The importance of the local interference environment in the frequency selection algorithm in the HF band

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FOI in brief

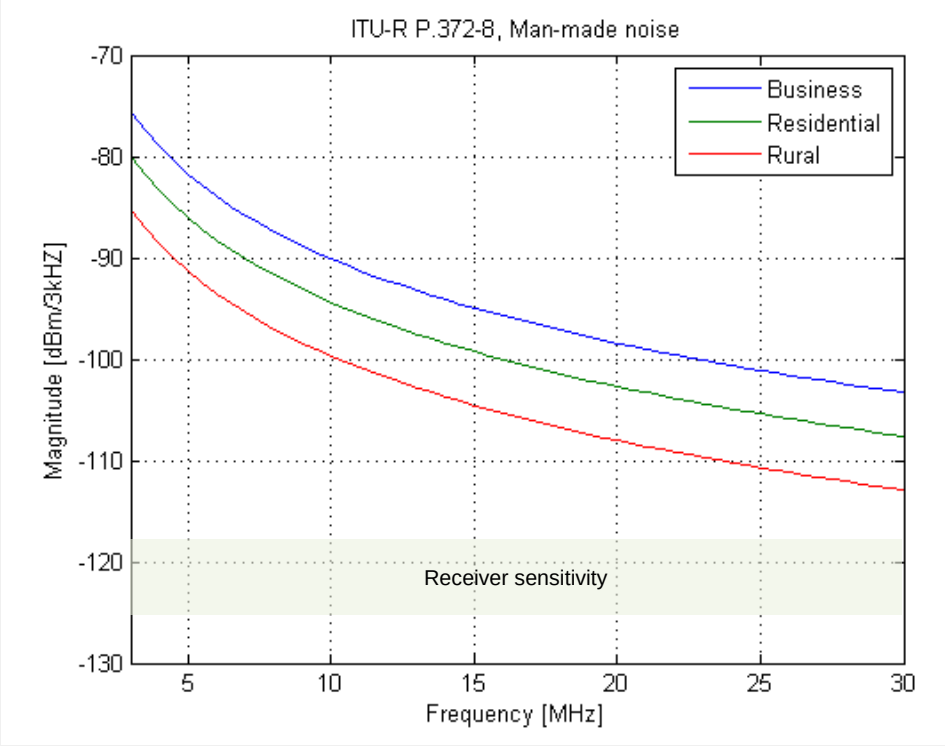
- An independent agency under the Swedish Ministry of Defence
- Financed through contracts and government appropriations for specific projects
- About 1000 employees, of which 800 researchers
- Board, Director General and Deputy Director General are appointed by the Cabinet

Agenda

- Background/Motivation
- Frequency selection based on local interference
  - Simulation results
- Interference detection
  - Detectors
  - Examples from measurements

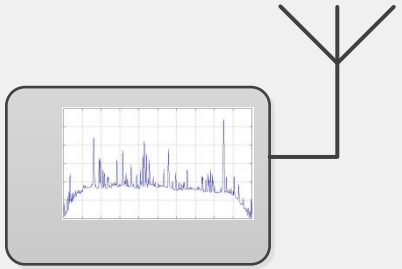
Bakground

- The robustness and data rate of a communication link is limited by the signal-to-noise ratio (SNR) at the receiver.
- Man-made noise stronger than the receiver noise.



Improve frequency selection

- Select frequencies with the highest SNR
- Measure the local interference at the receiver



- Goal
  - Increase the probability of a successful reception at the first transmission
  - Possibilities to increase the data rate or the robustness.

Local interference

- Platform dependent
- Location dependent

- Sources
  - Other transmitters
  - Man-made noise

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Local interference

- Impulse interferences can provide significantly higher bit error rate than Gaussian distributed interference with the same average power (energy).
- Typical sources
  - Electrical engines
  - Voltage converters
  - Fluorescent lamps
  - Thunderstorms

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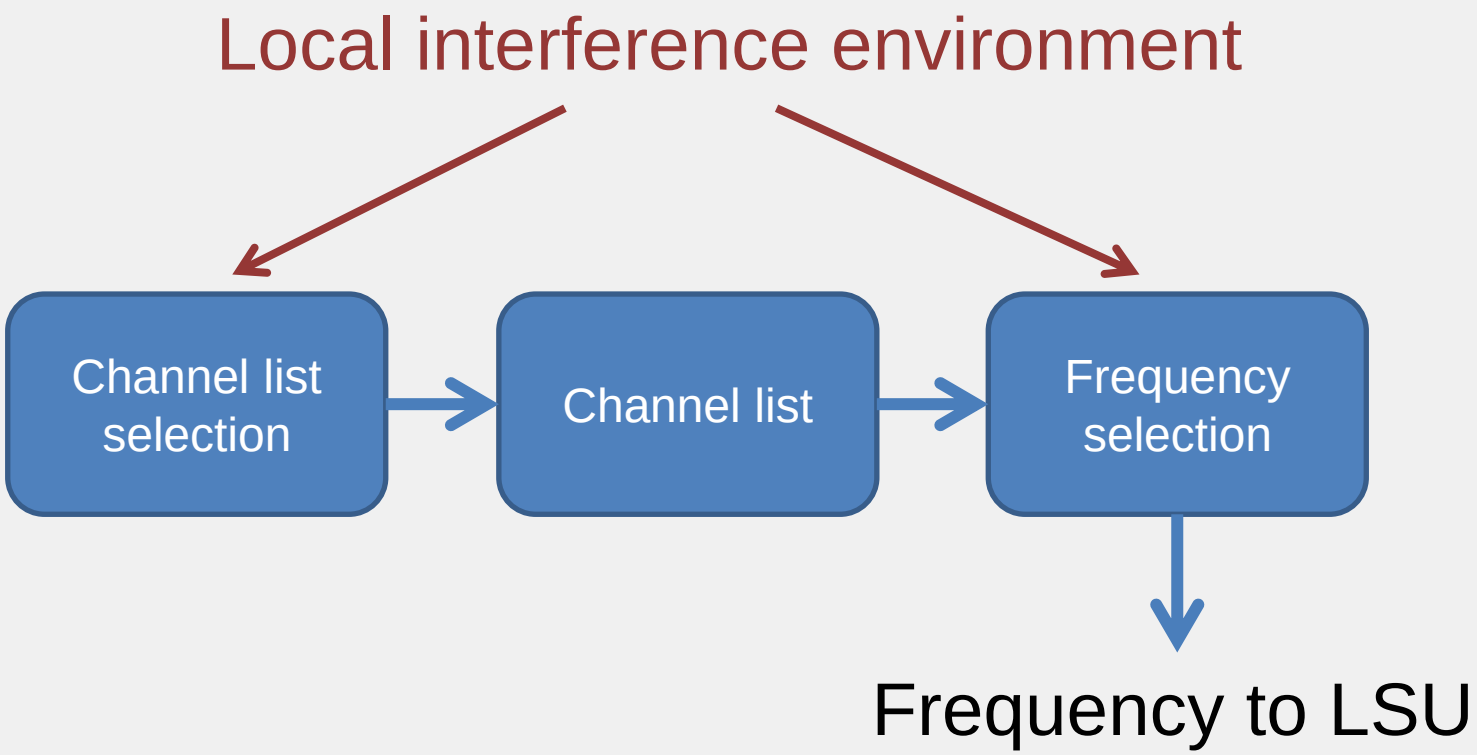
Frequency selection STANAG4538



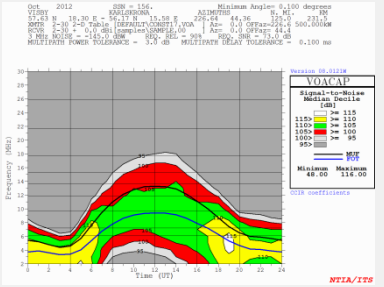
Selection of channel list

Notional links

Experiences

Frequency policies

Propagation prediction tools



Channel list

Local interference environment

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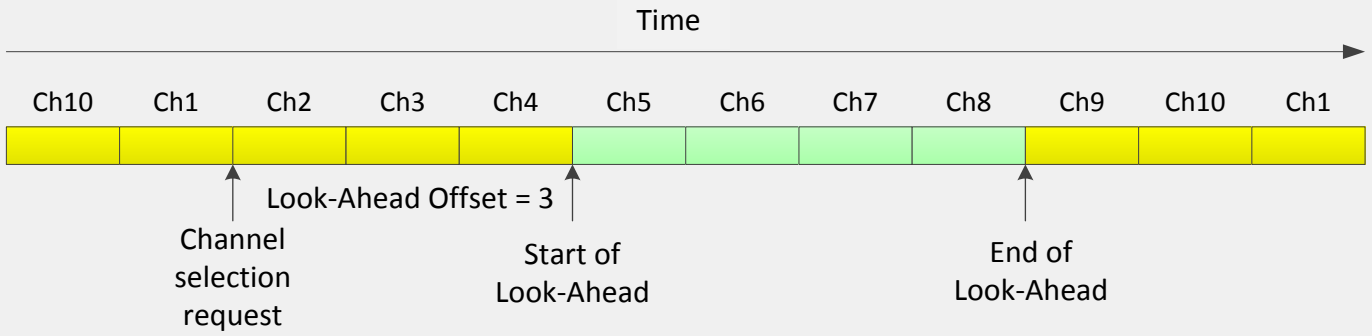
Frequency selection



- Select the best frequency inside the Look-Ahead window
- Frequency performance in the Link Quality Analysis (LQA)-table
  - Predicted or measured SNR
  - Occupied
  - Number of failed LSU attempts
  - Etc.

LBT vs. Interference detection

- Listen-Before-Transmit (LBT)
  - Occupancy detection
    - Detect different waveforms
  - Not degrade QoS in others communication
  - Polite
- Interference detection
  - Avoid man-made interference at the platforms
    - Classify noise
  - Improve QoS in my link
  - Greedy

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Assessment of suggested method

- Evaluation of different traffic types for a navy network
- Influence of local interference environment

Different traffic types - Used

Administrative

- Unicast
- (Non-)Confirmed
- Large messages (typical 40kByte – x Mbyte)
- Data rate: adaptive
- No latency requirement
  - Look-Ahead < Size of channel list
- Updates to the LQA-table with experience

Tactical

- Broadcast
- Non-Confirmed
- Small messages (typical 200 byte)
- Data rate: typical 200 bit/s
- Requirement of maximum latency
  - Look-Ahead = 2
- No experience from transmissions

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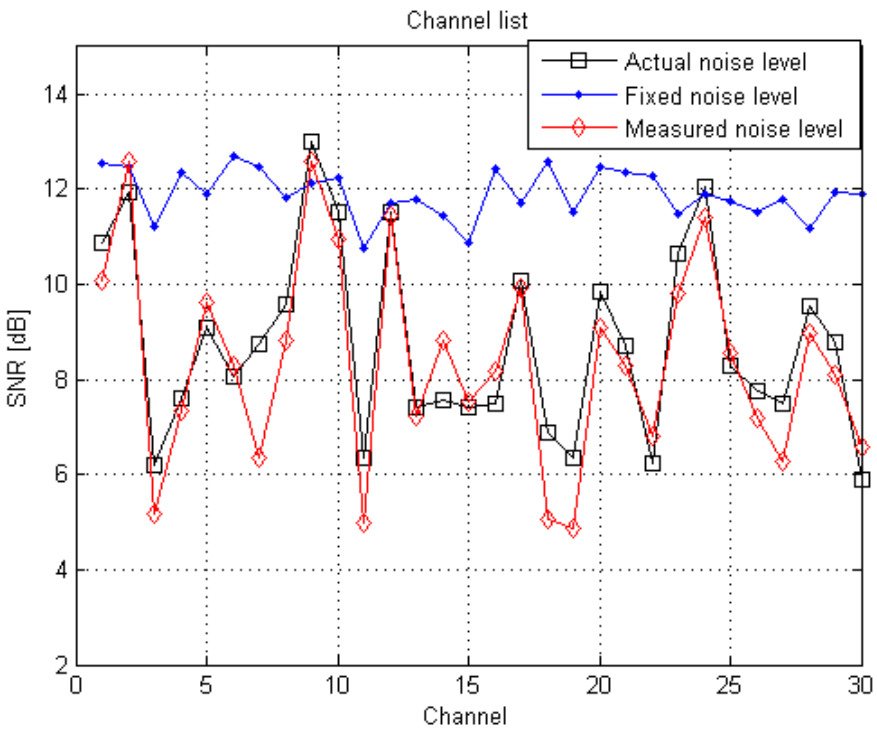
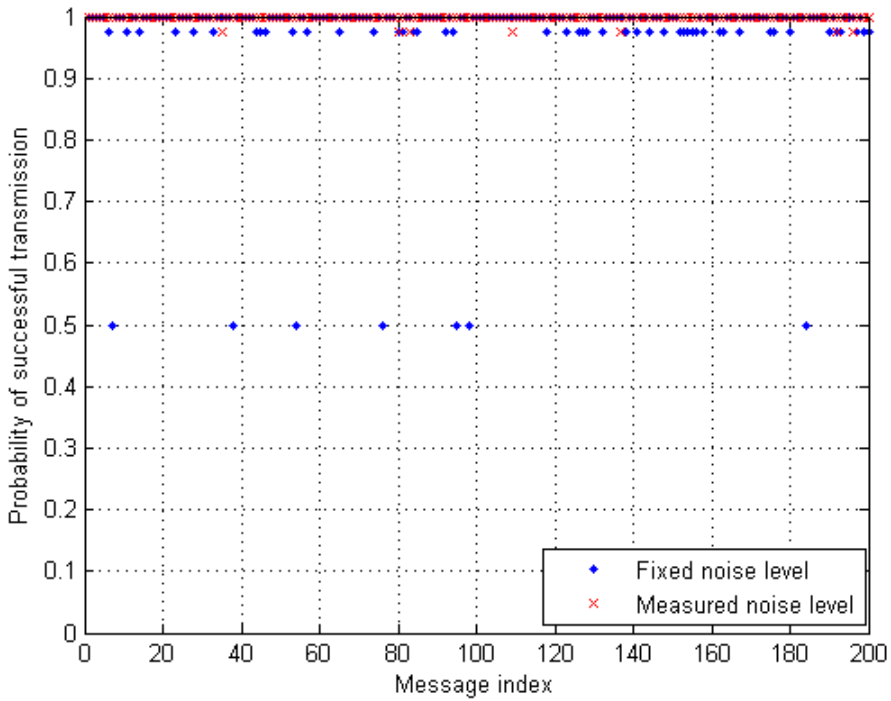
Evaluation model

- Tactical network
  - 10 nodes
- Administrative network
- Generated channel list
- Frequency selection
  - Fixed noise level (local interference excluded)
  - Measured noise level (local interference included)



Results: Tactical network

- Increased probability to reach all nodes in a tactical network
- Retransmissions decrease
- The Look-Ahead window decreases the set of possible frequencies in the scanning list
- Example of results
  - Local interference is excluded: 27 % of the messages needs retransmission.
  - Local interference is included: 4 % of the messages needs retransmission.



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Results: Administrative network

- Non-Confirmed: The total tranmission time is tremendously decreased.
- Confirmed: Initially a better frequency selection. During the transmission a good SNR is retrieved.

Example of results

	Total transmission time	
	Confirmed	Non-Confirmed
Fixed noise level	9991	18260
Measured noise level	8635 (13%)	8615 (53%)

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Interference detection

- Energy detection
  - Measures the average energy
  - Works good for Gaussian distributed noise
    - Large errors for impulsive interference
  - Interference waveform not considered
- Extended detection [1], [2], [3]
  - Impulsiveness correction factor (ICF)
    - Impulsiveness ratio (IR)
    - Amplitude probability distribution (APD)

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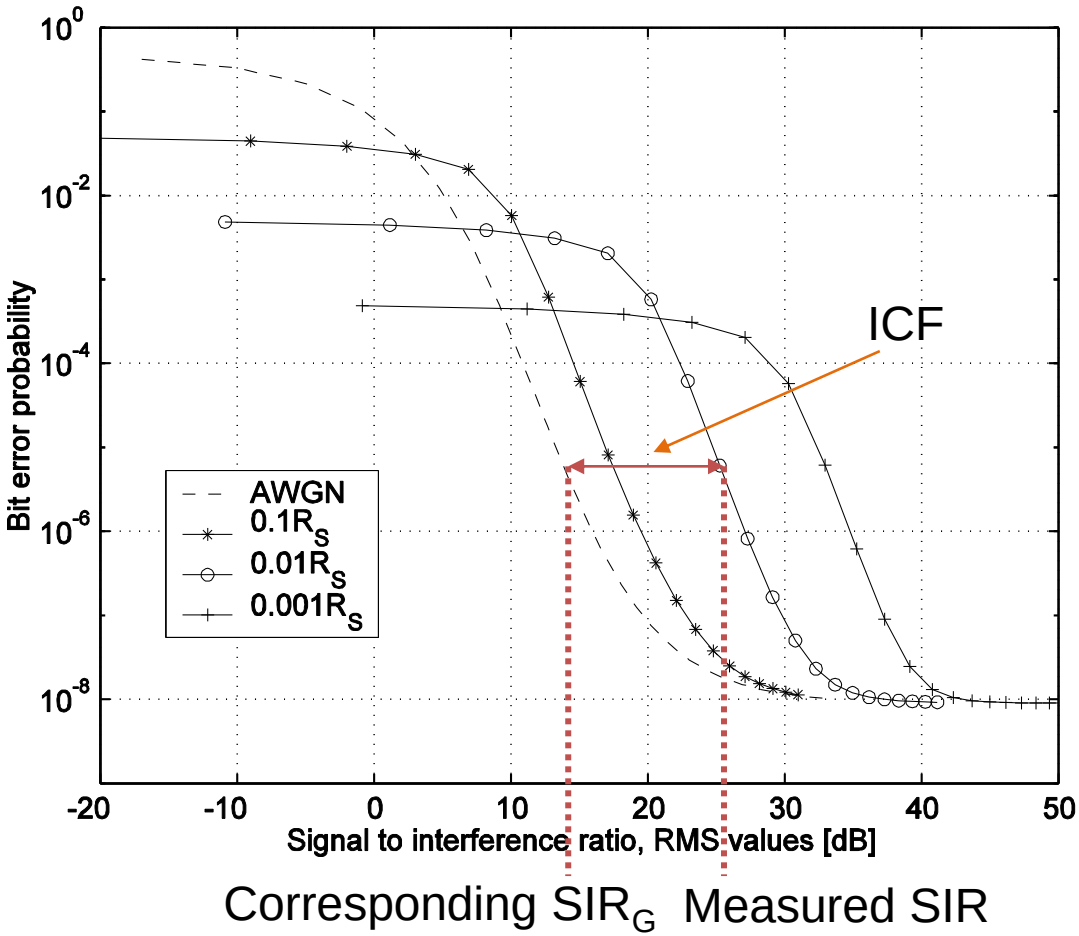
Impulsive correction factor, ICF

- The ICF: is a correction of the SIR_G in the AWGN-approximation

$$\mathrm{BEP} = \mathrm{f}\left(\frac{E_b}{N_0 + N_I ICF} \right)$$

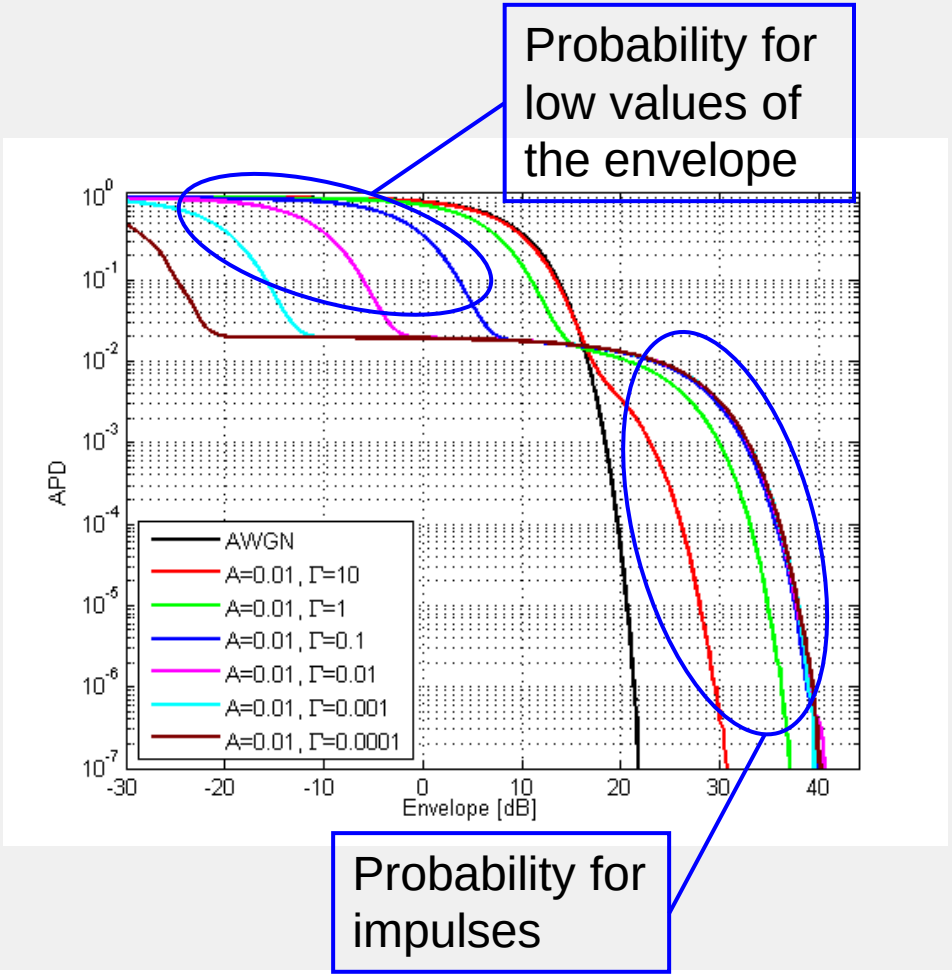


Amplitude Probability Distribution, APD

- Def.: The part of time the measured envelope exceeds a certain level

$$\mathrm{APD}_R(r) = 1 - F_R(r)$$

- $$f_R(r) = \frac{d}{dr} F_R(r) = -\frac{d}{dr} \mathrm{APD}_R(r)$$



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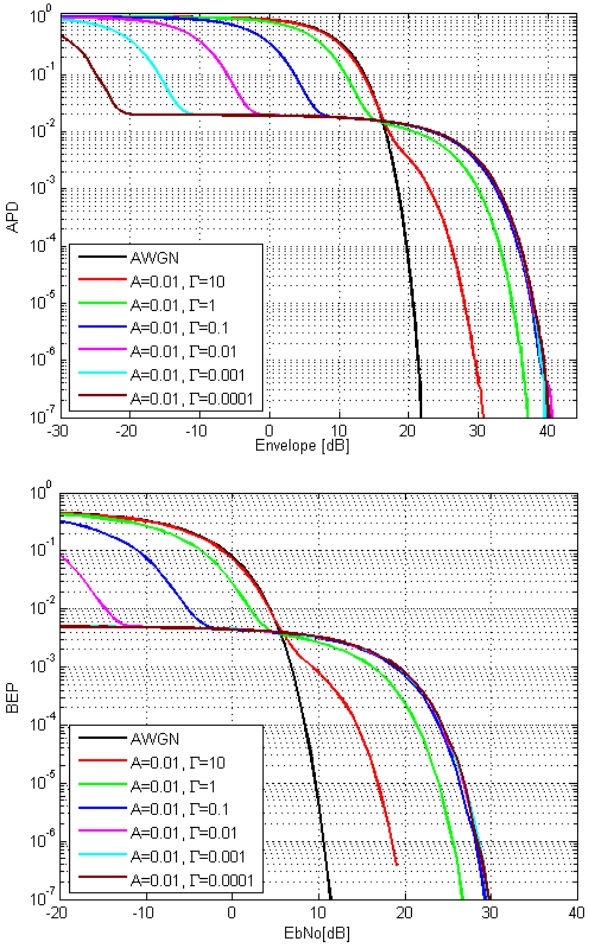
- Relation between the APD of an interfering signal and the maximum BEP



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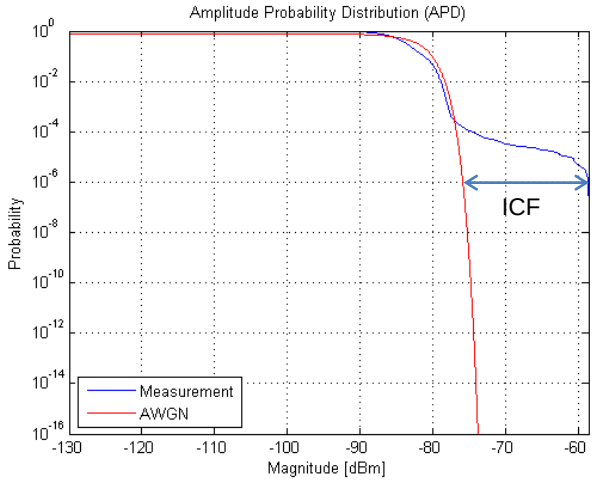
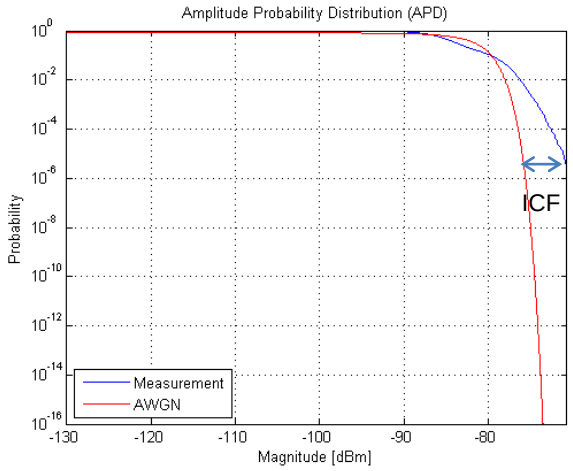
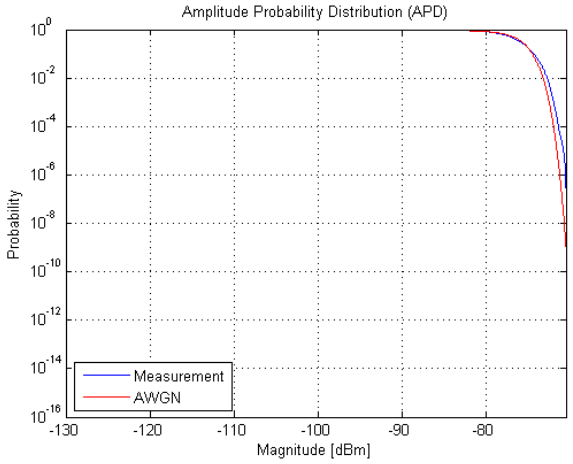
Measurements example

- Measured APD of interference environment at a military vessel
- Large variations in ICF depending on the frequency







Conclusion

- High importance that the local interference is considered in the frequency selection.
  - Transmission time and number of retransmissions are reduced
- Extended interference waveform detection is crucial (ICF information)
  - Avoids large errors in the bit error probability (BEP) estimate for non-Gaussian noise.

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Questions?

References

[1] Stenumgaard, P. F. ‘A Simple Impulsiveness Correction Factor for Control of Electromagnetic Interference in Dynamic Wireless Applications’, *IEEE Communication Letters,* 2006,10, pp. 147-149

[2] Wiklundh, K. ‘Relation Between the Amplitude Probability Distribution of an Interfering Signal and its Impact on Digital Radio Receivers.’, *IEEE Transactions on electromagnetic compatibility,* 2006, 48,pp. 537-544

[3] Eliardsson, P. and Karlsson, J. ’Dynamic frequency allocation in impulsive noise environments’ *Electronics Letters, IEE,* 2012*, 48*, pp. 657-658

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