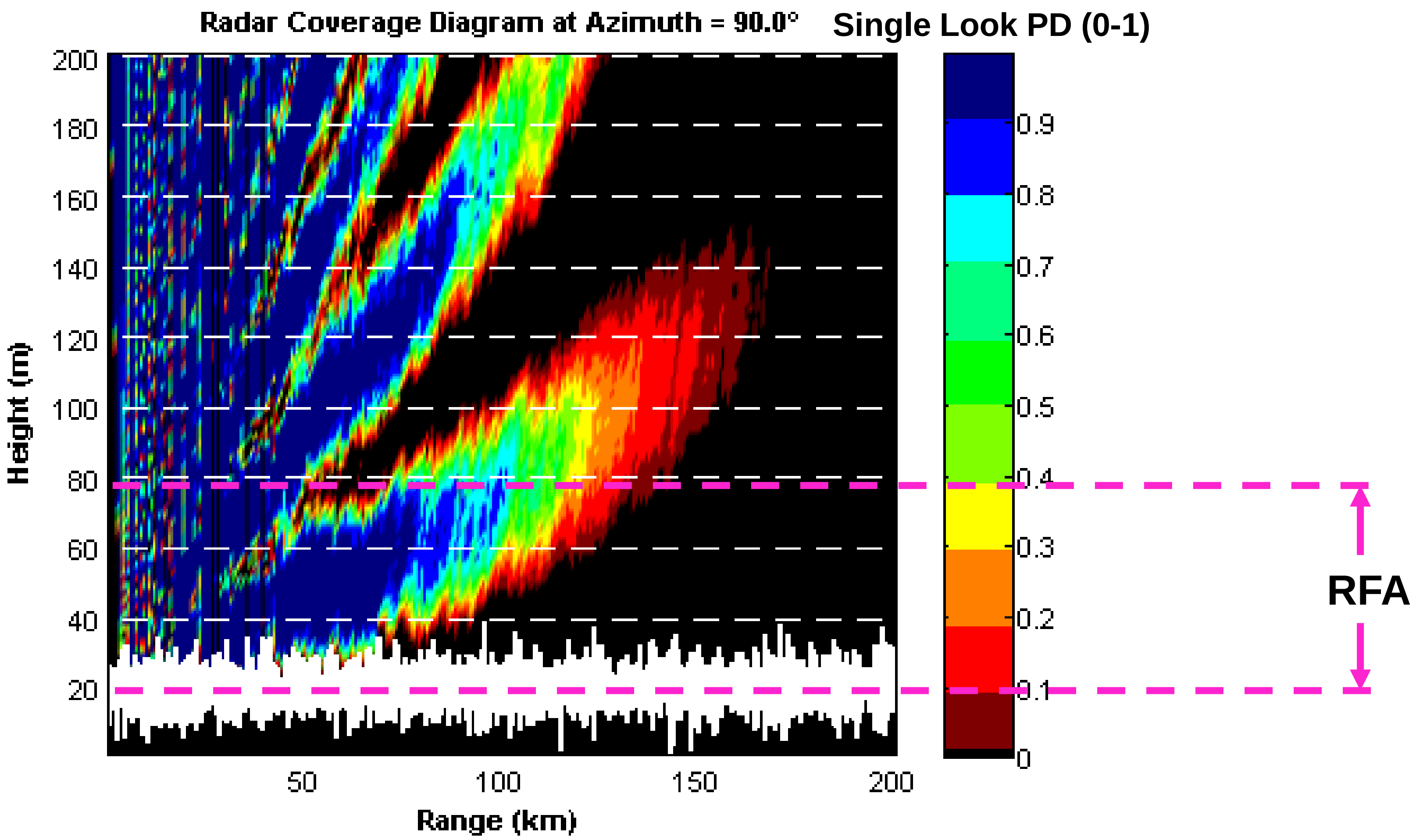
# Advanced Propagation Model Sea State 5



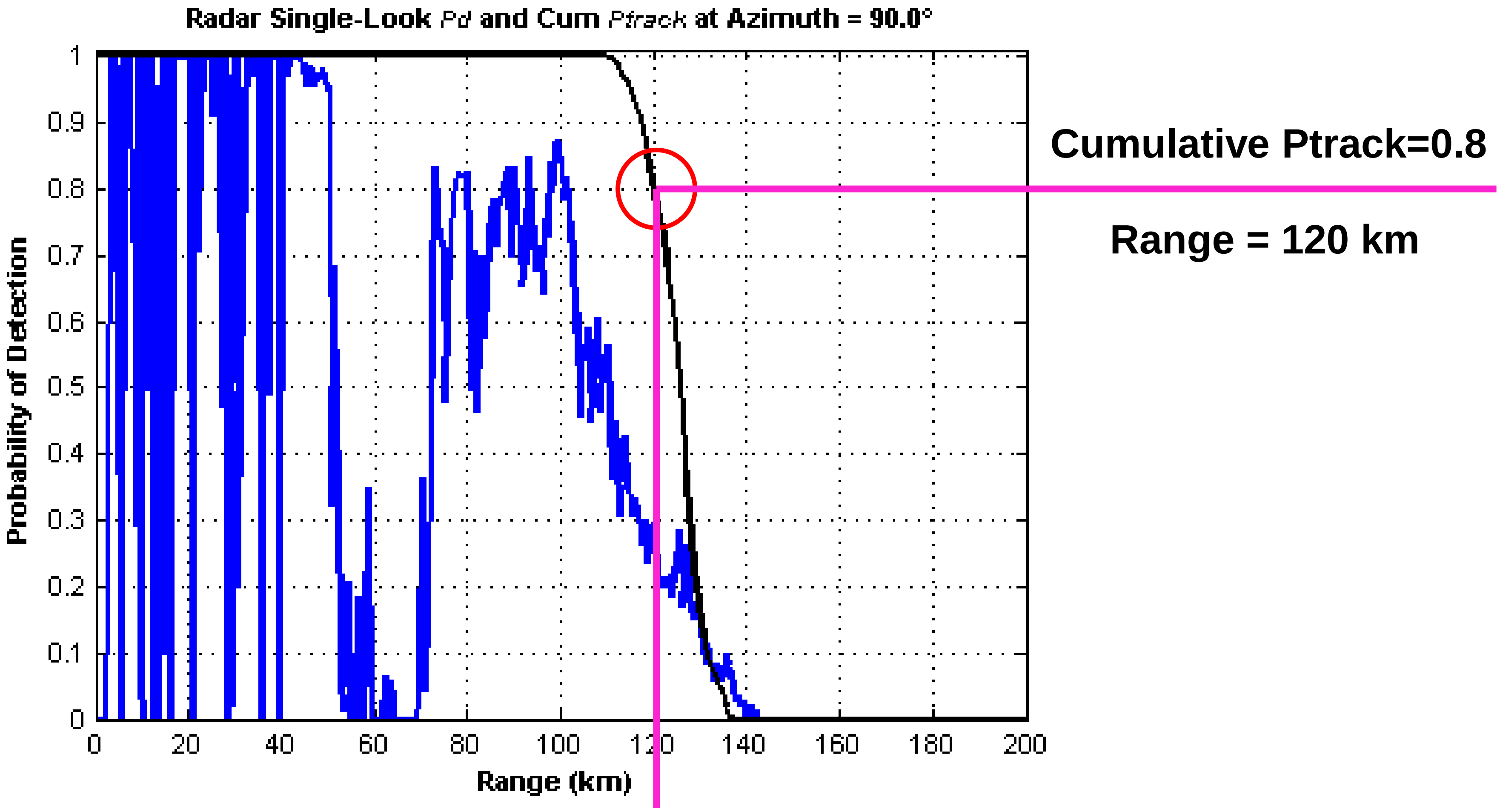
# Advanced Propagation Model Sea State 6



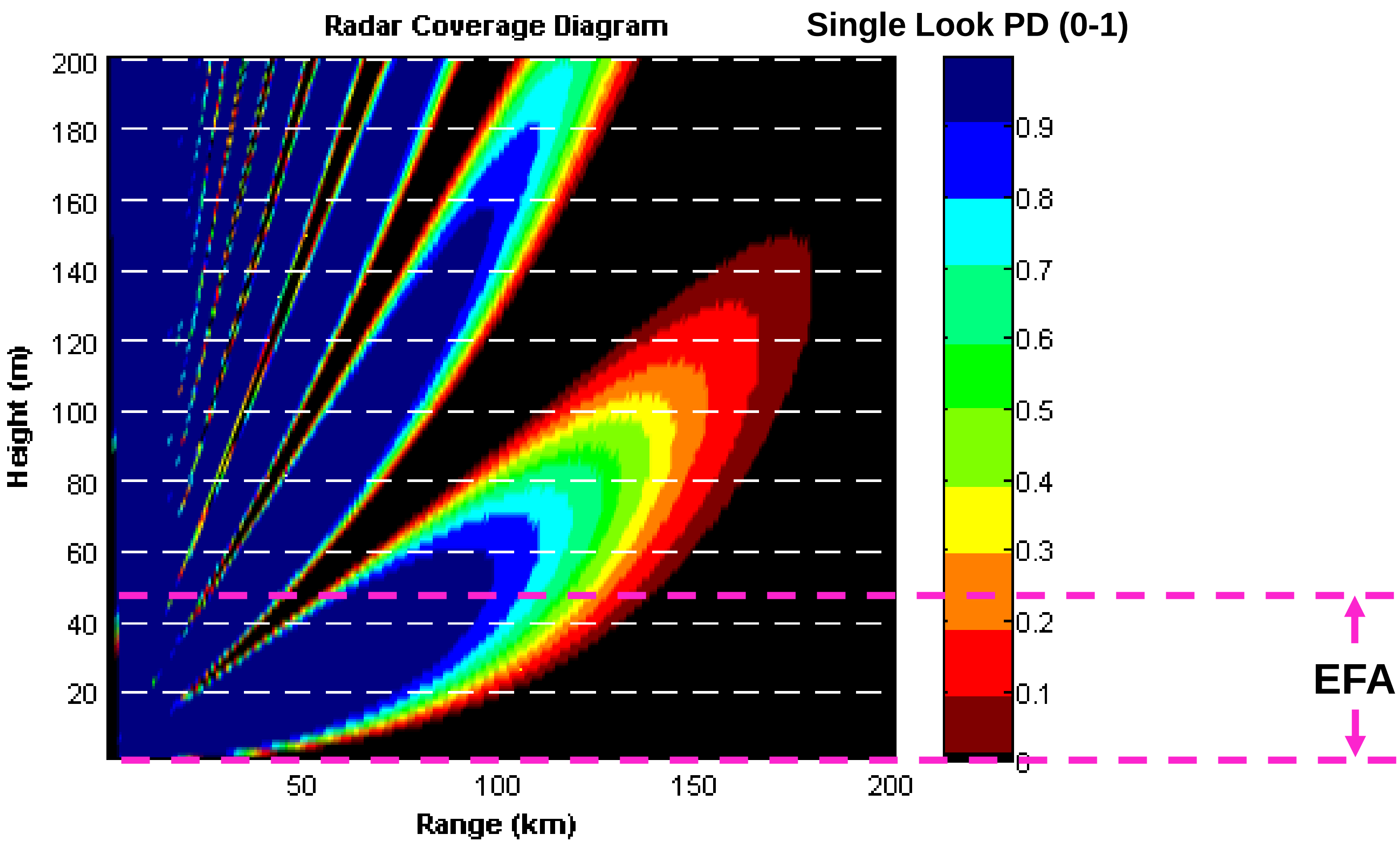
# The radar power is adjusted so target detection takes place at a chosen range for a given Real Flight Altitude (RFA).



# 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.



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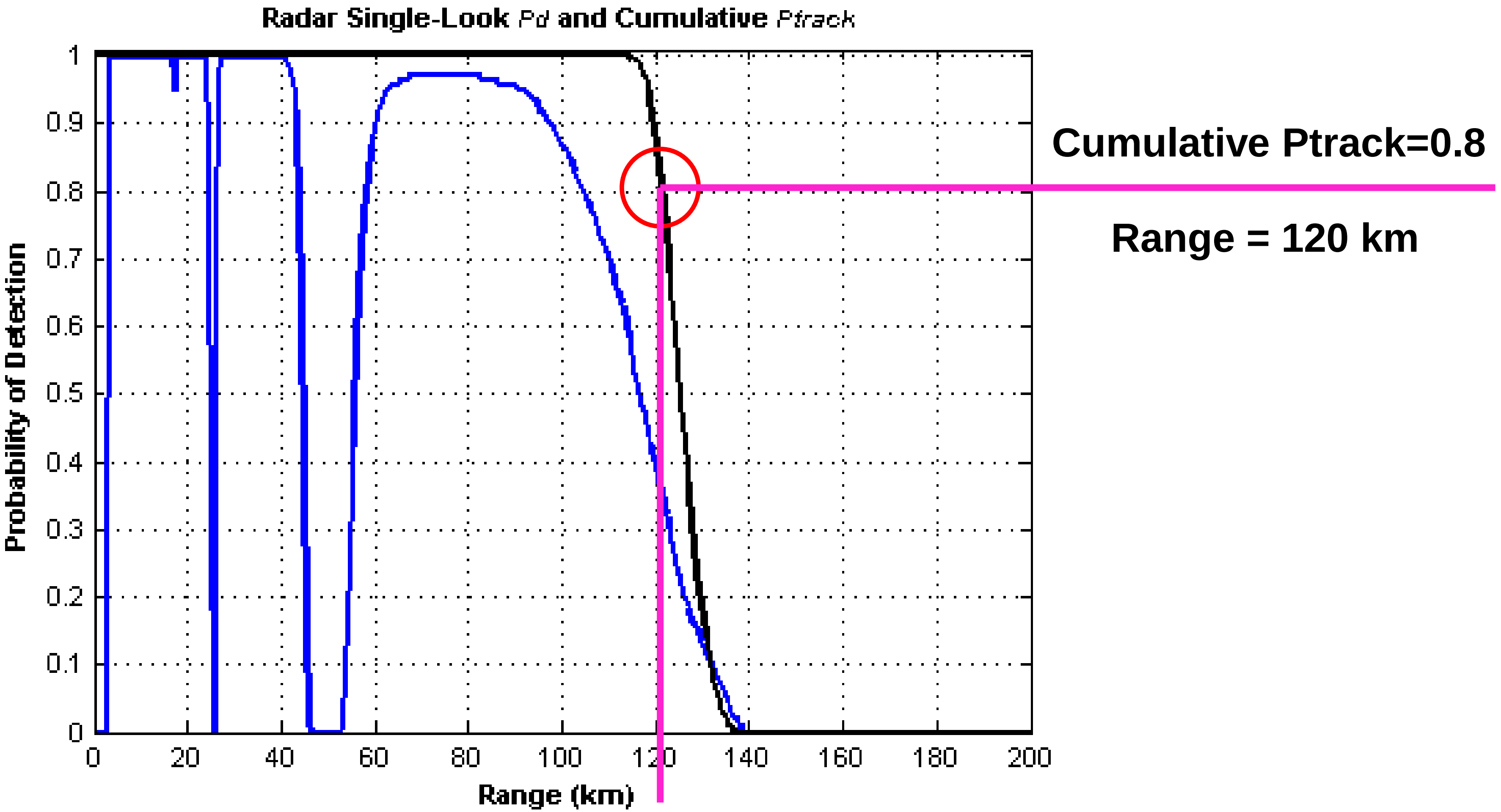
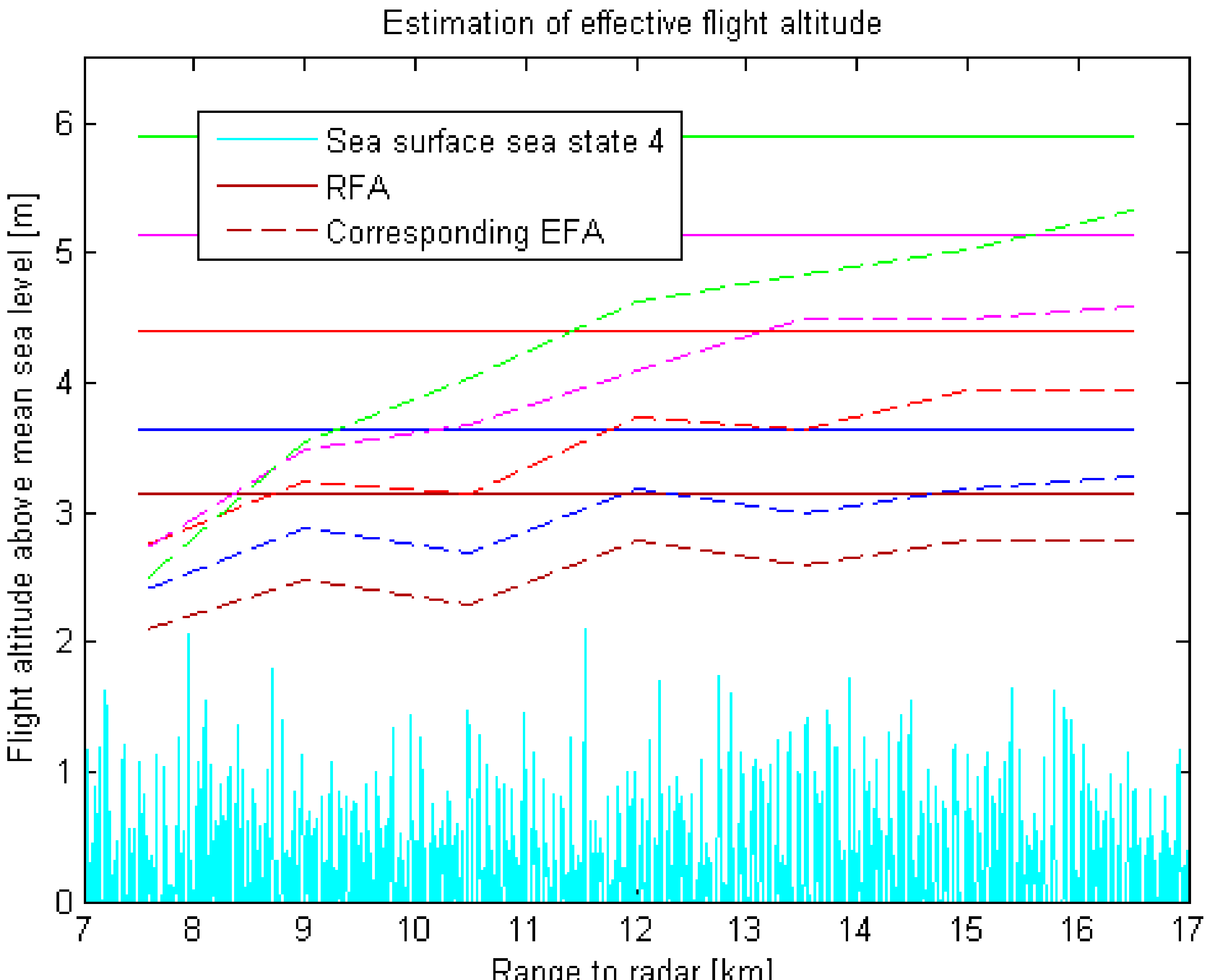
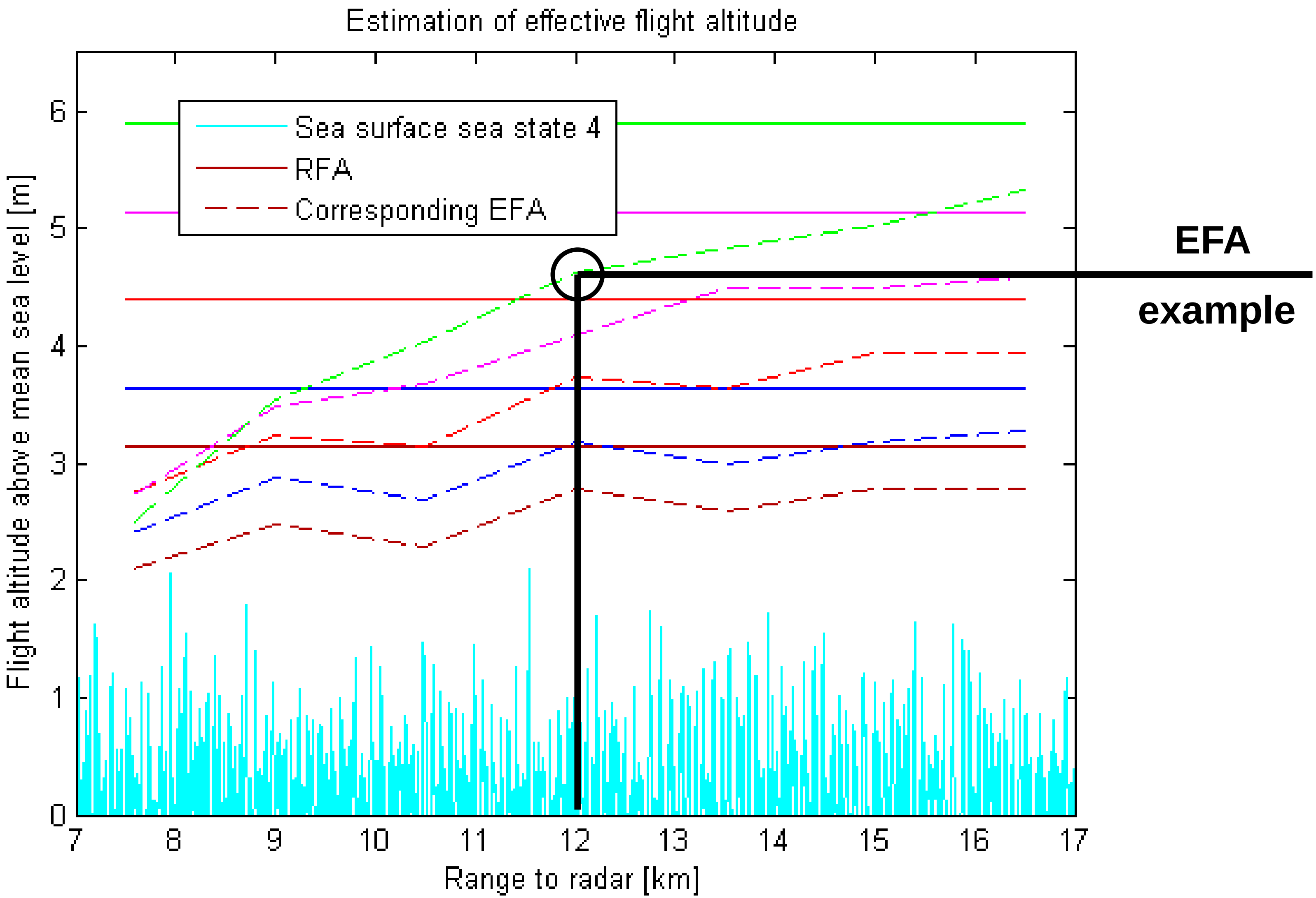


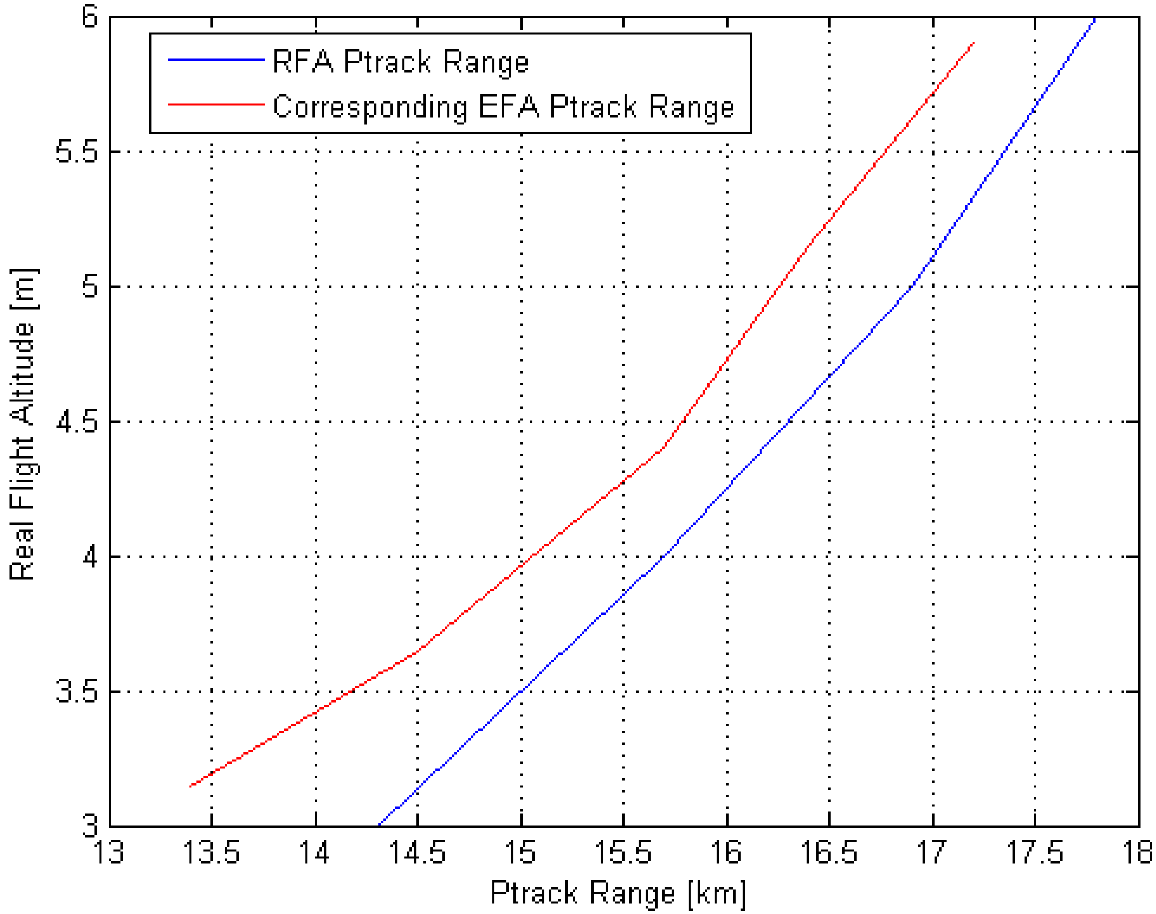
# A parametric presentation of EFA and generic low RFA versus range to radar for sea state 4



# 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 math 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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