Analysing the Performance of Dynamic Frequency Selection as a HF Frequency Management Technique

HFIA Meeting 4th February 2010

Connecting & Protecting

SELEX Communications

Overview

- Introduction
- Purpose of the Tests
- DFS Overview
- Test Setup
- Evaluation Method
- Analysis
- Results

Introduction

- HF2000 HF Radio System has been developed by SELEX Communications Ltd for the Swedish Armed Forces
- It is primarily a 3G Automatic Link Establishment (ALE) System
  - Uses STANAG 4538 to provide link establishment
  - Supports Mil-Std-188-141B ALE
  - Operator manual control
- Design to operate with minimum operator intervention
- The system uses a powerful frequency management tool that uses Dynamic Frequency Selection (DFS) to select frequencies with adequate performance for the traffic type
- Developed by SELEX in partnership with the Swedish Defence Materiel Administration (FMV) and their consultants FOI
- Extensive testing of Dynamic Frequency Selection (DFS) is currently underway

Purpose of the Trial

- To test the Dynamic Frequency Selection algorithm used within the HF2000 HF radio system
  - Requires a methodology to developed to evaluate its performance

- To compare the performance of Dynamic Frequency Selection (DFS) for 3G ALE with that of the ‘conventional’ fixed frequency pool generation more commonly found with ALE systems
  - To establish the effectiveness of using DFS as a technique for HF2000

What is DFS?

- DFS is a HF frequency management method that allows the automated population of ALE channel frequency pools
- It has a powerful frequency prediction tool embedded that allows it to select frequencies predicted to propagate over the required path
- It overcomes the problem of populating all the nodes in an ALE network by doing this deterministically at each node in the network
- It uses allocated frequency bands rather than actual frequencies
- It uses a pseudo random selection of frequencies to spread the traffic load over the available frequency band

Benefits of DFS

- DFS is more efficient way to manage frequencies
- Provides frequency sharing between networks (synchronous) and within networks
- Provides traffic load management of the HF band
- Increase bandwidth available
- Compatible with existing ALE standards
- Further information on the technique can be found in the IET paper

Advanced HF Spectrum Management Techniques

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Possible Issues

- Continuously uses different frequencies to perform link establishment
  - Conventional LQA analysis is not available

- Questions we wanted answer to
  - Does the lack of conventional LQA techniques significantly affect the performance of the system?
  - Does the DFS algorithm used in HF2000 produce ‘adequate’ channels for the traffic to be delivered?

Defining the Performance Parameters

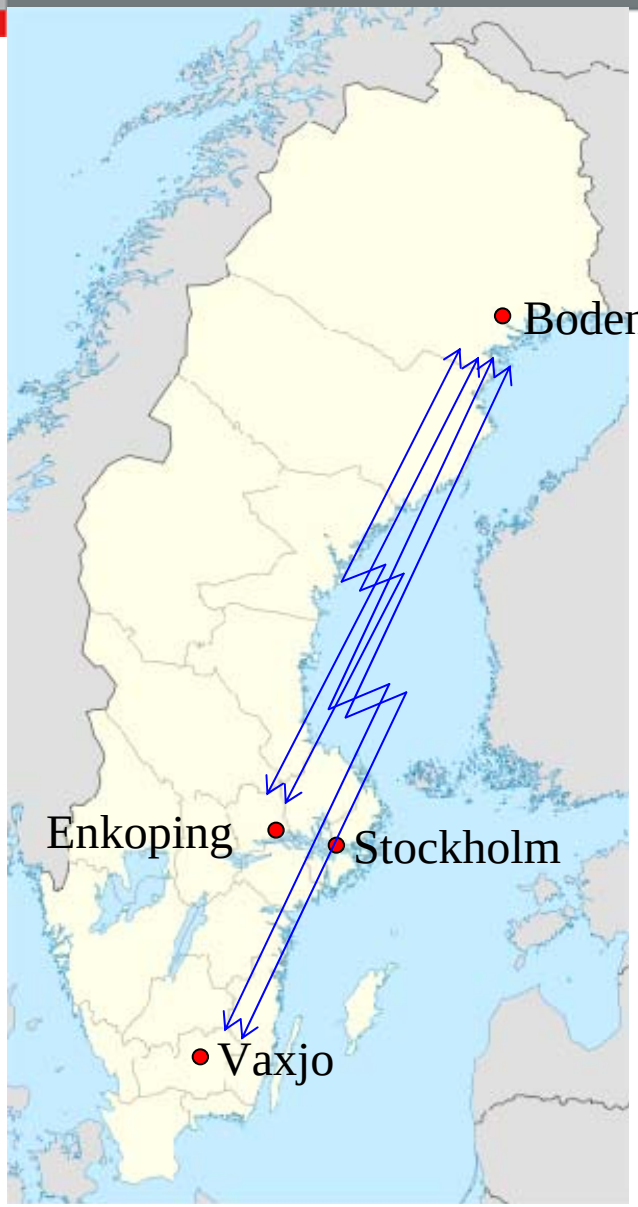
- Establish a number of criteria to compare
  - Directly related to system performance
  - They had to be measurable
  - Avoid complicated data analysis
- The tests developed had to allow direct comparison
  - Within a sensible time frame of measurement.
  - Eliminate as many variables as possible
- Allow comparison between the results and independent frequency prediction programs.
  - Such as REC533 or VOACAP
- Ionosphere soundings taken during the trials

Parameters to be Evaluated

- Links Statistics
  - Link requests made
  - Links successfully made*
  - Link attempt failures
- Frequency Use Analysis
  - Frequencies on which link attempt was successful
  - Frequencies on which link attempt failed
- Link Performance Analysis
  - Message delay (end to end through the system)
  - Message delivered (cumulative)
- AFP Generation performance Analysis
  - Successful links before and after AFP generation against fixed frequency pool

* A successful link is a link that successfully passed the message that it was set up for.

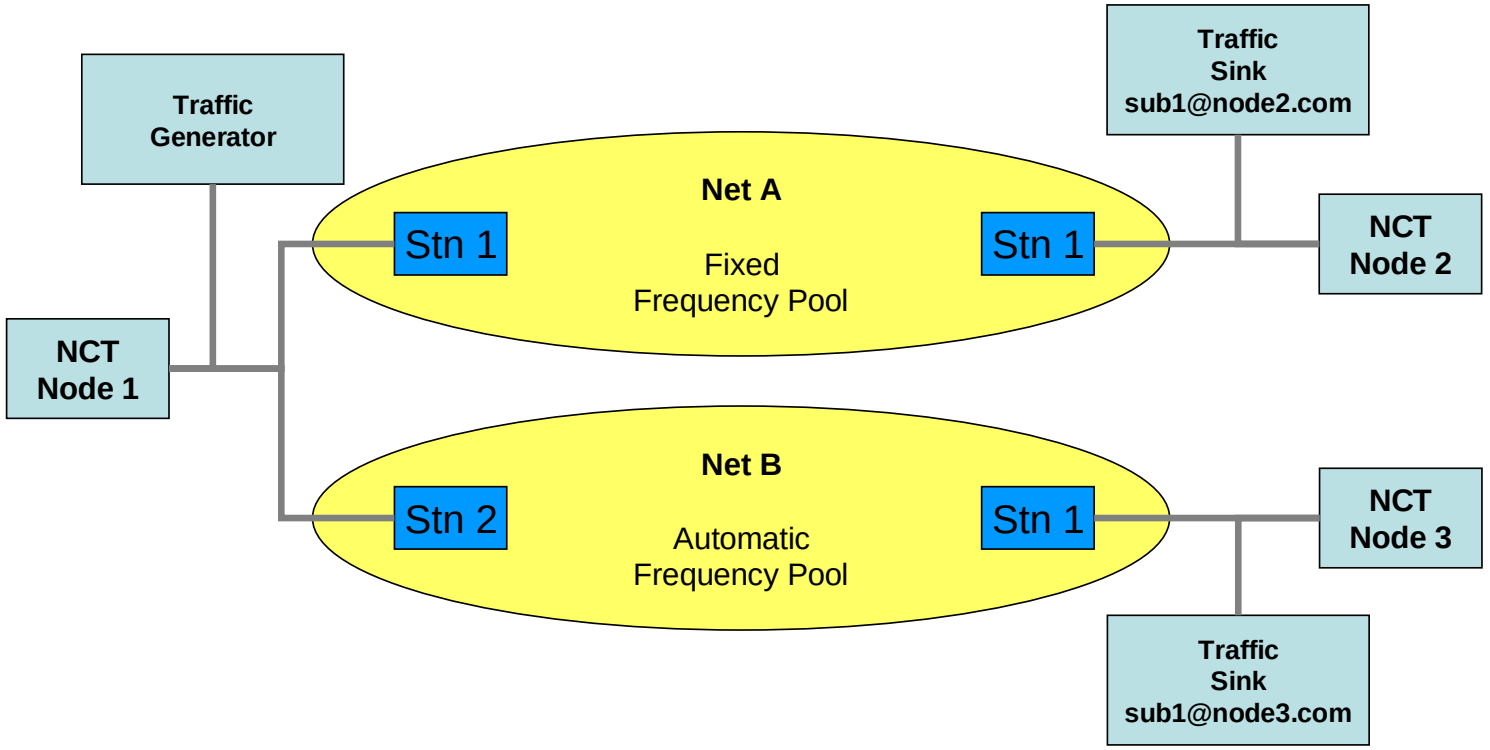
Test Setup



- FMV facilities in Sweden
- Between Boden and Enkoping/Vaxjo
- Identical Equipment types used
- Links of approximately 1000 km
- Initial tests conducted between December 08 and February 09
- More tests are planned for late spring 2010

Trials Test Configuration

- Two identical links
- Traffic submitted to each net simultaneously
  - To remove propagation variations
- One net set for fixed frequency pool selection the other set for AFP



System Configuration

- **Traffic types**
  - ARQ with Email
  - ARQ with IP datagrams

- **Frequency Management for Net A & B**
  - 3G Frequency Information (subset)
  - AFP Size: 12
  - Threshold SNR: 15dB
  - AFP Duration: 30 mins
  - Frequency Mode: Single Freq

- **Traffic Transfer**
  - Fixed data rate
  - Modem Waveform: STANAG 4285
  - Data Rate: 1200bps
  - Interleave: Short

Email Trial, System Configuration 2

- **Traffic Submission**
  - Fixed size E-Mail messages
  - Message Size: 2000 bytes
  - Message per Hour: 12
  - Message Distribution: Regular

IP Trial, System Configuration (3)

- Changes From Email trial
  - IP On-air Linking Attempts Limit
  - Failed Message Transfer Attempts Limit

- IP Trial System Configuration
  - IP datagram size: 5000 bytes (5112 OTA)
  - On-air link attempts: 1
  - Message rate: 12 per hour
  - Failed message attempts: 1
  - Frequency pool size: 12
  - Look ahead: 7
  - AFP duration: 30 minutes

Data Analysis

- HF2000 provides a comprehensive logging system that allowed the capture of the HF system activity
- Each log file covered a 24 hour period
- Software was written to turn this raw data into a format that allowed easy comparison between the two frequency management method
- Microsoft excel was used to generate the charts

Results

- The final results of this work will not be presented here
- Results are due to be published in a paper that is due to be presented at the Nordic HF Conference later this year
- The following results are just for illustration of the method used and should not be used to draw any conclusions!!

Link Stats

- Basic link statistics were produced that showed
  - How many links were attempted
  - What percentage were successful
  - What percentage failed
  - Output are in terms of station 1 & 2 as equipment was rotated to eliminate any potential equipment bias.

- Statistics for linking performance
  - Given as a totals and percentage

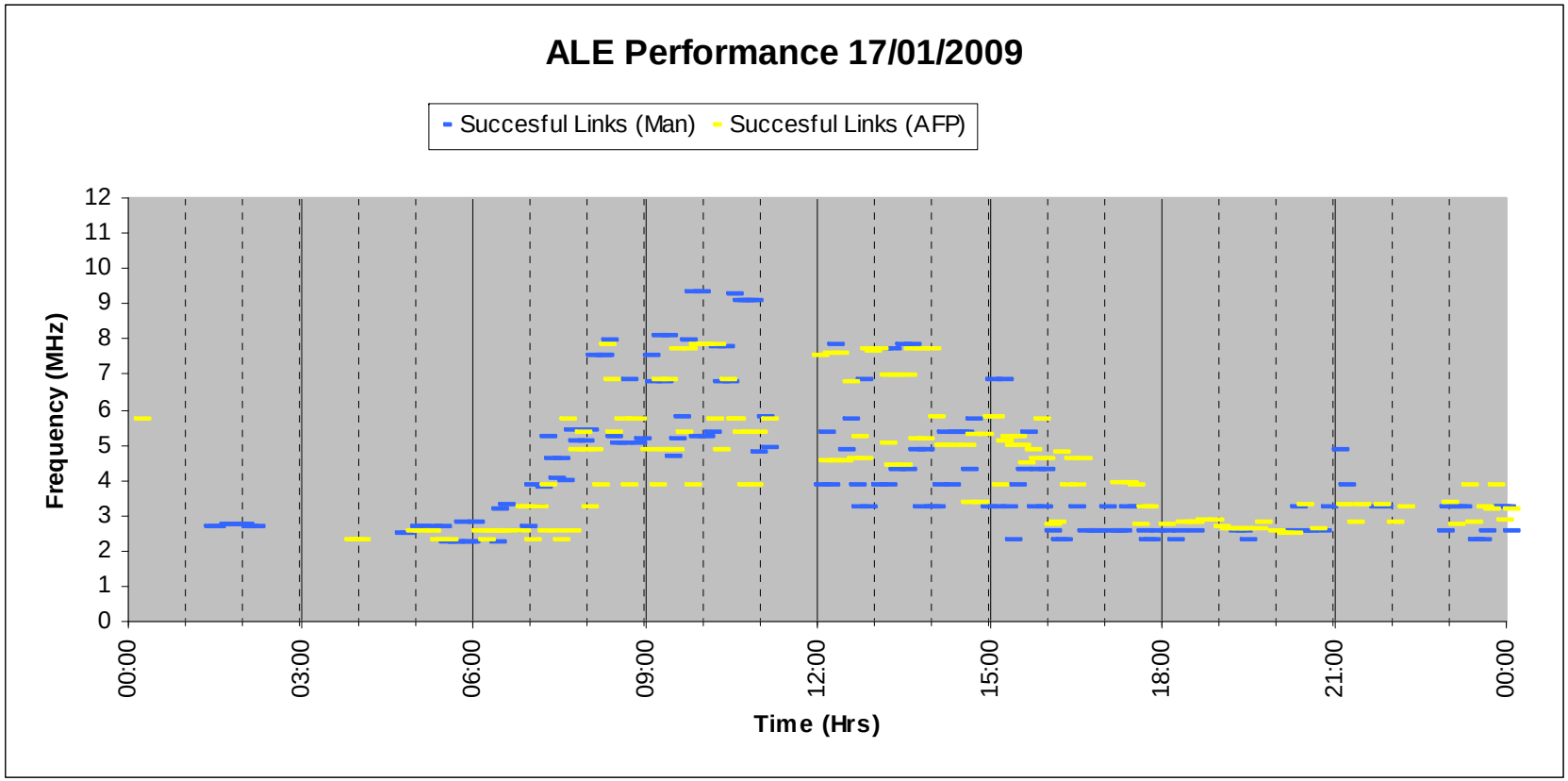
Link Statistics for the: 30/01/2009

Station 1	Totals	%
Link Requests	962.00	
Links Made	207	21.5
Attempt Failures	755	78.5

Station 2	Totals	%
Link Requests	726	
Links Made	462	63.6
Attempt Failures	264	36.4

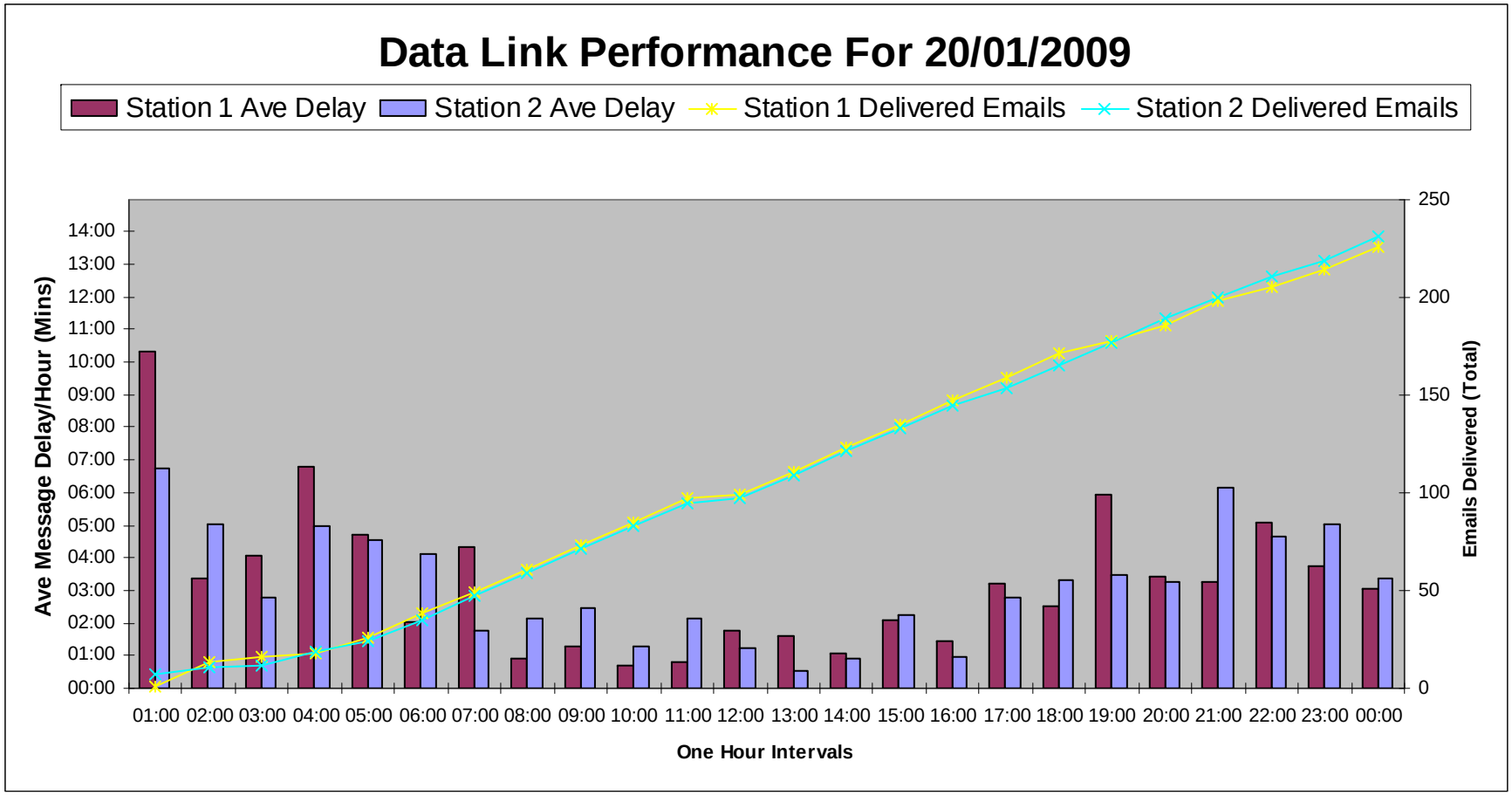
Frequency Selection

- Plot showing successful attempts for both nets
- Clearly shows a typical useable frequency plot for a 24 hour period



Link Performance

- Graph showing message delay and total number successful links



AFP Generation

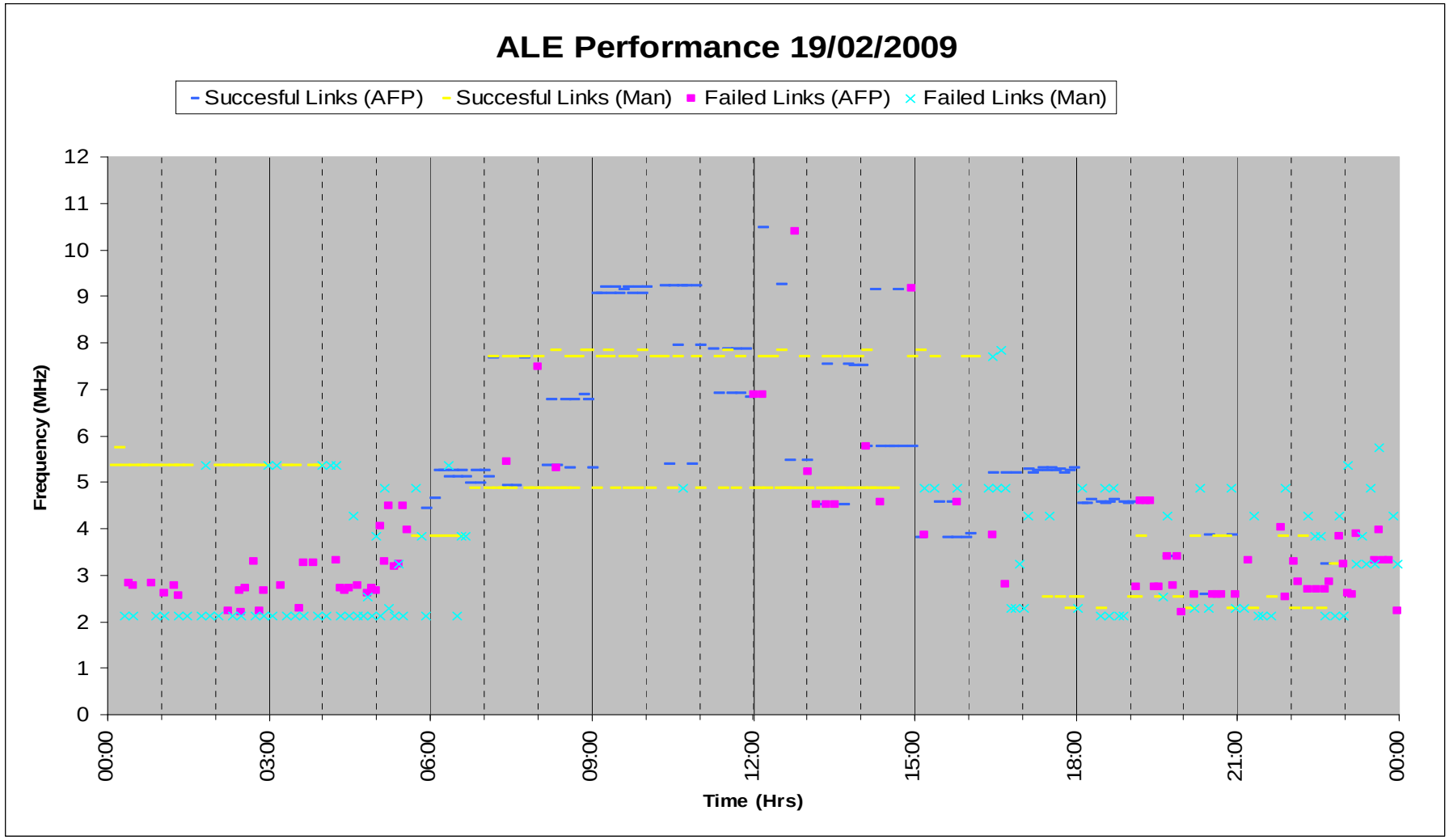
- Statistics to compare the affect of changing the net frequency pool every 30 minutes
- Compare performance when an AFP is generated
  - 15 minutes before and after a new frequency pool change with that of the net where there is new frequency pool

- Output

Station 1	64 Link Successes for Old AFP	Station 2	84 Link Successes for Old AFP
	63 Link Successes for New AFP		82 Link Successes for New AFP

And Something Interesting!

- A Night time phenomena
  - Observed on several nights



REC533 Predictions February 2009

```
FEB    2009          SSN =   2.                        Path
Boden                VÄXJÖ                  AZIMUTHS <Short> N. MI.      KM
65.82 N   21.70 E    56.88 N   14.82 E     203.32   17.27     571.4   1058.1
MIN ANG  3.0 DEG
XMTR  2-30 +   0.0 dBi[samples\SAMPLE.00     ] Az=  0.0 OFFaz=203.3   1.000kW
RCVR  2-30 +   0.0 dBi[samples\SAMPLE.00     ] Az= 17.3 OFFaz=360.0
NOISE -150 dBW            S/N 90% of Days @  45 dB  in    1 Hz RX Bandwidth
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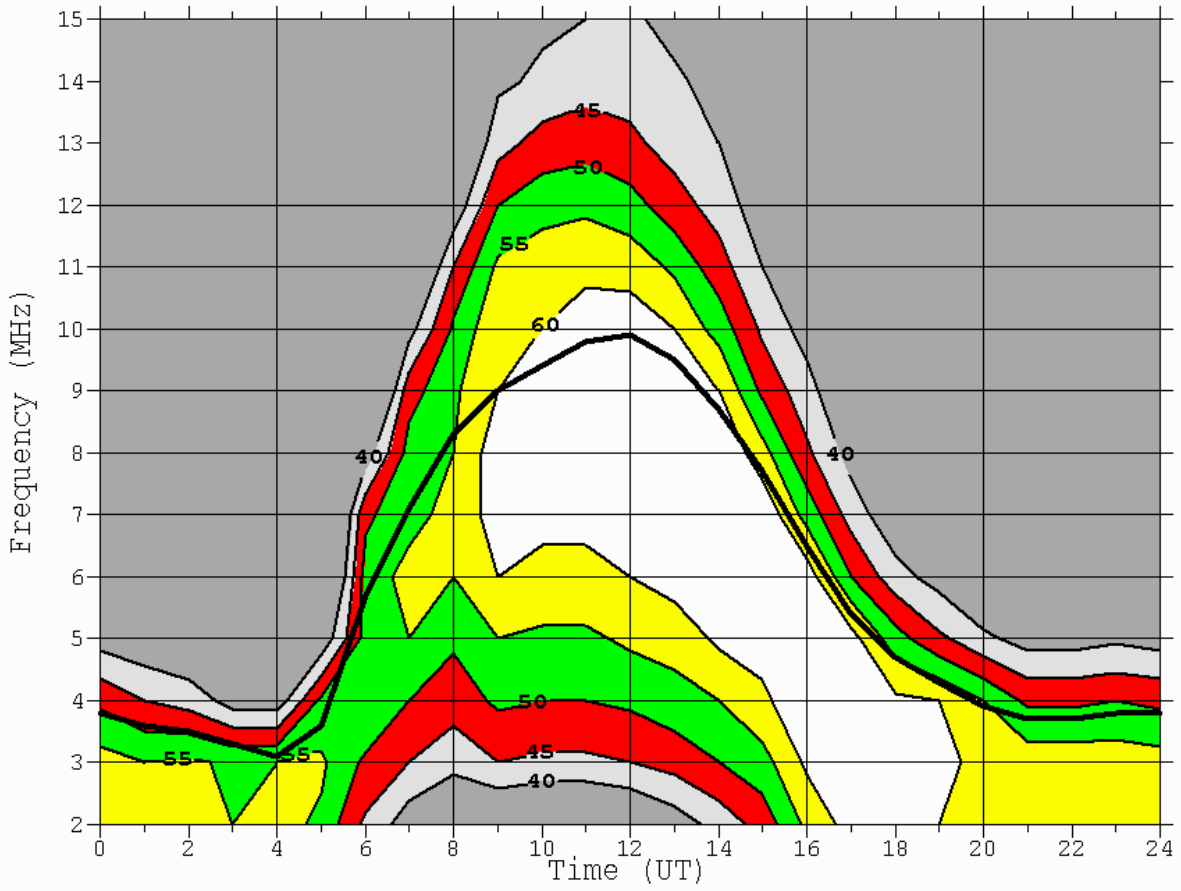
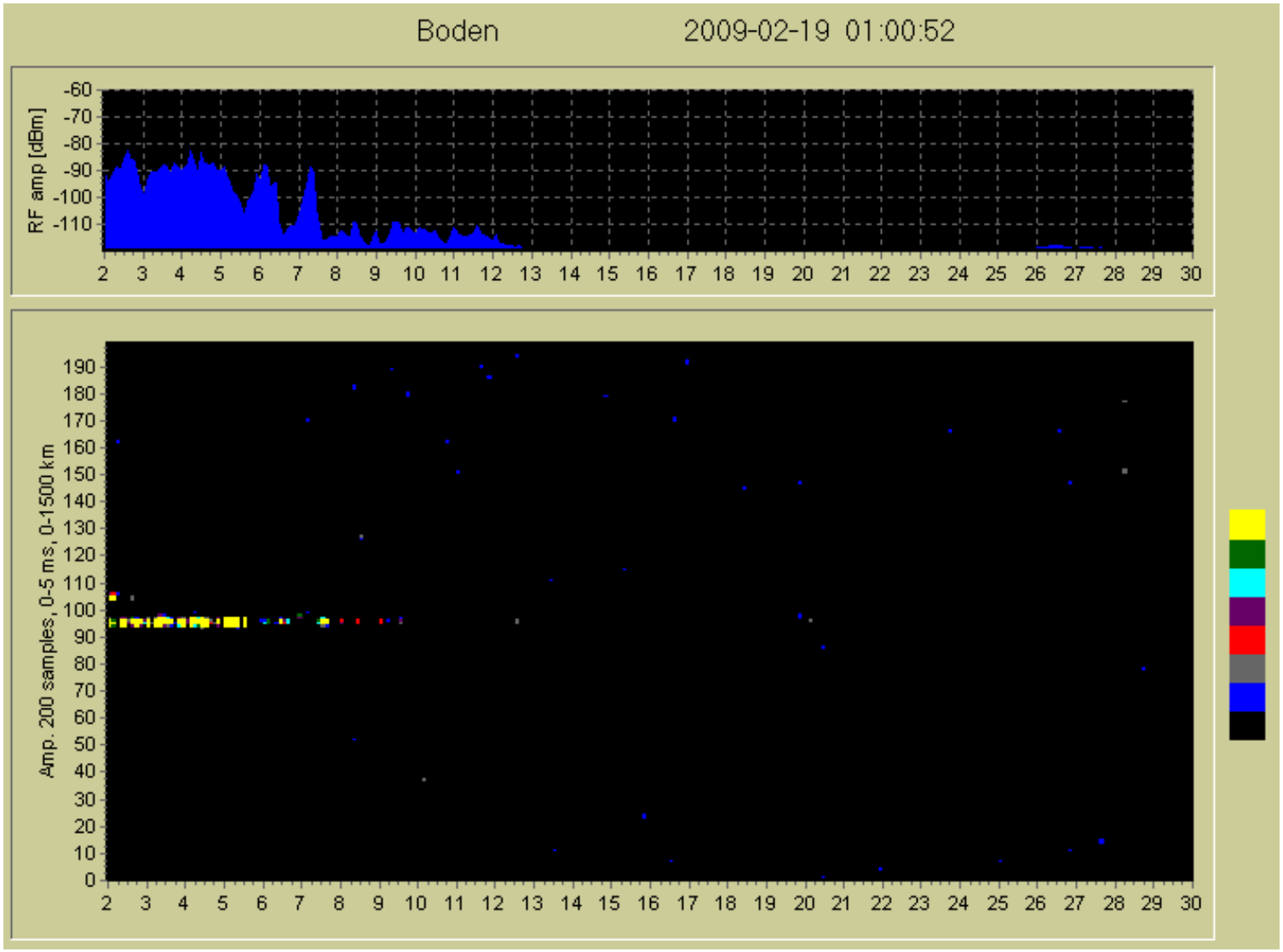


NTIA/ITS

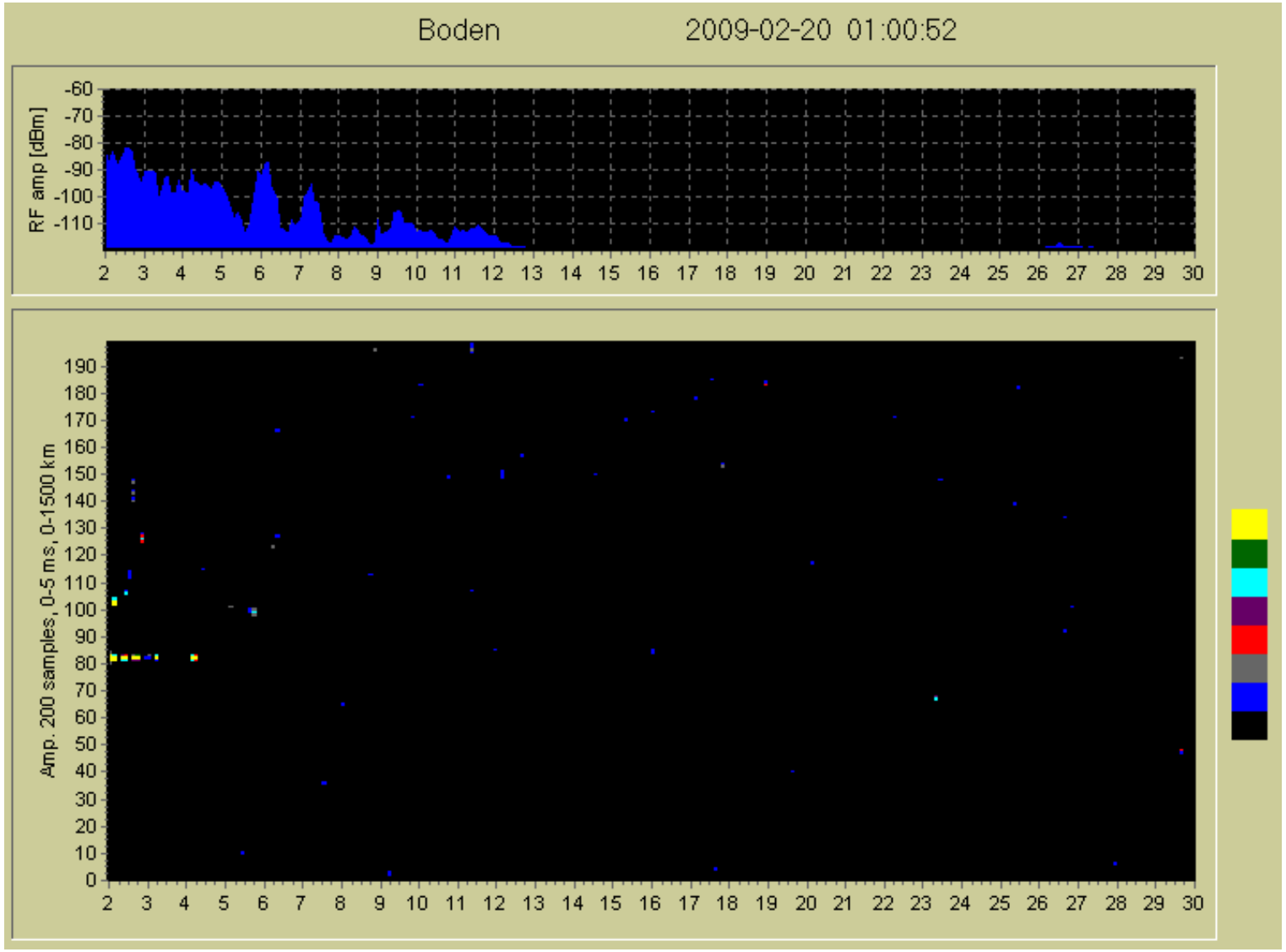
Ionosphere Sounding

- Not predicted by REC533



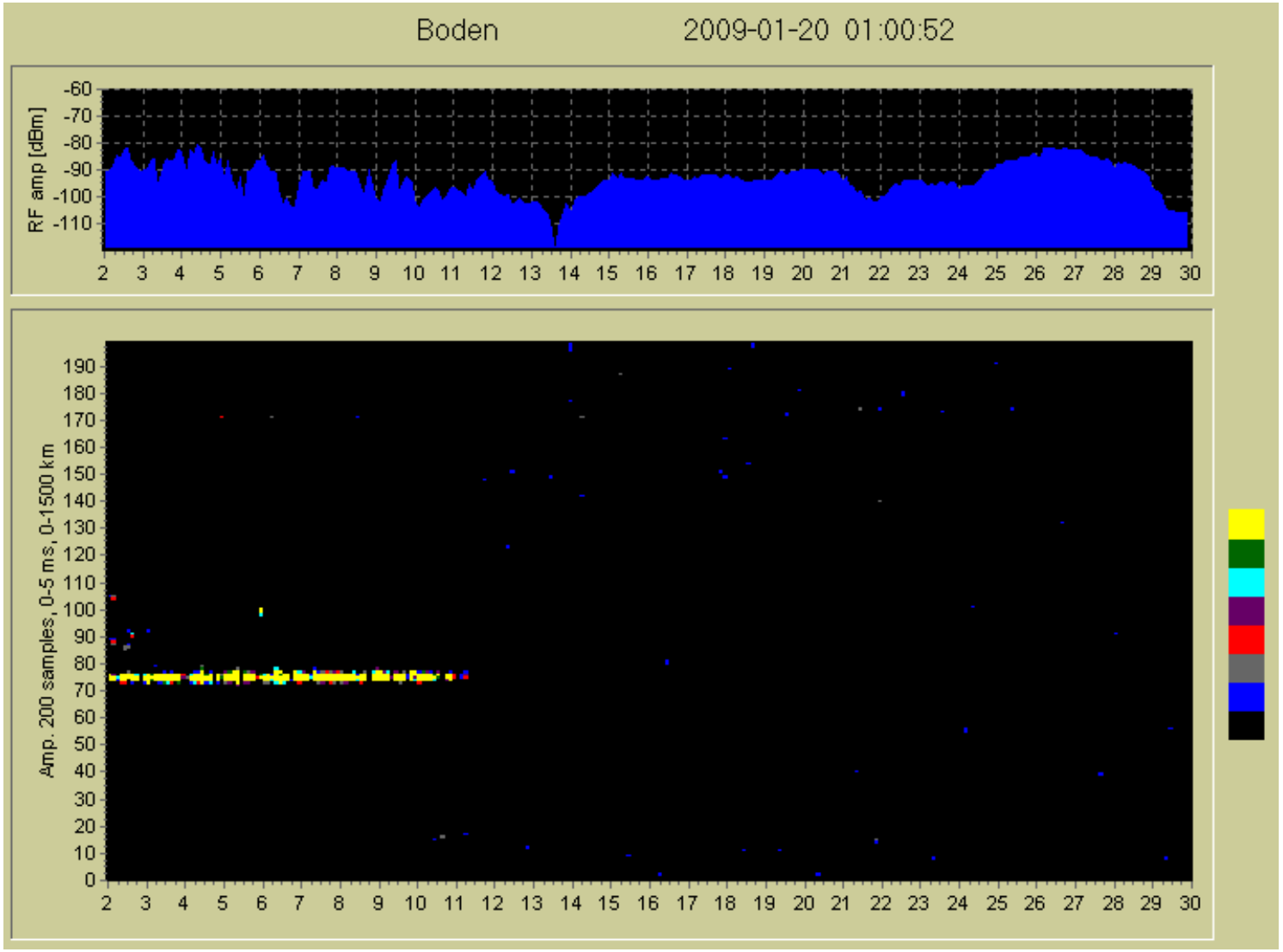
Ionosphere Sounding 2

- Same time the following night



Another example!

- Not predicted by REC533



A Limitation

- Sporadic E events that are not predicted show a limitation in the current algorithm

- Need to develop techniques in the future that will automatically make use sporadic E events.

Summary

- A test method has been developed that allows direct comparison between the two methods of frequency management
- A set of test parameters were established that allowed the collected data be analysed in a straightforward way
- Tests have not yet been completed and further trials using this test methodology will be performed later this year
- The full results from the trials conducted are planned to be presented at the Nordic HF Conference*.

**Nordic HF Conference 17-19 August 2010. Fårö Kursgård, Fårö*

End

Any Questions?

SELEX Communications