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

Man-made noise is 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
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
Frequency selection STANAG4538

Local interference environment

Channel list selection → Channel list → Frequency selection

Frequency to LSU
Selection of channel list

- Notional links
- Experiences
- Frequency policies
- Propagation prediction tools

Local interference environment

Channel list
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
Assessment of suggested method

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

<table>
<thead>
<tr>
<th>Administrative</th>
<th>Tactical</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Unicast</td>
<td>• Broadcast</td>
</tr>
<tr>
<td>• (Non-)Confirmed</td>
<td>• Non-Confirmed</td>
</tr>
<tr>
<td>• Large messages</td>
<td>• Small messages</td>
</tr>
<tr>
<td>(typical 40kByte – x Mbyte)</td>
<td>(typical 200 byte)</td>
</tr>
<tr>
<td>• Data rate: adaptive</td>
<td>• Data rate: typical 200 bit/s</td>
</tr>
<tr>
<td>• No latency requirement</td>
<td>• Requirement of maximum latency</td>
</tr>
<tr>
<td>– Look-Ahead &lt; Size of channel list</td>
<td>– Look-Ahead = 2</td>
</tr>
<tr>
<td>• Updates to the LQA-table with experience</td>
<td>• No experience from transmissions</td>
</tr>
</tbody>
</table>
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 need retransmission.
  - Local interference is included: 4% of the messages need retransmission.
Results: Administrative network

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

<table>
<thead>
<tr>
<th></th>
<th>Total transmission time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Confirmed</td>
</tr>
<tr>
<td>Fixed noise level</td>
<td>9991</td>
</tr>
<tr>
<td>Measured noise level</td>
<td>8635 (13%)</td>
</tr>
</tbody>
</table>

**Example of results**
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)
The ICF: is a correction of the $\text{SIR}_G$ in the AWGN-approximation

$$\text{BEP} = f\left(\frac{E_b}{N_0 + N_I ICF}\right)$$
**Def.**: The part of time the measured envelope exceeds a certain level

\[ \text{APD}_R (r) = 1 - F_R (r) \]

\[ f_R (r) = \frac{d}{dr} F_R (r) = -\frac{d}{dr} \text{APD}_R (r) \]
Amplitude Probability Distribution, APD

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

\[ APD_R (r) = 1 - F_R (r) \]

- \( f_R (r) = \frac{d}{dr} F_R (r) = - \frac{d}{dr} APD_R (r) \)

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

References