Novel Target Detection Enhancement Algorithms in HF Surface Wave Radar

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Outline

1. Introduction
2. Clutter Suppression by Clutter Canceller BF
3. Novel Correlation Detector
4. Conclusion

Outline

Shipborne HF SWR

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- ➢ Norton surface wave propagation
- ➢ Range of up to 200 km over conducting sea water
- ➢ Motivation : Cheap ocean surveillance
  - ✓ Control trafficking
  - ✓ Exclusive Economic Surveillance
  - ✓ Tracking pirates
- \- External noise (Sea Clutter) limited
- ✓ New target detection enhancement
  - ✓ Clutter Reduction
  - ✓ Better Detection

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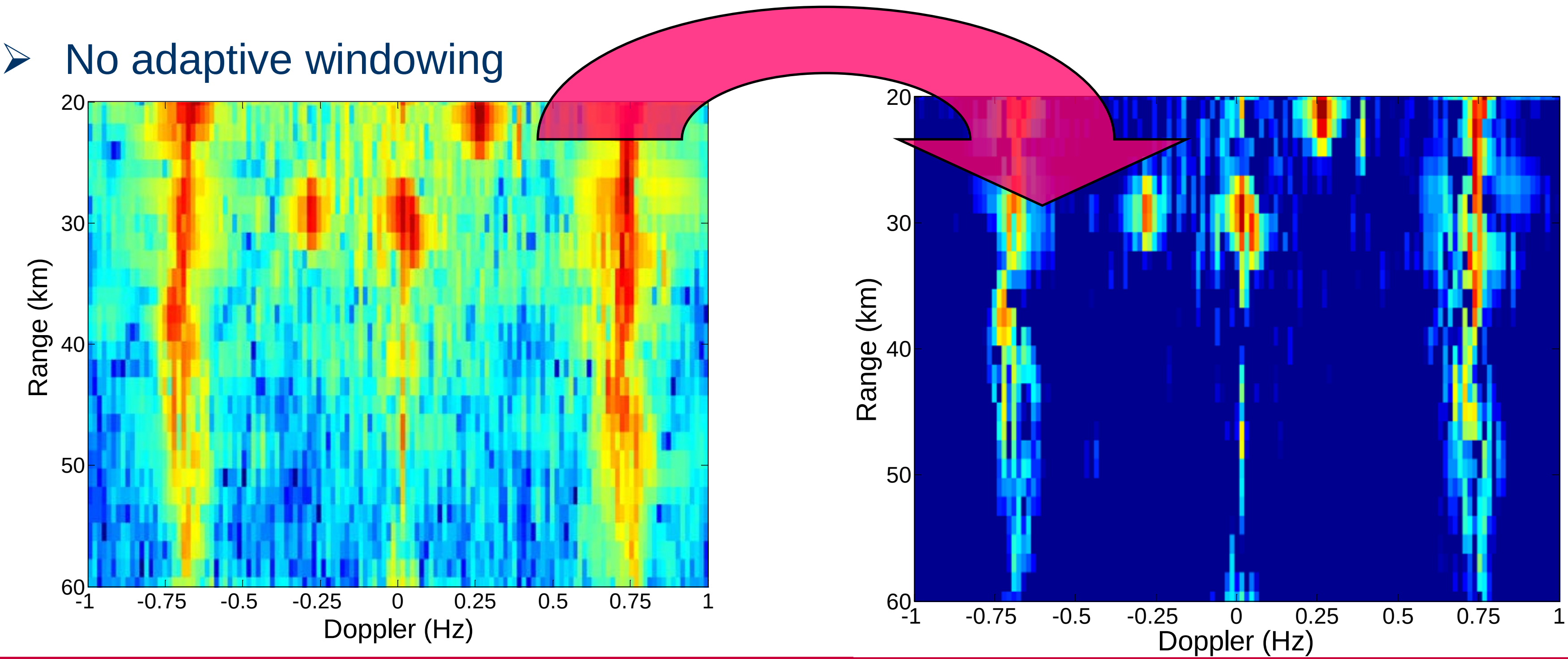
Clutter Canceller BeamFormer (BF)

- Clutter estimation by an auxiliary beam
- Coherent clutter reduction
- Non linear target power amplifier
- No adaptive windowing



Design of Clutter Canceller BF

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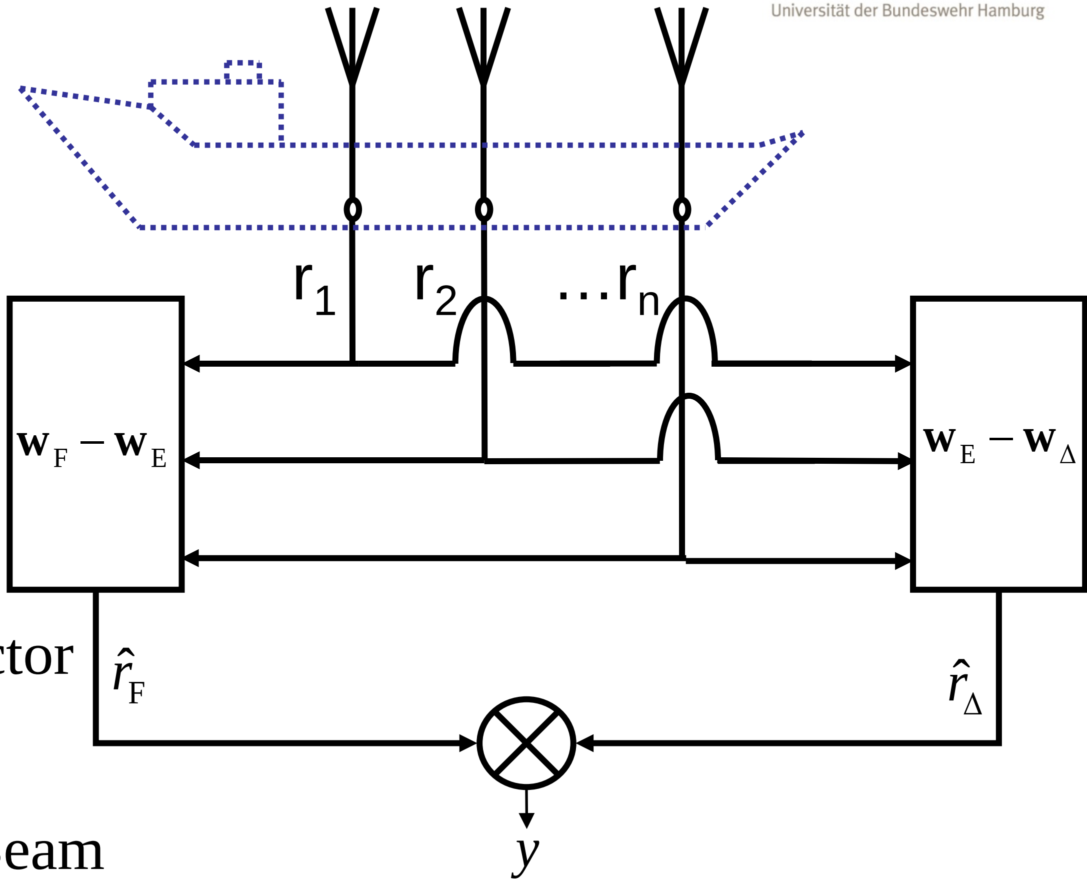
$$\mathbf{r} = [r(1), r(2).....r(n)]^{\mathrm{T}}$$

$$r_{\mathrm{F}} = \mathbf{w}_{\mathrm{F}}^{\mathrm{H}}\mathbf{r}$$

$$r_{\Delta} = \mathbf{w}_{\Delta}^{\mathrm{H}}\mathbf{r}$$

$$r_{\mathrm{E}} = \mathbf{w}_{\mathrm{E}}^{\mathrm{H}}\mathbf{r}$$



$\mathbf{r}$ = elemental measurement vector

r_F = output of the Flat Beam

r_{Δ} = output of the Difference Beam

r_E = output of the Estimator Beam

Design of Clutter Canceller BF

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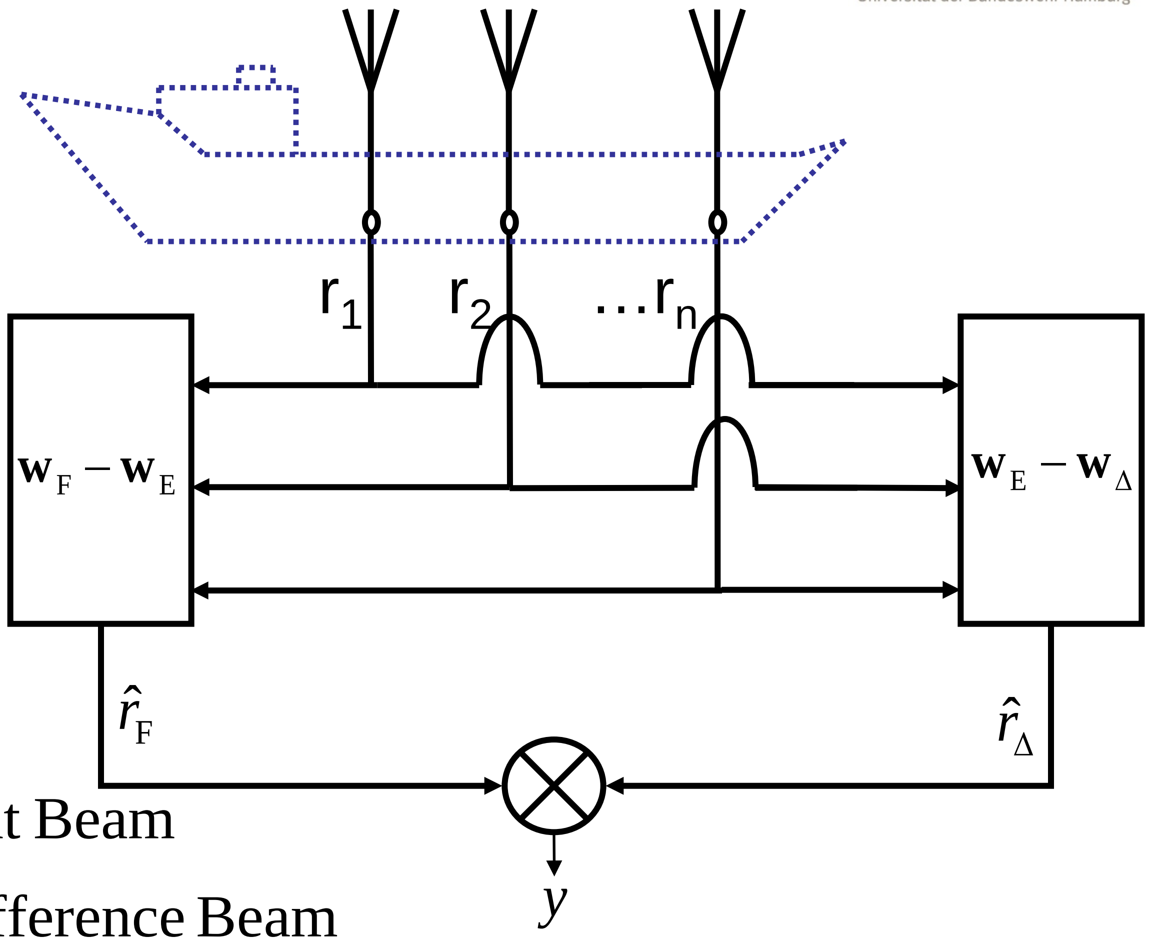
$$\hat{r}_F = (\mathbf{w}_F^T - \mathbf{w}_E^T)\,\mathbf{r}$$

$$\hat{r}_\Delta = (\mathbf{w}_E^T - \mathbf{w}_\Delta^T)\,\mathbf{r}$$

$$y = \hat{r}_F \hat{r}_\Delta$$

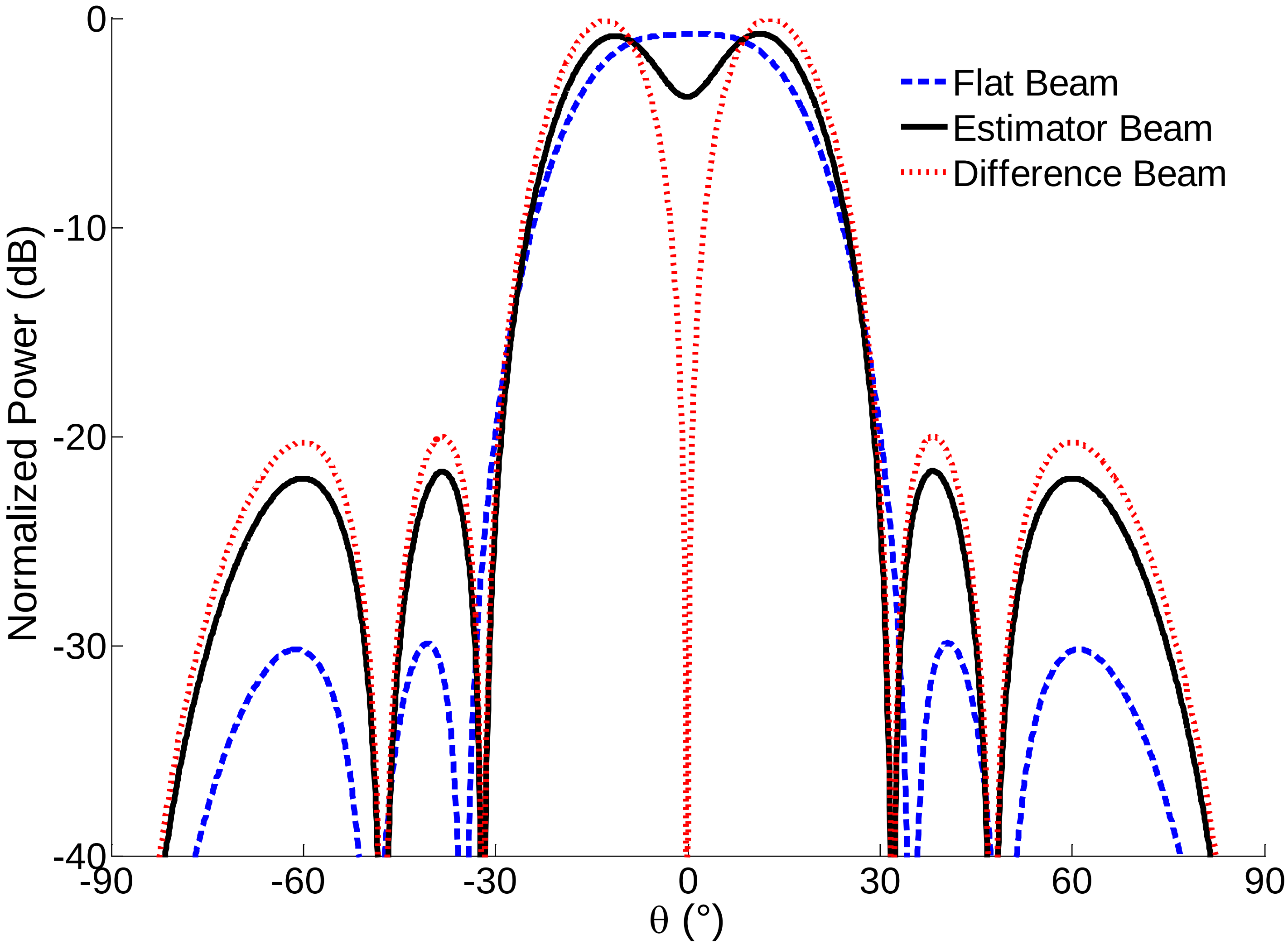


$\hat{r}_F$ = output of estimated Flat Beam

$\hat{r}_\Delta$ = output of estimated Difference Beam

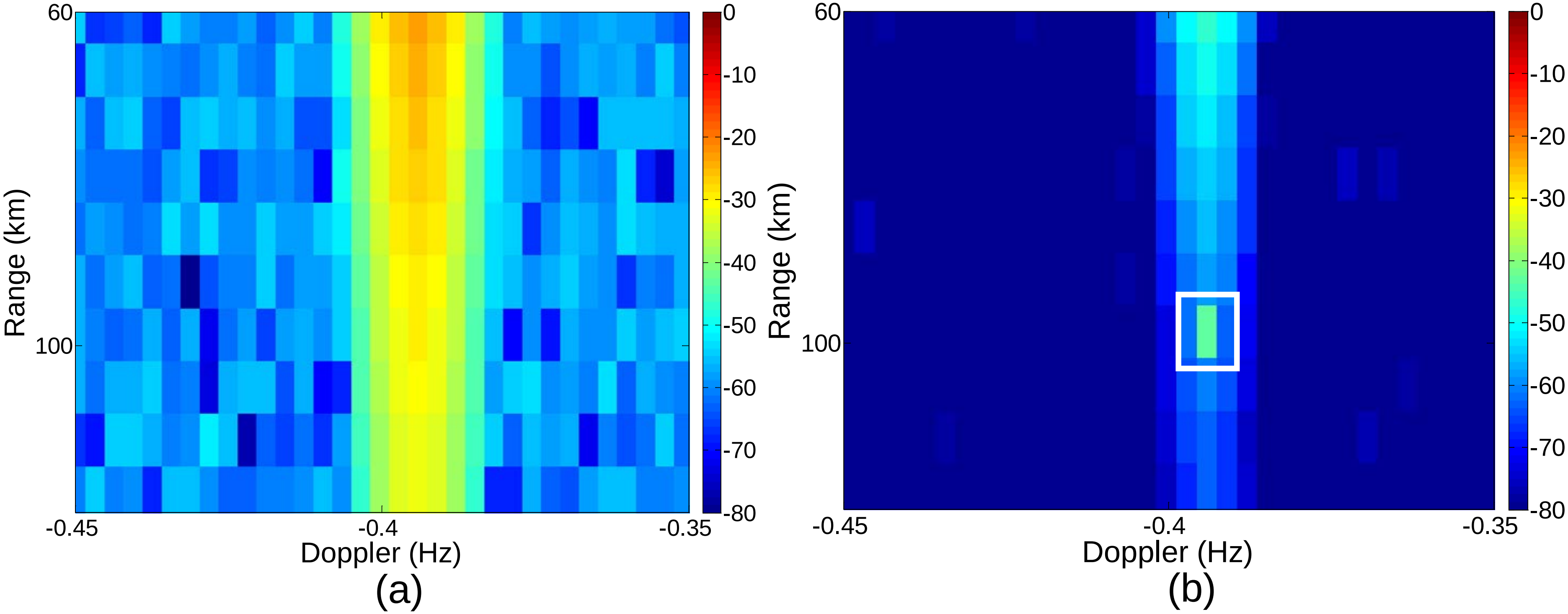
y = beamformer output

Beam Pattern



Power pattern of the Flat Beam (FB), Difference Beam (DB) and Estimator Beam (EB) for a 7 element array with inter element distance = 0.5λ

Suppression by Clutter Canceller BF



RD map (dB) for look angle = 0° (boresight). Target azimuth= 0°, Target RCS=32 dBsm, velocity= 7.9 m/s, range= 100 km; (a)16 element Chebyshev beamformer (b) 7 element sea clutter canceller.

Advantages of Clutter Canceller BF

- Effective increase in SCR
- Better azimuth resolution
- Target amplification within first order Bragg possible
- Applicable to shipborne & land based system

Outline

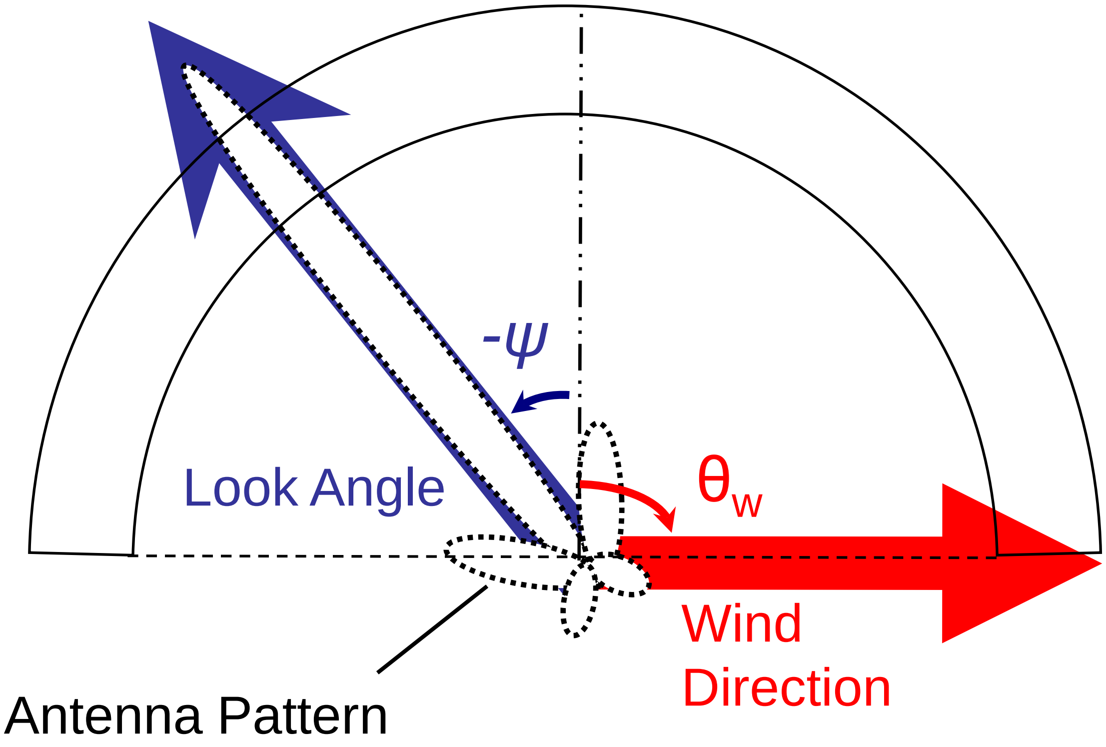
Why new detector ?

- Non specialized state of the art detection scheme
  - Statistical clutter power estimation
  - Black box clutter model
  - No a priori knowledge of clutter characteristics

- Oceanographic knowledge can help develop efficient detection scheme

Directional Spectrum of Sea Clutter

Broad beam sea clutter RCS is the convolution of narrow beam sea clutter RCS and antenna radiation pattern



Directional Spectrum of Sea Clutter

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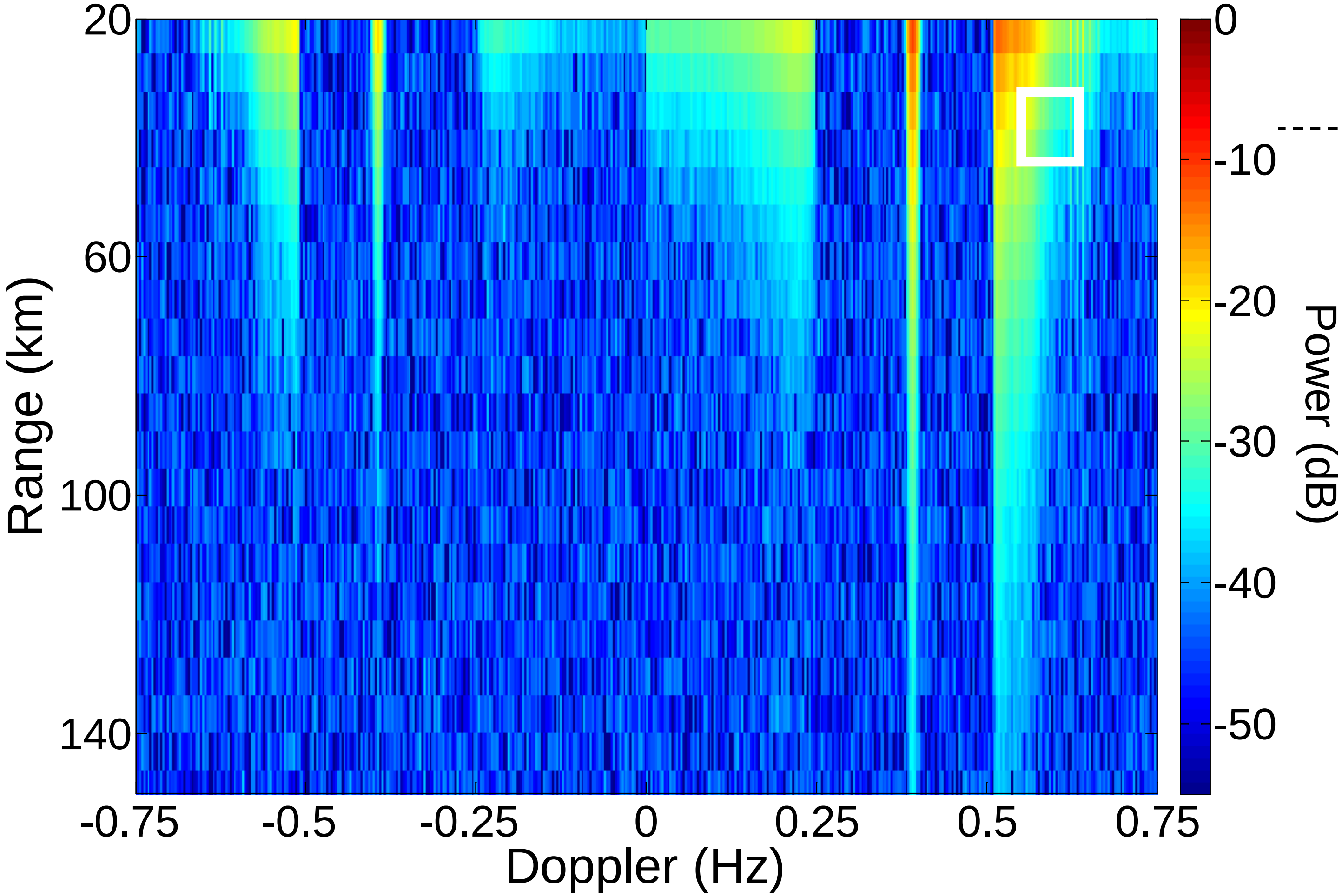
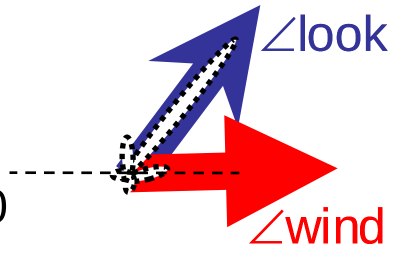
θ_w= 90 ; ψ = +30





Directional Spectrum of Sea Clutter

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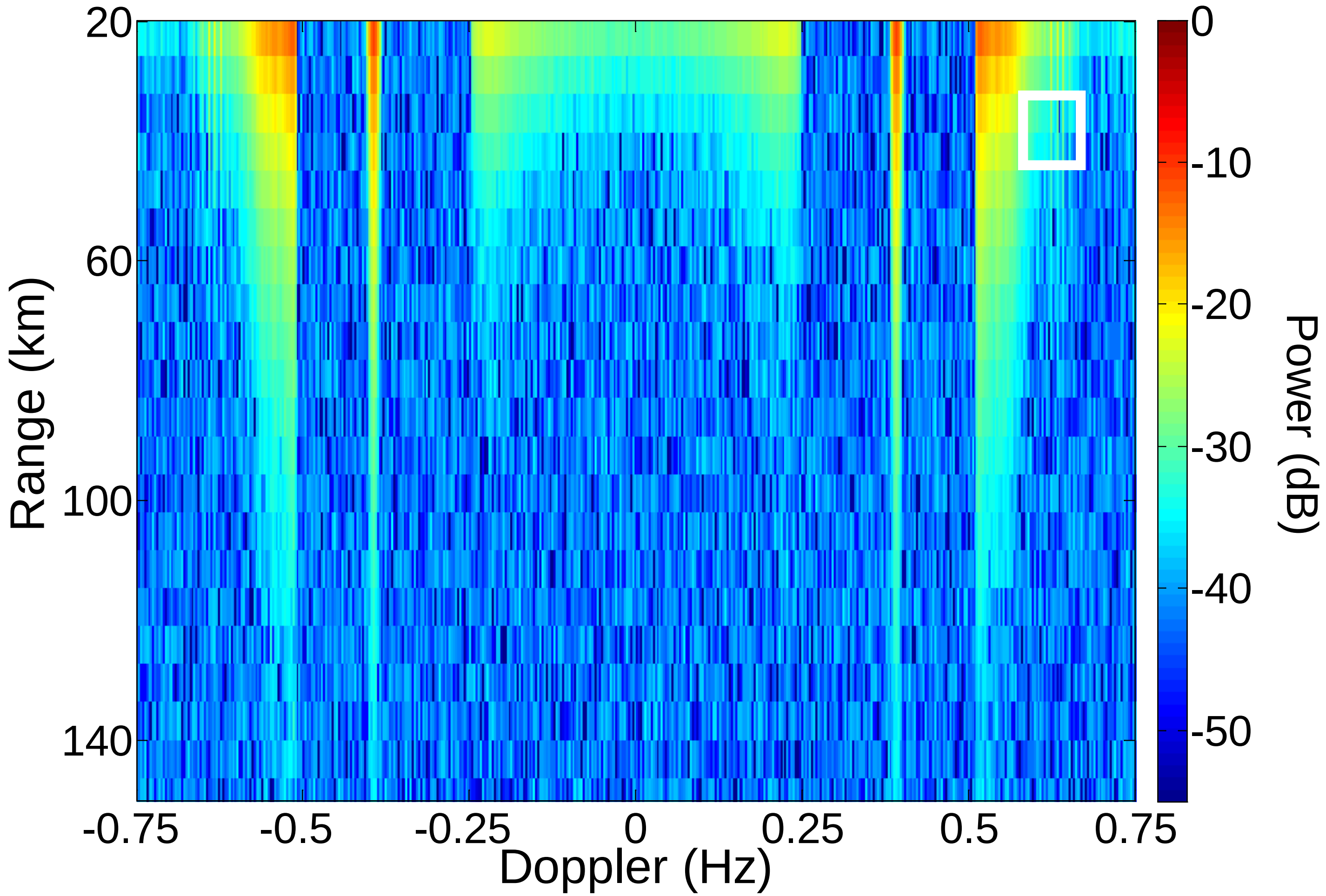
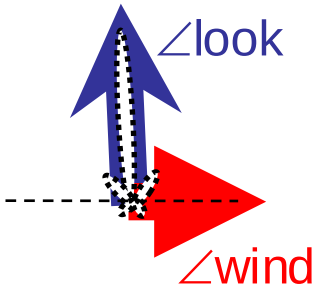
$\theta_w = 90$; $\psi = 0$





Directional Spectrum of Sea Clutter

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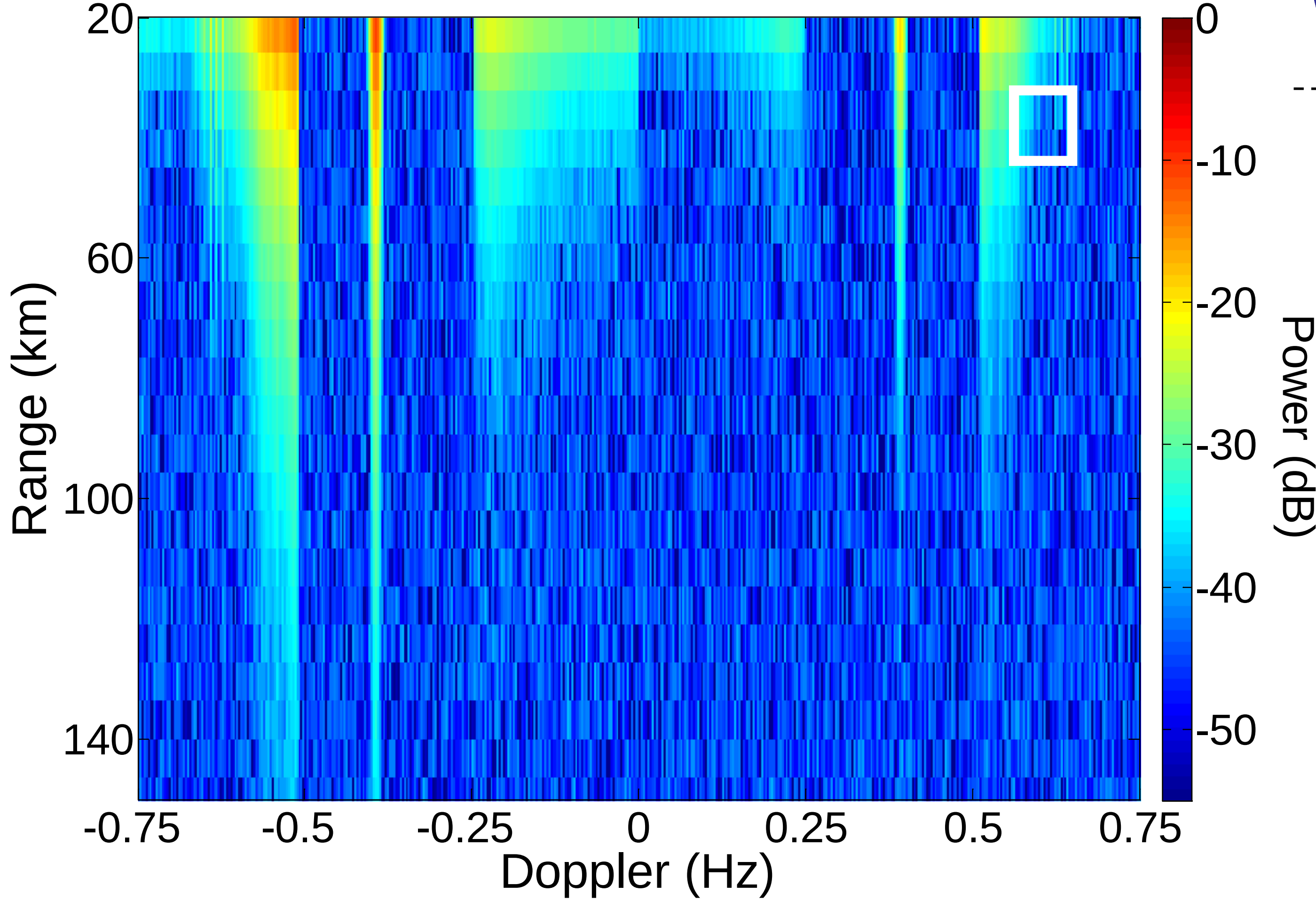
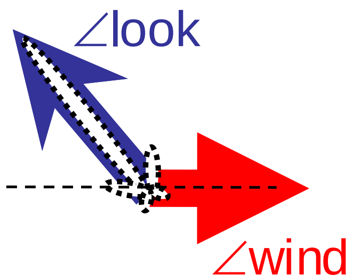
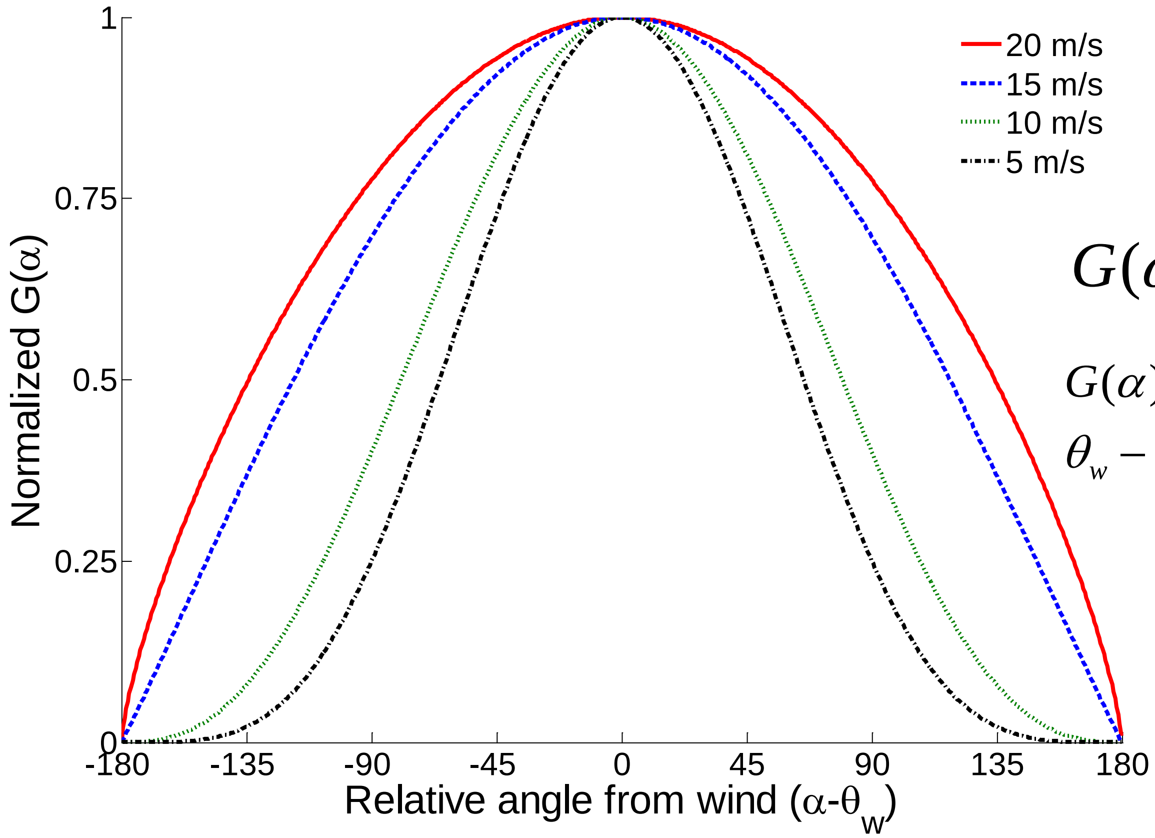
$\theta_w = 90$; $\psi = -30$





Directional Spread of Wave Energy



$$G(\alpha) = A\cos^{2S}\left(\frac{\alpha-\theta_w}{2}\right)$$

$G(\alpha)$ – Directional spread of wind enegy

θ_w – Direction of wind

Unimodal wave directional spectrum: normalized $G(\alpha)$ versus relative angle from wind for different wind speed.

Directional Spread of Wave Energy

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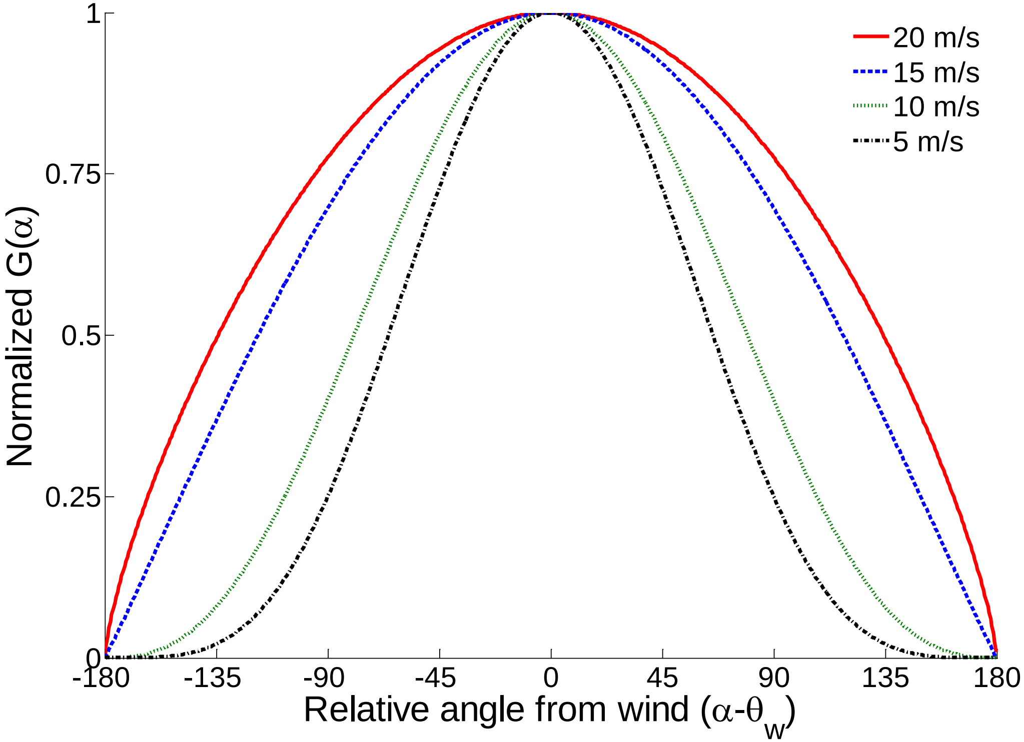


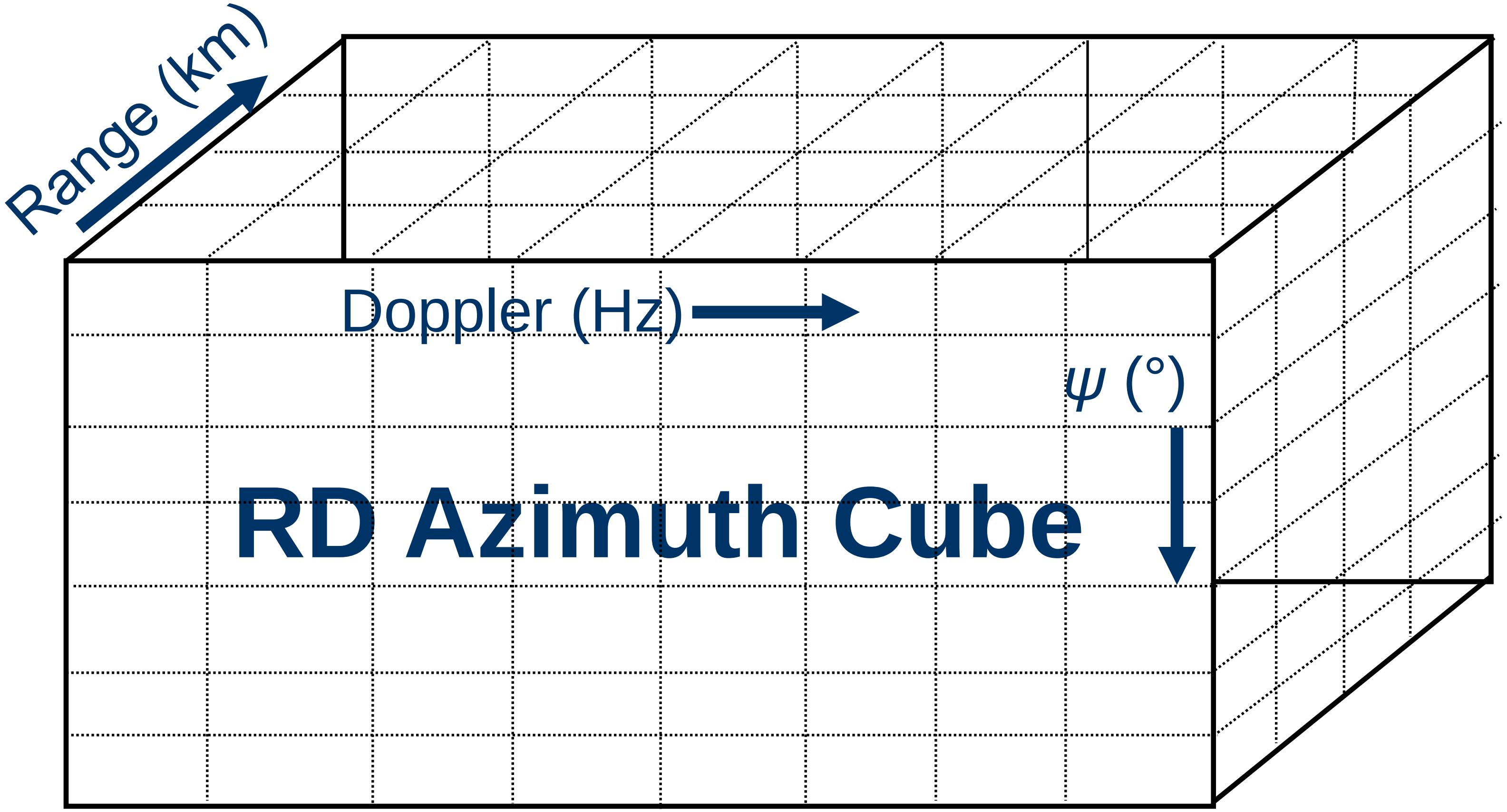
$$G(\alpha) = A\cos^{2S}\left(\frac{\alpha-\theta_w}{2}\right)$$

$G(\alpha)$ – Directional spread of wind enegy

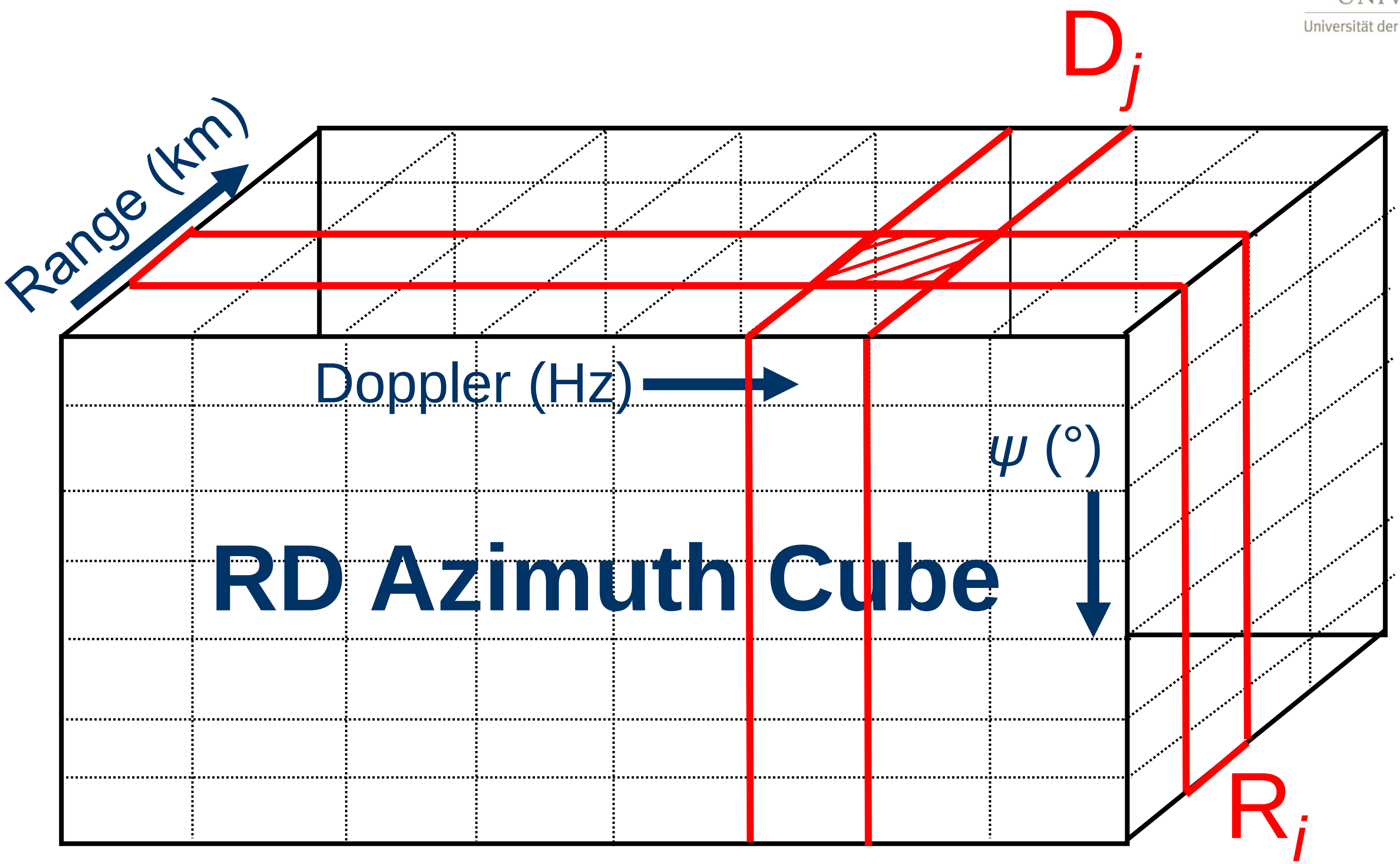
θ_w – Direction of wind

- ✓ Azimuth variation of clutter power Correlated along adjacent RD cells
- ✓ Correlation increases in presence of a target

RD Azimuth Cube

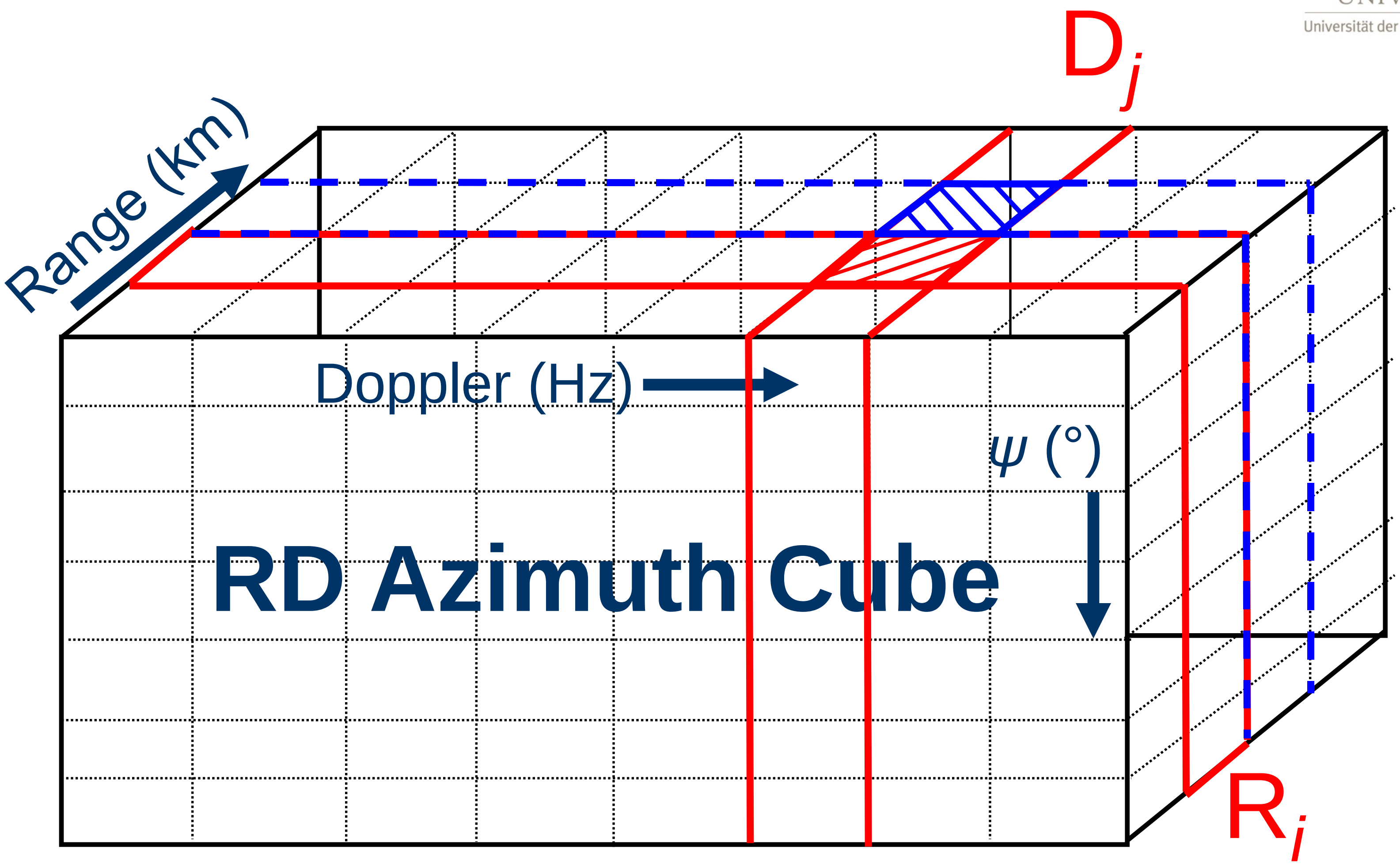


RD Azimuth Cube



$CUT = R_i D_j$

RD Azimuth Cube

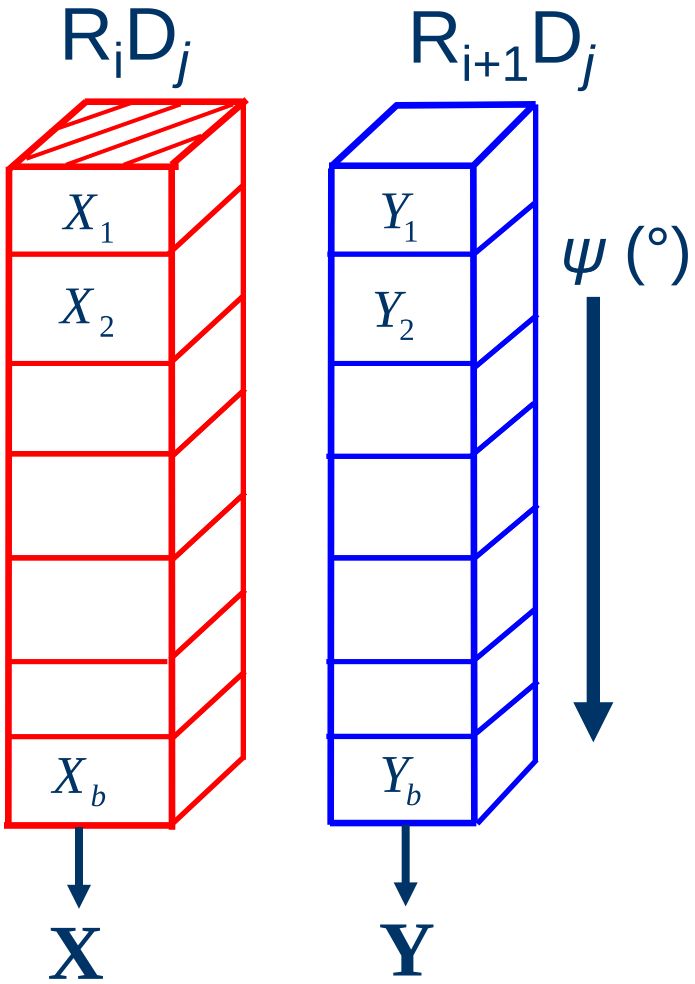


CUT= R_iD_j

Correlation calculation

$$r = \frac{\sum_{i=1}^{b}\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)}{\sqrt{\sum_{i=1}^{b}\left(X_i - \overline{X}\right)^2}\sqrt{\sum_{i=1}^{b}\left(Y_i - \overline{Y}\right)^2}}$$

$r \equiv$ Pearson Product Moment Correlation



CUT= R_iD_j

Block Diagram of Detector

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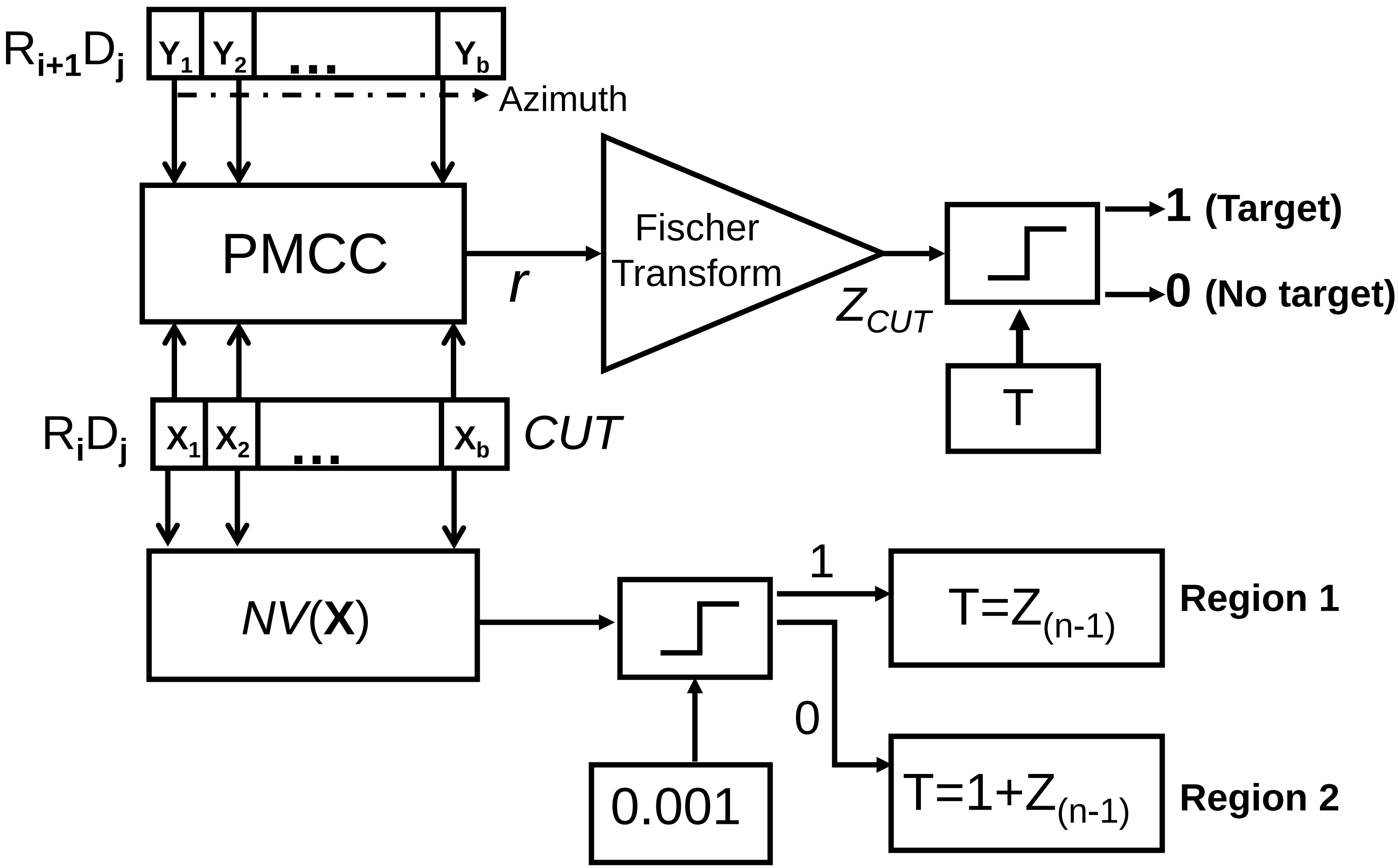
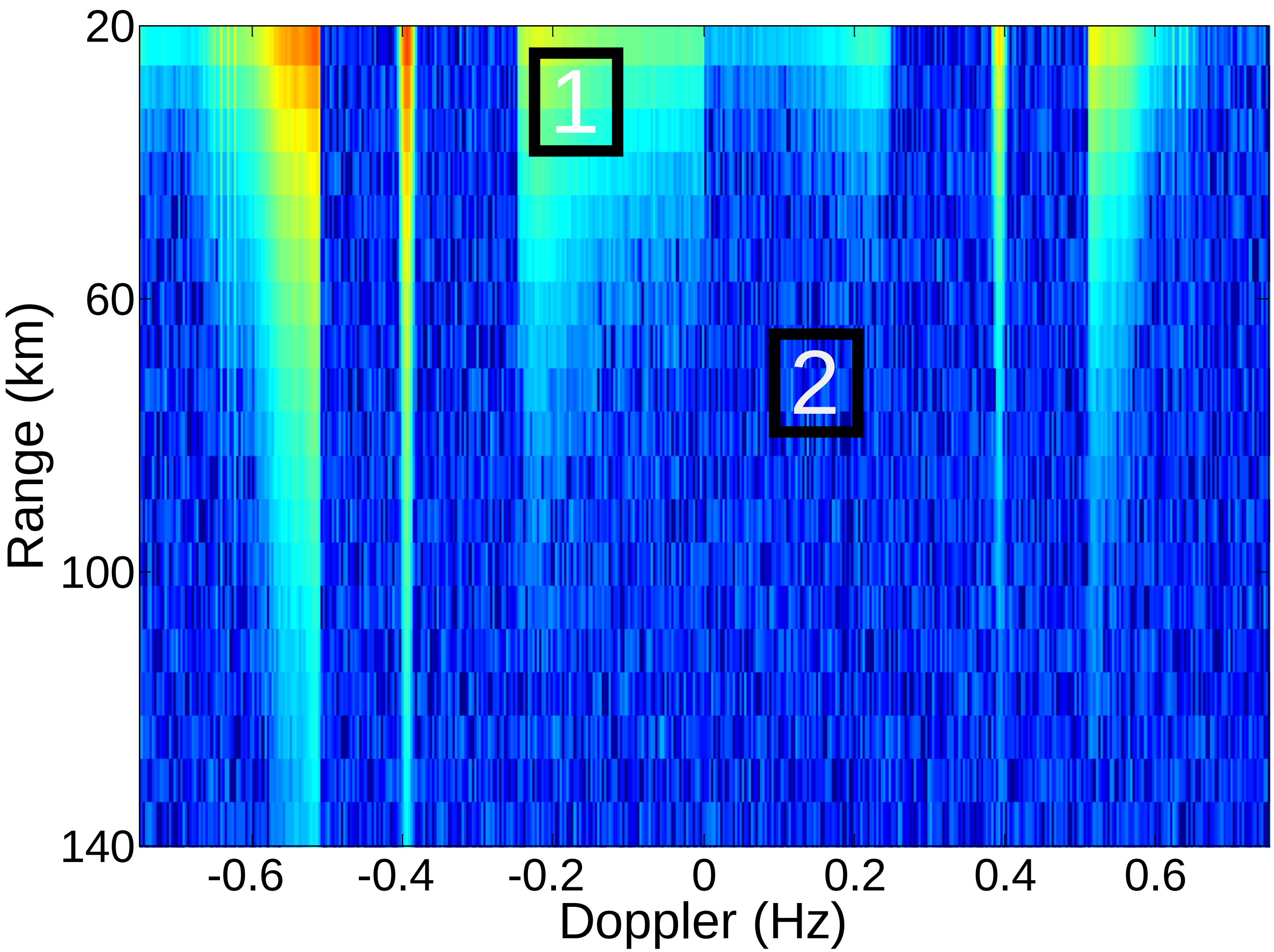
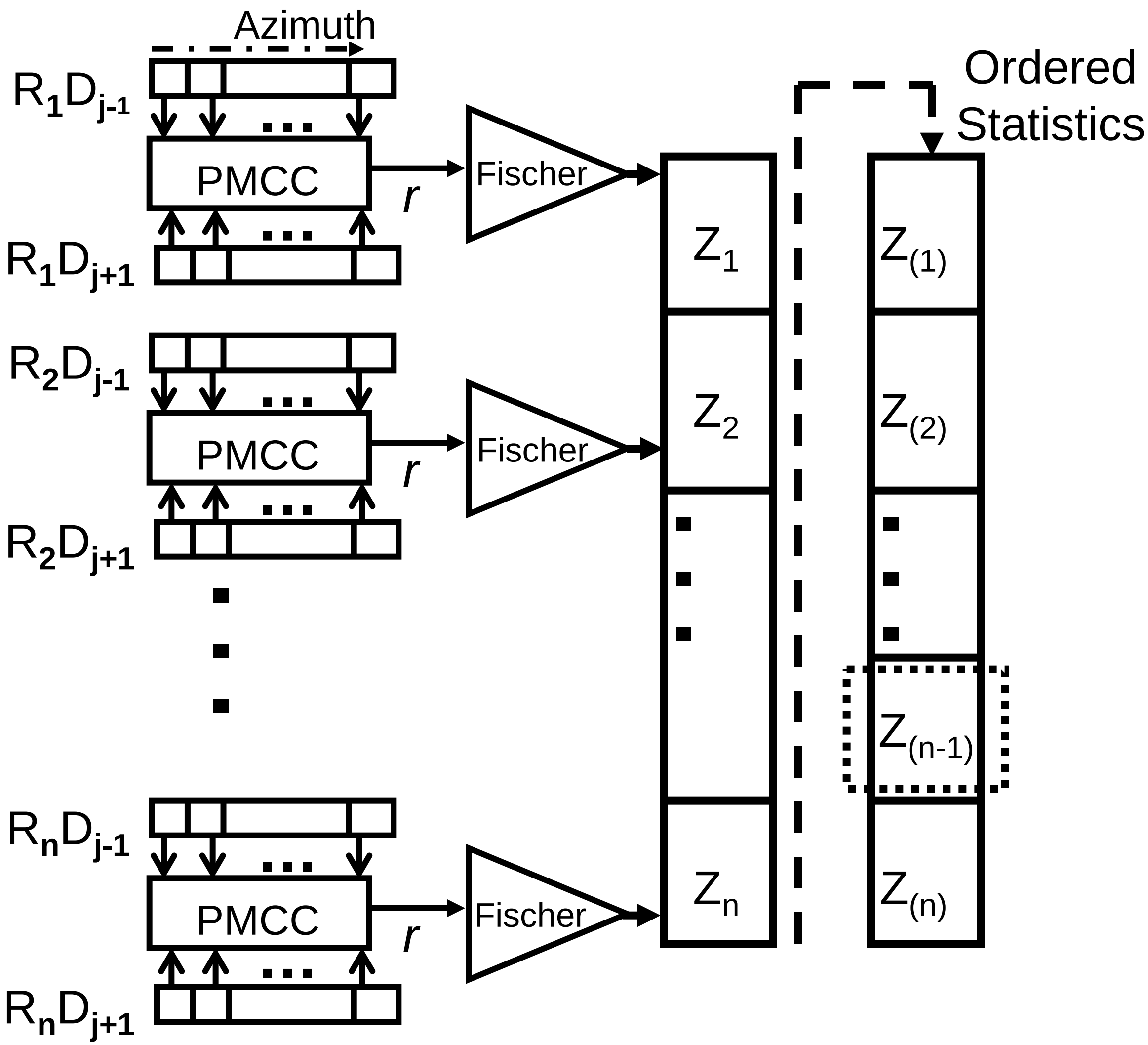


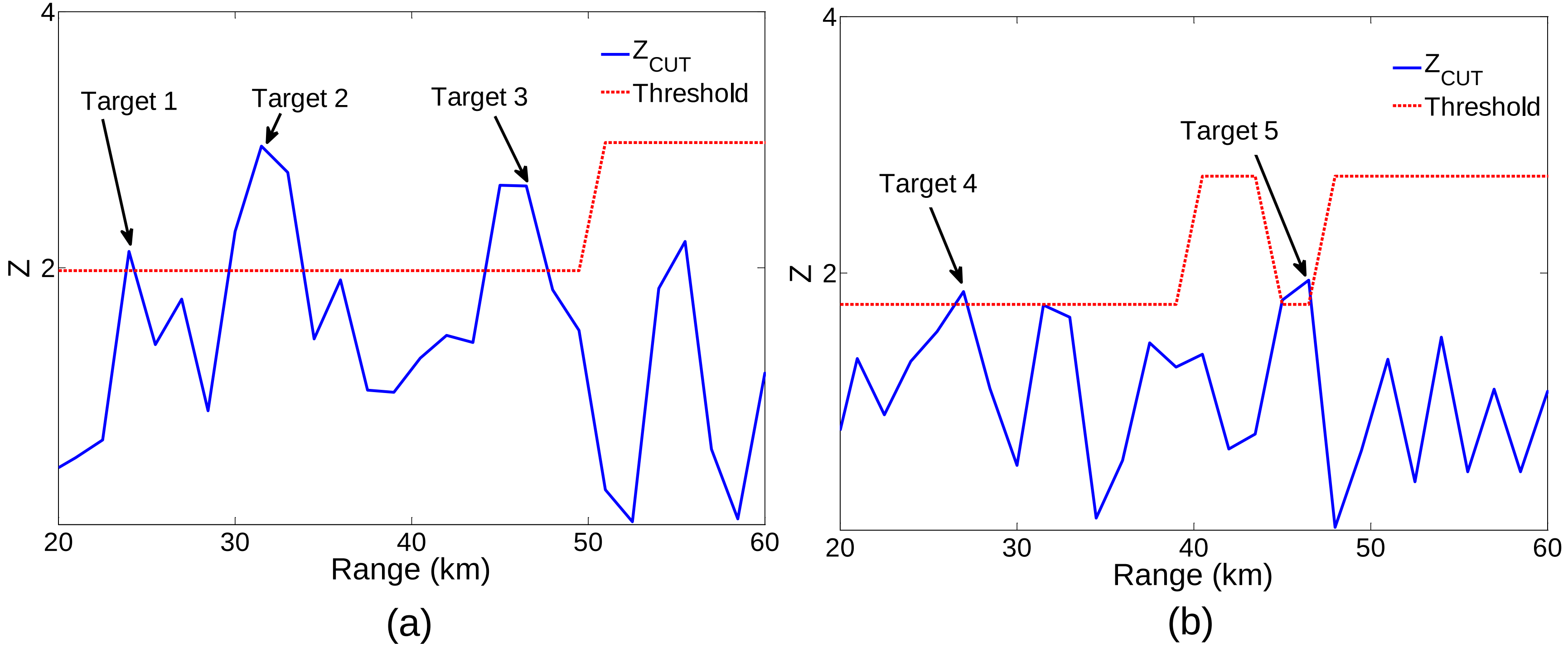
Adaptive Threshold Estimation



Adaptive Threshold Estimation



Target Detection within Bragg



Variation of Z_{CUT} across all range bins for (a) Negative Bragg line (b) Positive Bragg line.

Conclusion

- Coherent clutter reduction coupled with non linear gain
- Oceanographic model based detection
- Target detection within Bragg line possible !!
- Target detection at clutter edges possible


Thank You!