

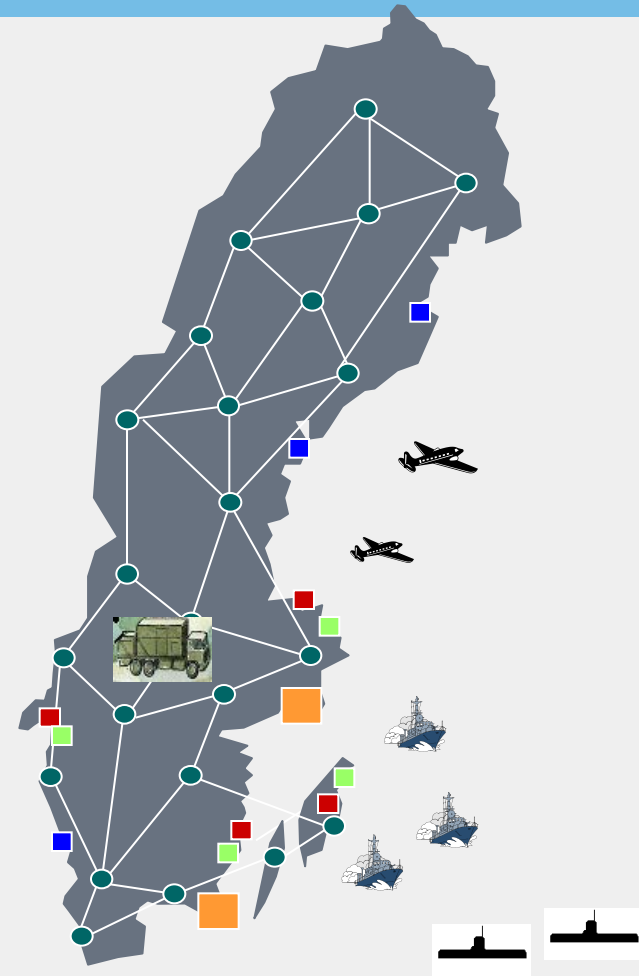
Wide band measurement of HF Spectral Occupancy in the Baltic Region

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Background





Research Questions

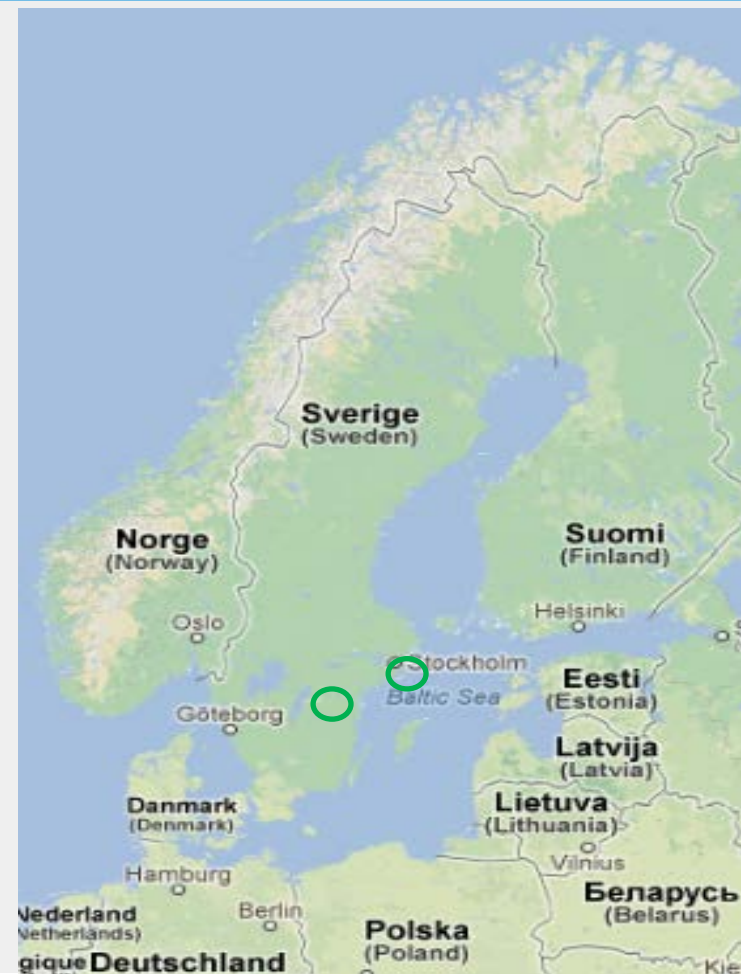
- Will interferences considerable reduce wide band HF capacity?
- Contiguous vs. channel-bonded frequency band?
- Distinction between horizontal and vertical polarization?
- Is the Laycock-Gott occupancy model still valid?
- Consequence of high local Noise level?

Method

- Based on the CRC Method for HF Spectral occupancy
 - Same evaluation criteria
 - Different measurement system
 - Occupancy Threshold: 10 dB SNR $\approx$ LBT in STANAG 4538
 - Real-time noise estimates
 - Unoccupied Channel if Occupancy < 5 % on 9 days out of 10.
 - Alternative criteria: Unoccupied if Occupancy < 50 % on 9 days out of 10

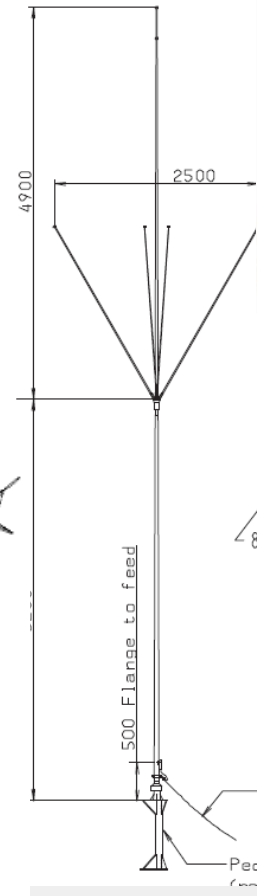
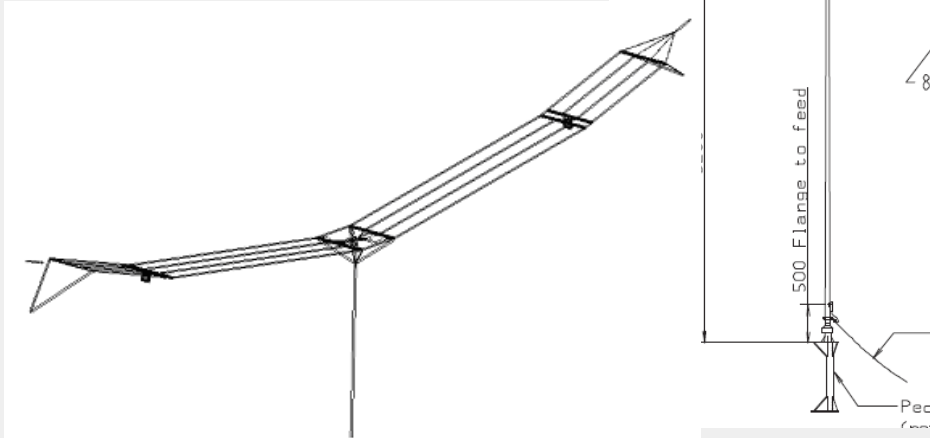
Locations

- Stockholm archipelago
 - Vertical monopole
 - Horizontal Broadband Dipole
 - Dec 2012 – Jan 2013
- Linköping
 - Horizontal Folded Dipole
 - Summer 2012



Measurement system

- Based on PERSEUS SDR
- Horizontal: BB Dipole
- Vertical: Whip 16 m, topload
- Scan 2-30 MHz in 15 s
- MATLAB





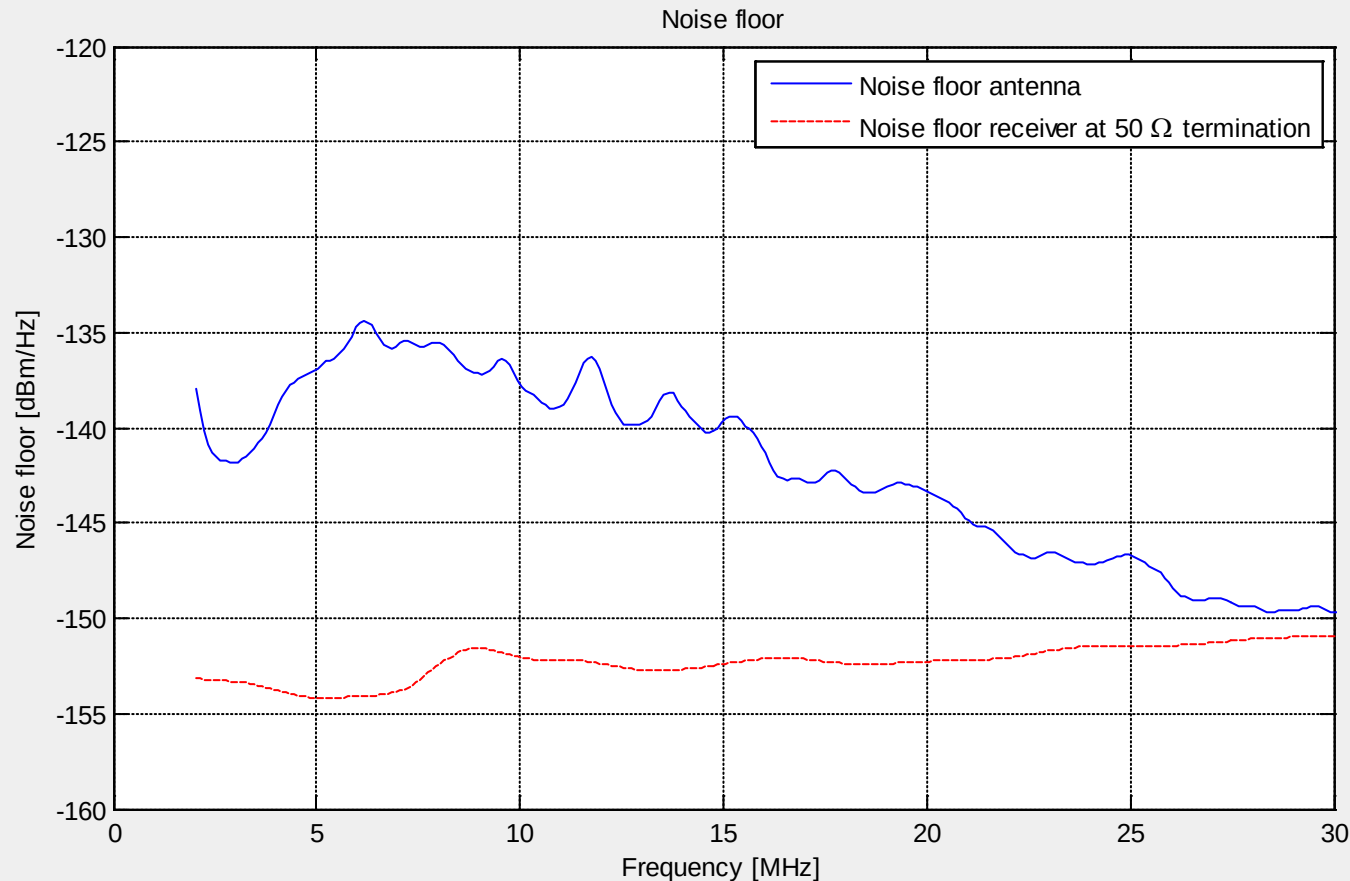
Measurement system

- Noise Factor (< 20 , typ. 17)
- Channel BW (1 kHz)
- Noise BW (100 kHz)
- Attenuation (0 dB)
- IF Bandwidth (3 MHz)
- Resolution BW (500 Hz)
- FFT Window (Blackman-Harris)
- Sampling Period (2 ms)
- Scanning rate (~ 2000 Channel/s)



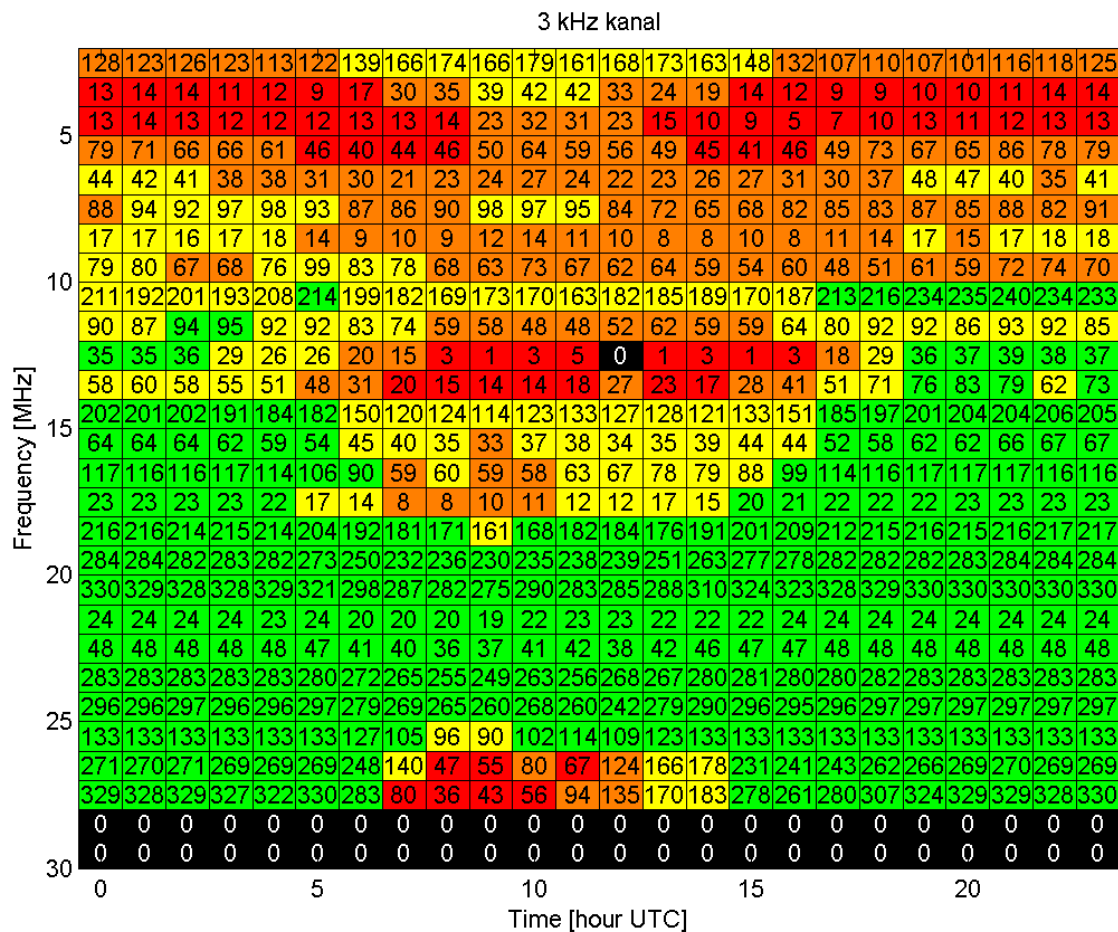
Noise Floor

Horizontal, Stockholm archipelago



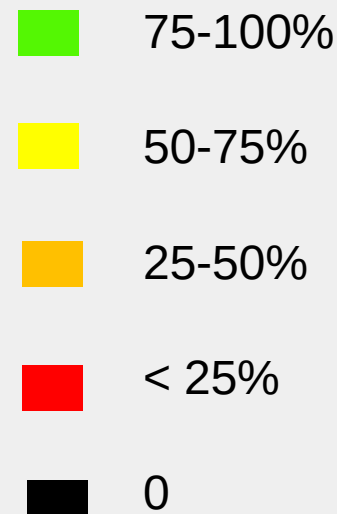
Date 131212
UT 11 00
Median

Unoccupied 3 kHz Channels, Fixed and Mobile, Horizontal, Stockholm archipelago

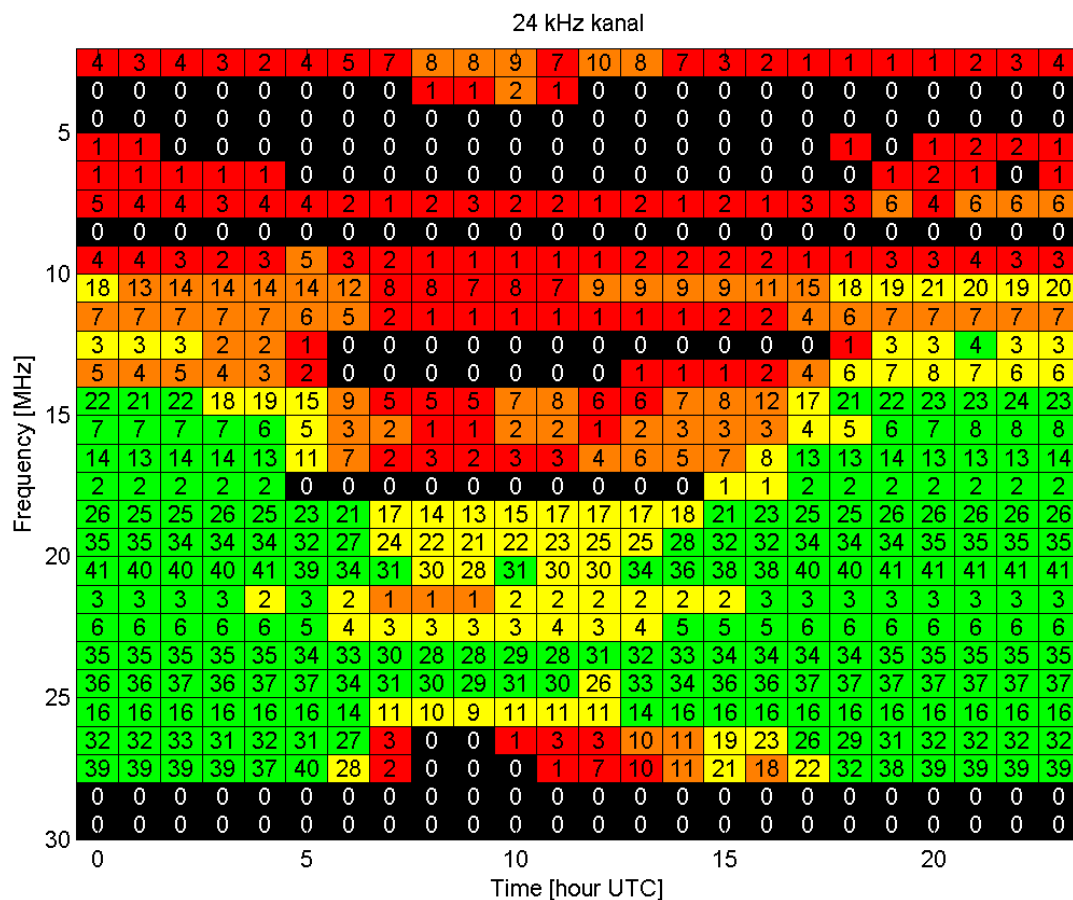


Each block
1 MHz * 1 hour

Unoccupied
channels



Unoccupied 24 kHz Channels, Fixed and Mobile, Horizontal, Stockholm archipelago



Each block
1 MHz * 1 hour

Unoccupied
channels

 75-100%

 50-75%

 25-50%

 < 25%

 0

Unoccupied 12 kHz Channels

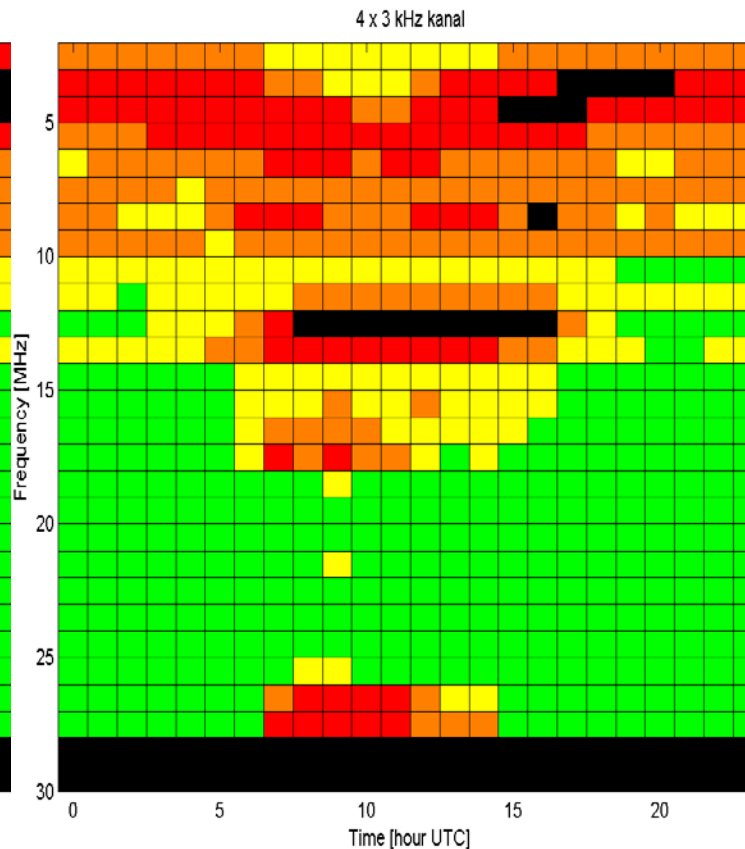
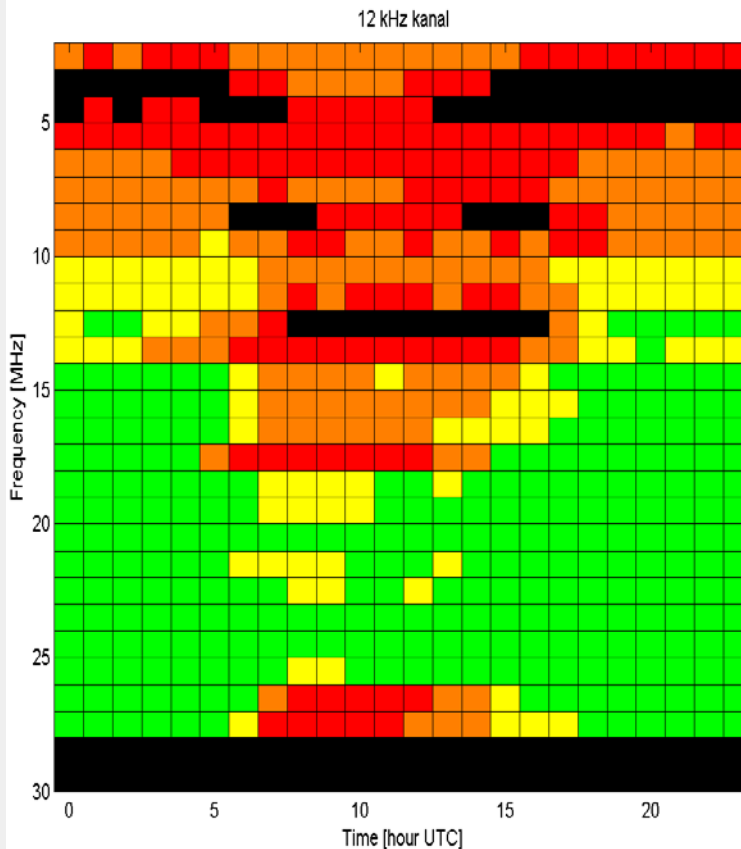
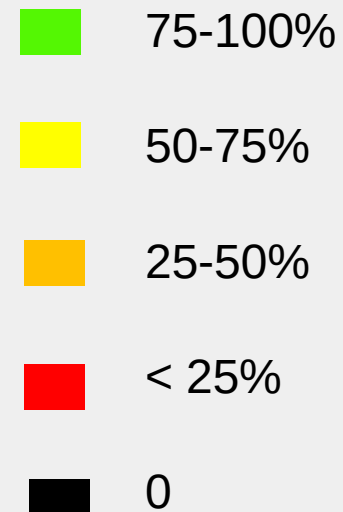
Fixed and Mobile, Horizontal, Stockholm archipelago

Contiguous

Channel-bonded over 24 kHz

Each block
1 MHz * 1 hour

Unoccupied
channels



Unoccupied 12 kHz Channels

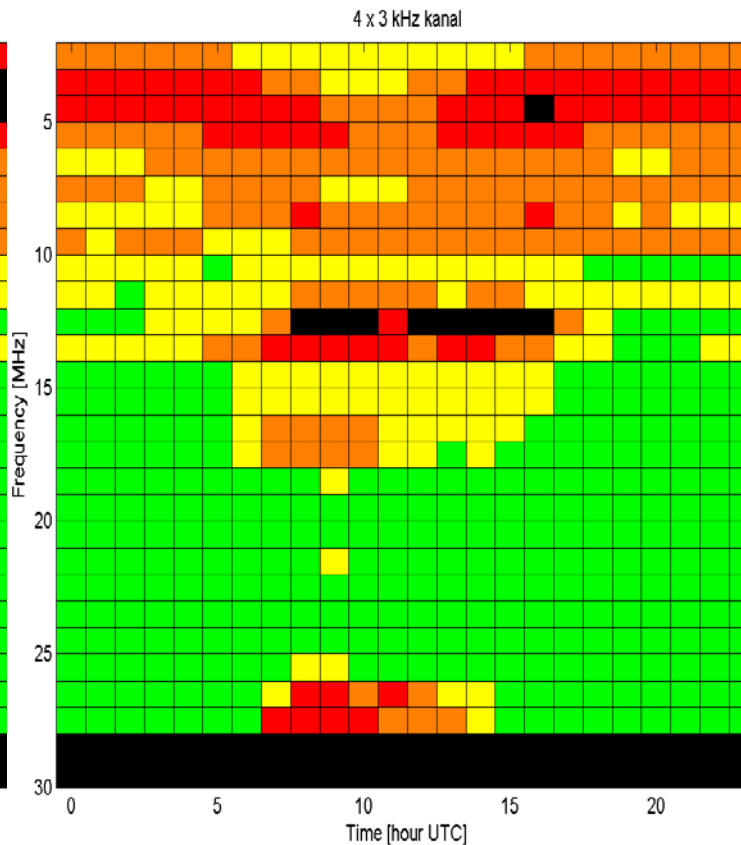
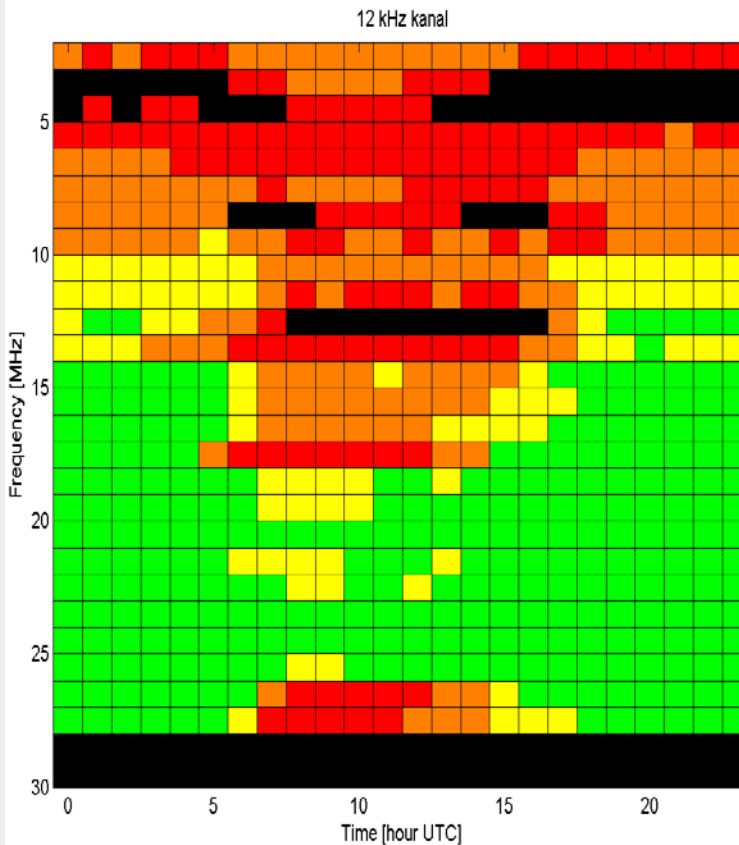
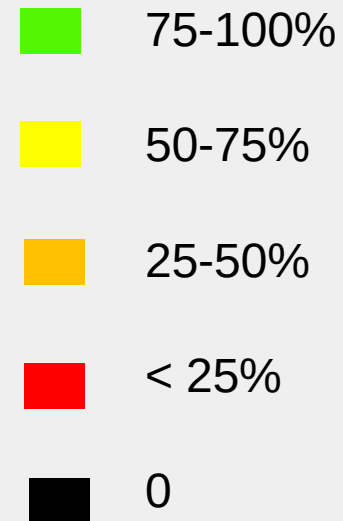
Fixed and Mobile, Horizontal, Stockholm archipelago

Contiguous

Channel-bonded over 48 kHz

Each block
1 MHz * 1 hour

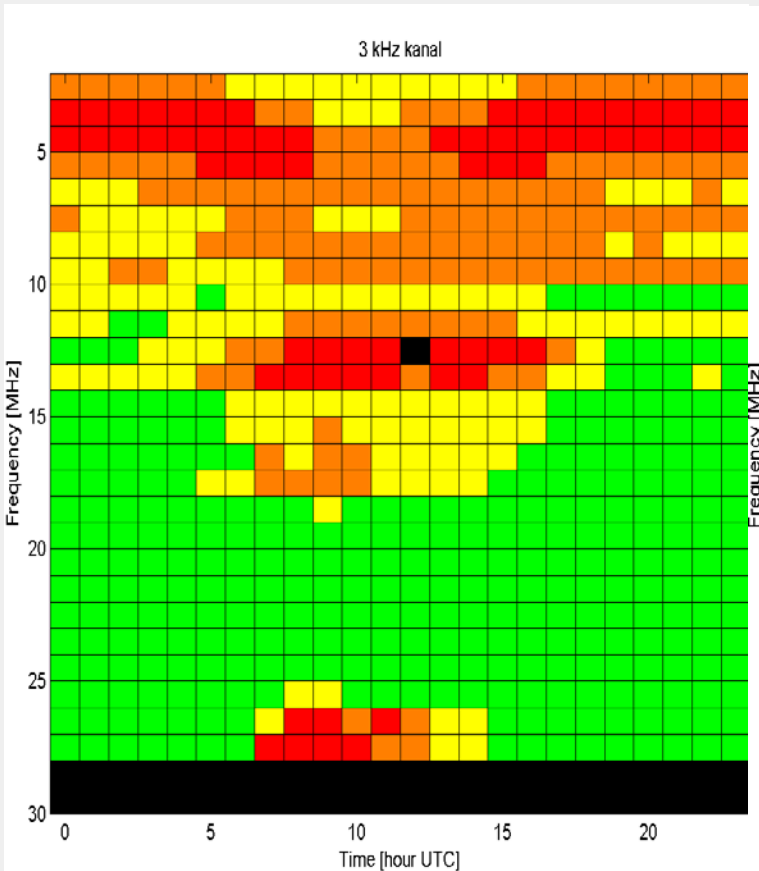
Unoccupied
channels



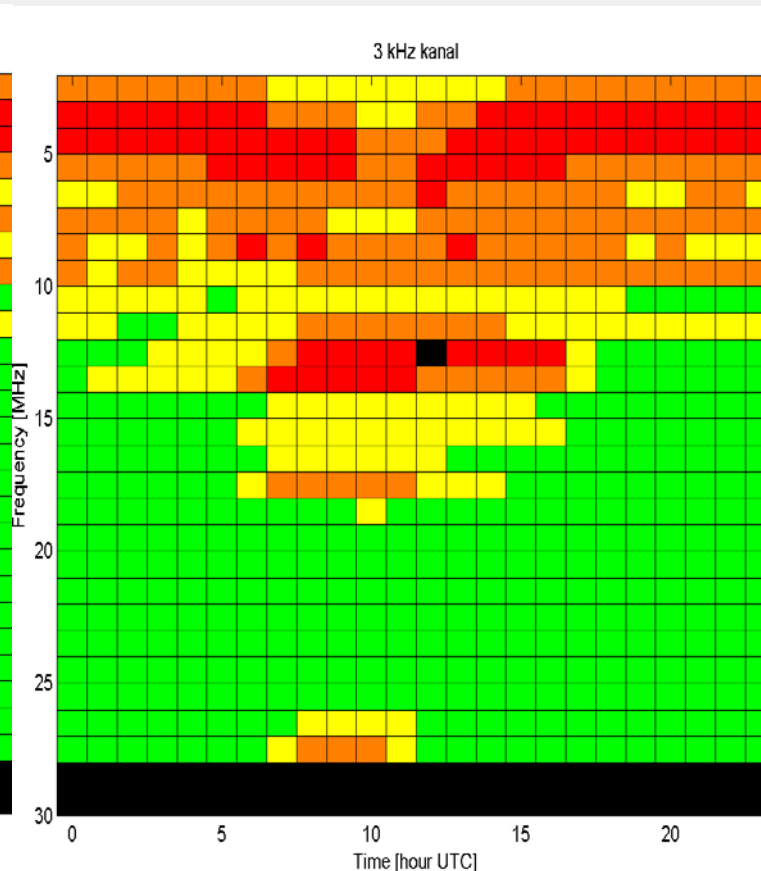
Antenna 3 kHz Channels

Fixed and Mobile, Stockholm archipelago

Horizontal

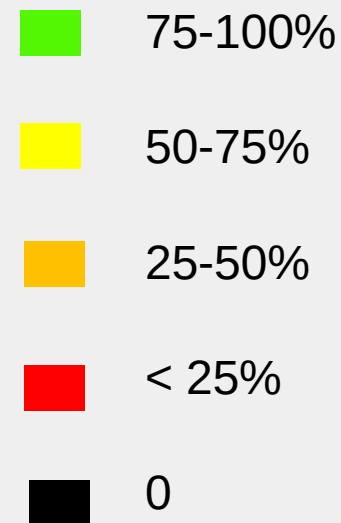


Vertical

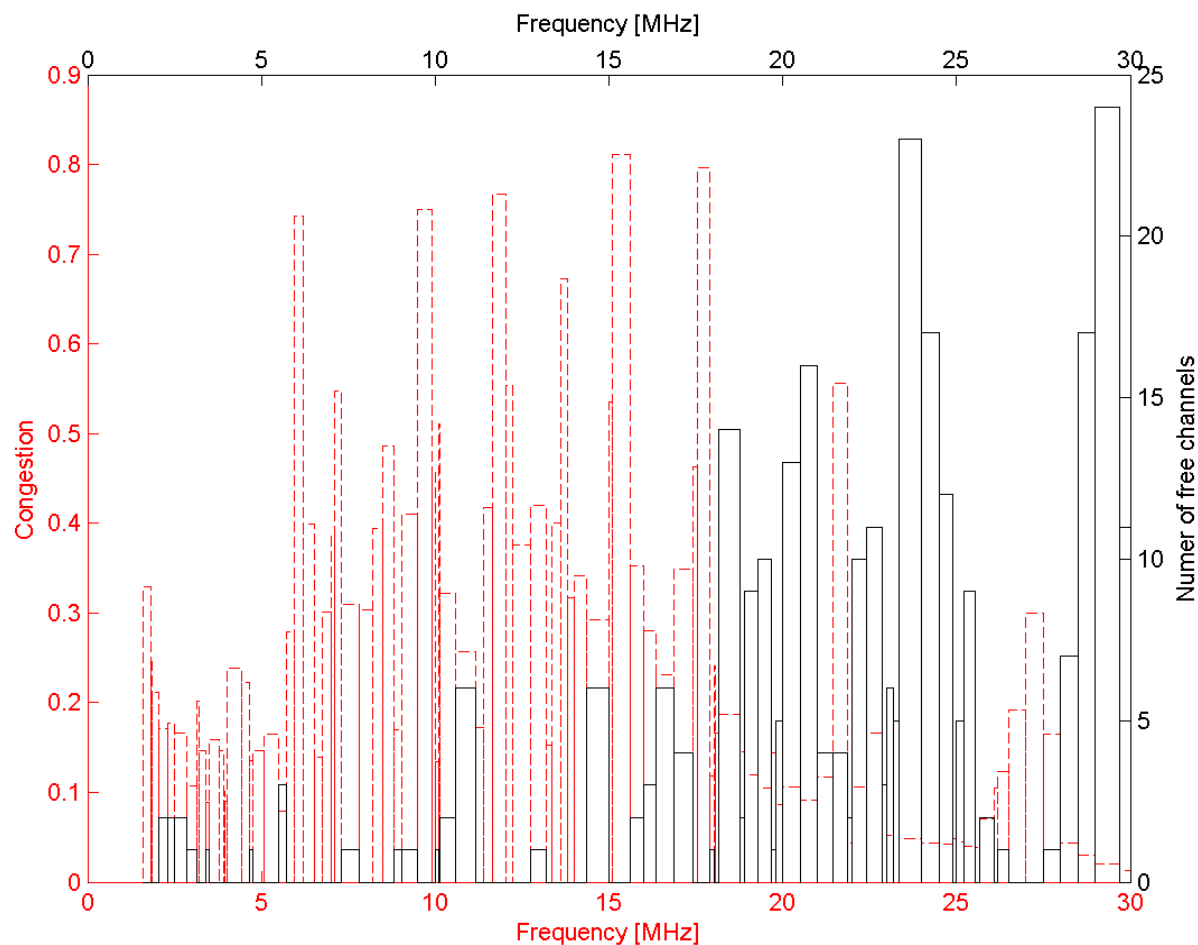


Each block
1 MHz * 1 hour

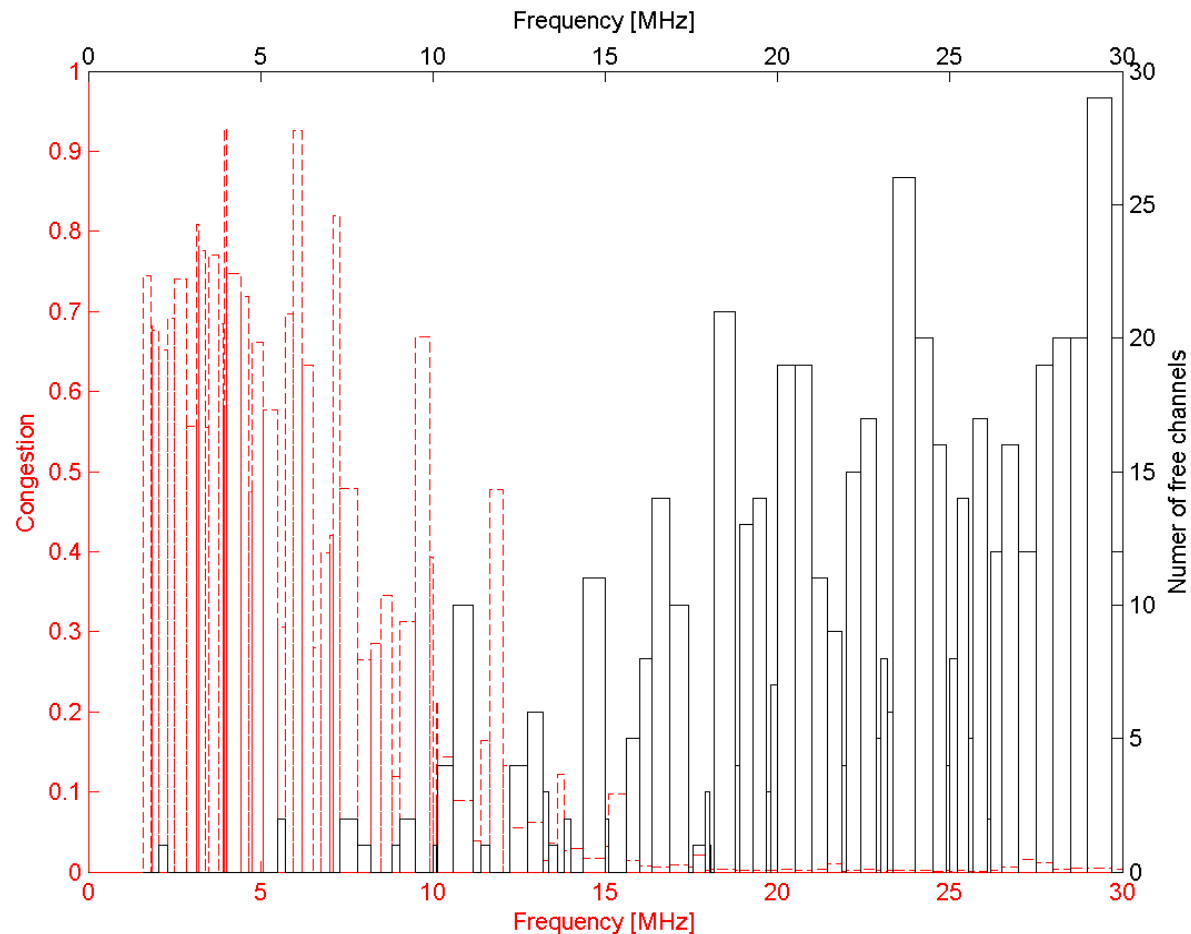
Unoccupied
channels



Laycock-Gott vs. Occupancy (Day)



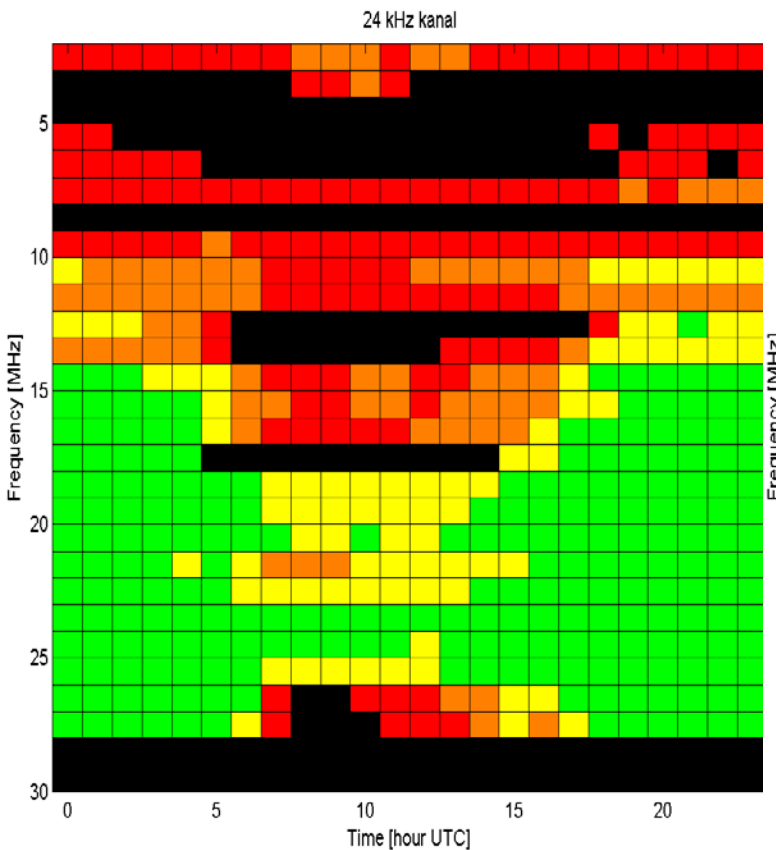
Laycock-Gott vs. Occupancy (Night)



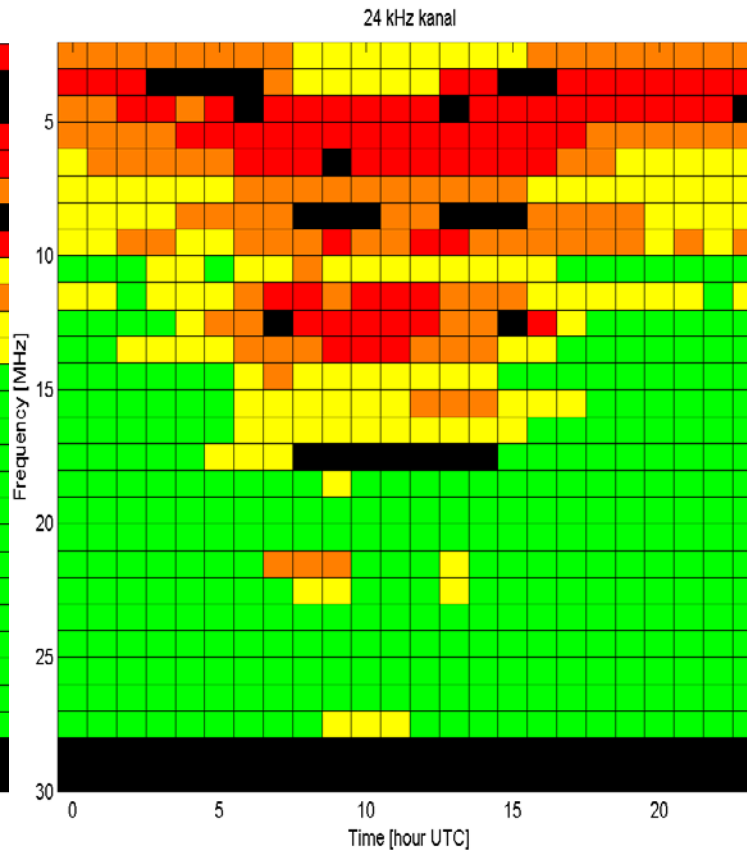
Noise level, 24 kHz Channels

Fixed and Mobile, Horizontal, Stockholm archipelago

10 dB Threshold

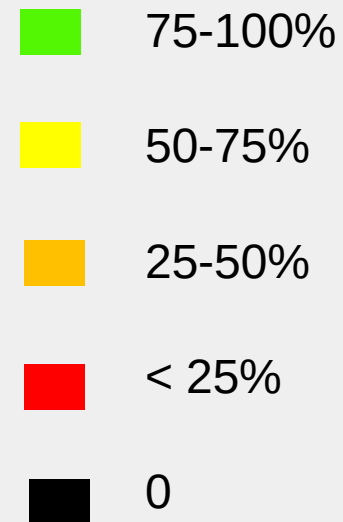


25 dB Threshold



Each block
1 MHz * 1 hour

Unoccupied
channels



Unoccupied 3 kHz Channels

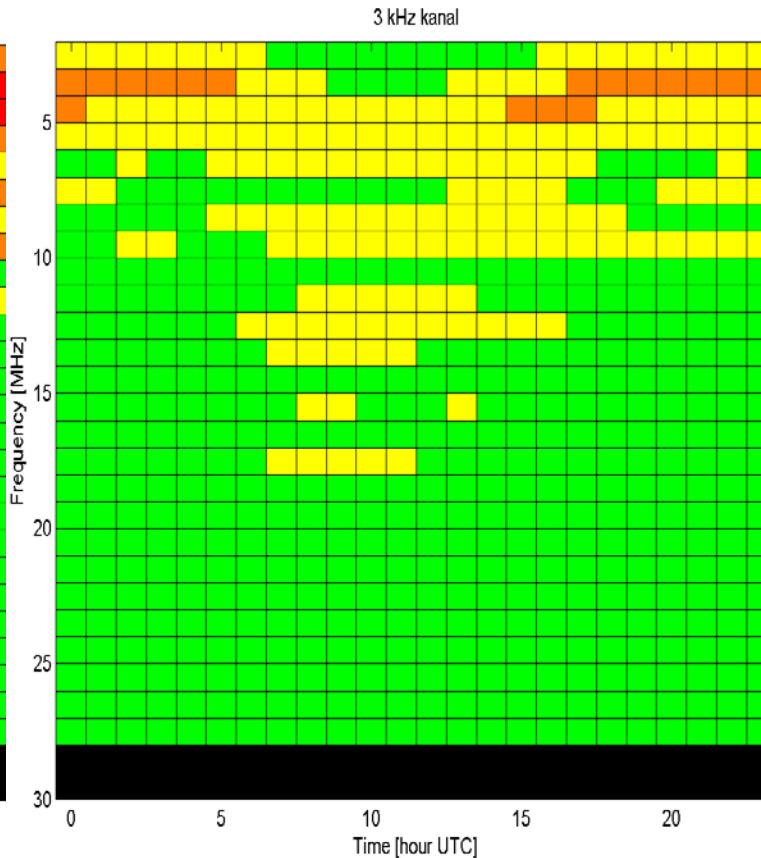
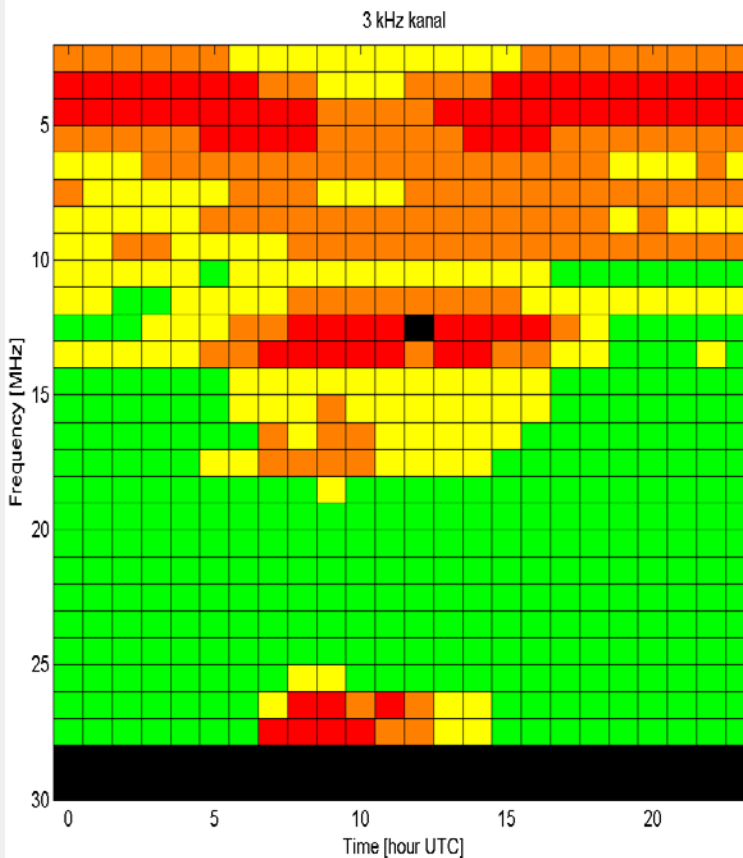
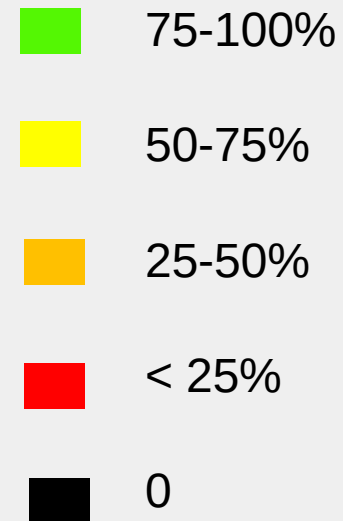
Fixed and Mobile, Horizontal, Stockholm archipelago

Occ. < 5 % on 9 days out of 10

Occ. < 50 % on 9 days out of 10

Each block
1 MHz * 1 hour

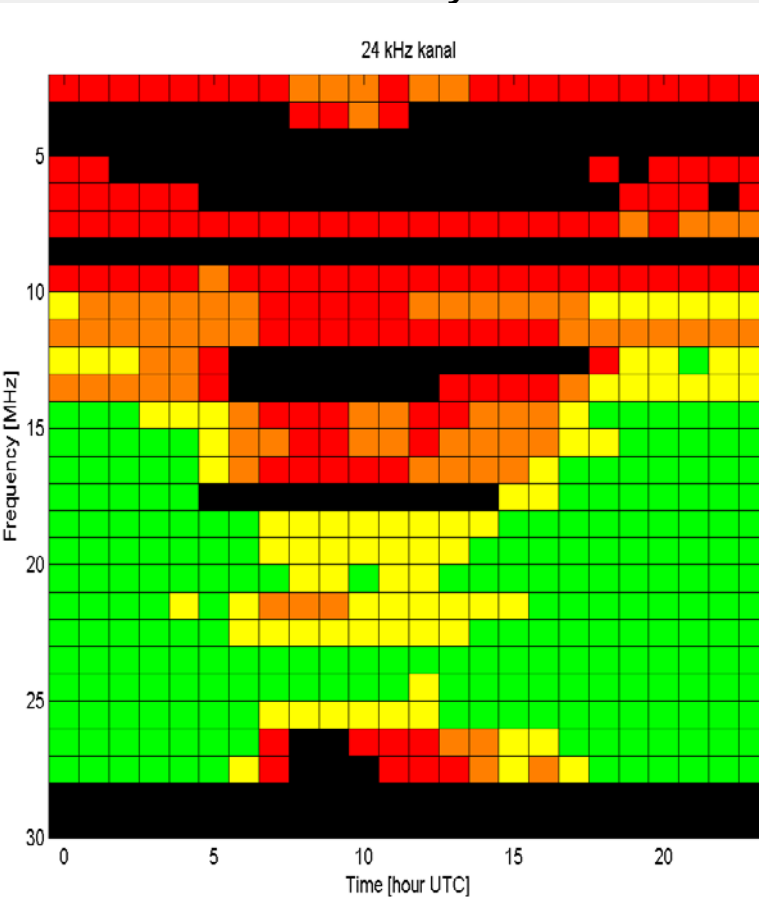
Unoccupied
channels



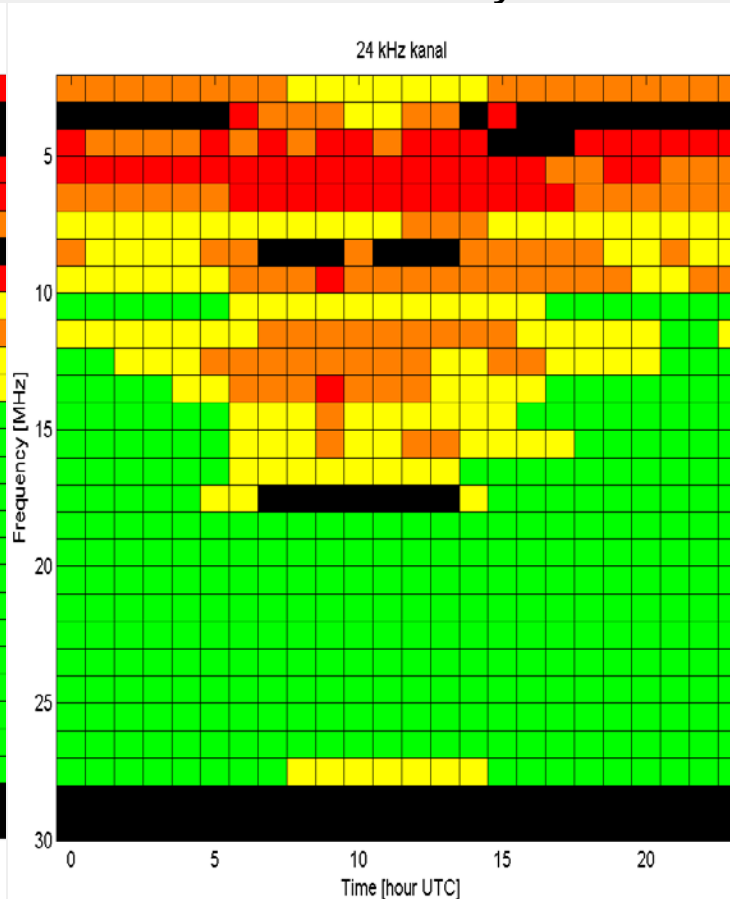
Unoccupied 24 kHz Channels

Fixed and Mobile, Horizontal, Stockholm archipelago

Occ. < 5 % on 9 days out of 10

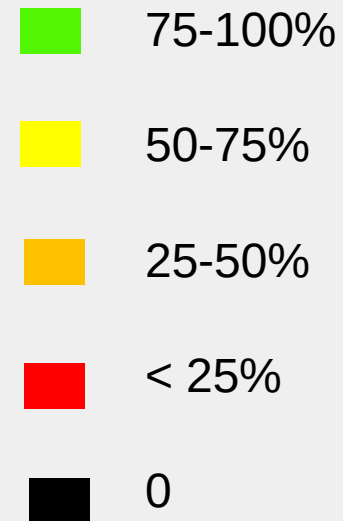


Occ. < 50 % on 9 days out of 10



Each block
1 MHz * 1 hour

Unoccupied
channels



Unoccupied 12 kHz Channels

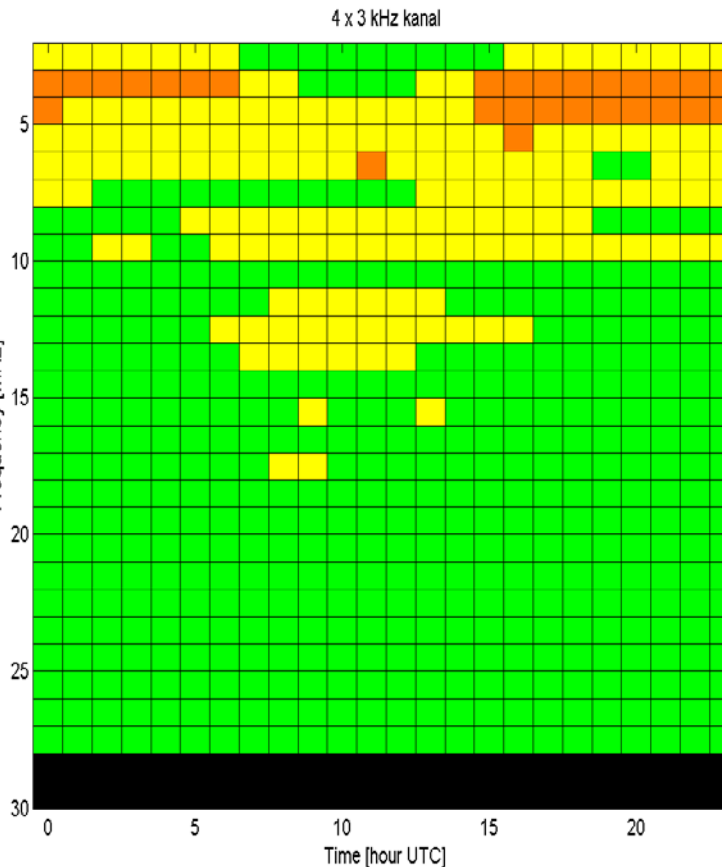
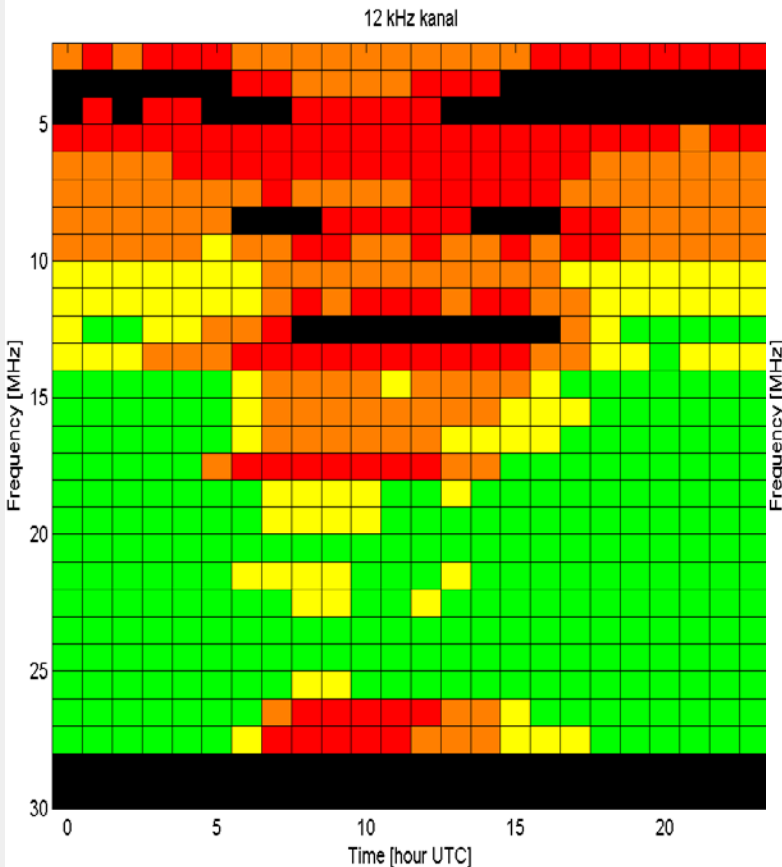
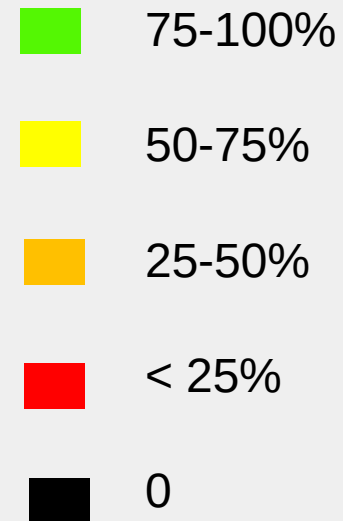
Fixed and Mobile, Horizontal, Stockholm archipelago

Occ. < 5 % on 9 days out of 10

Occ. < 50 % on 9 days out of 10

Each block
1 MHz * 1 hour

Unoccupied
channels



Conclusion (for Northern Europe)

- Occupancy will reduce capacity for fix frequency wideband HF
- Frequency adaptive system has potential for better wideband capacity.
- Channel-bonded approach improve but don't solve the Occupancy problem
- Antenna polarization insignificant for Occupancy statistic

Conclusion cont.

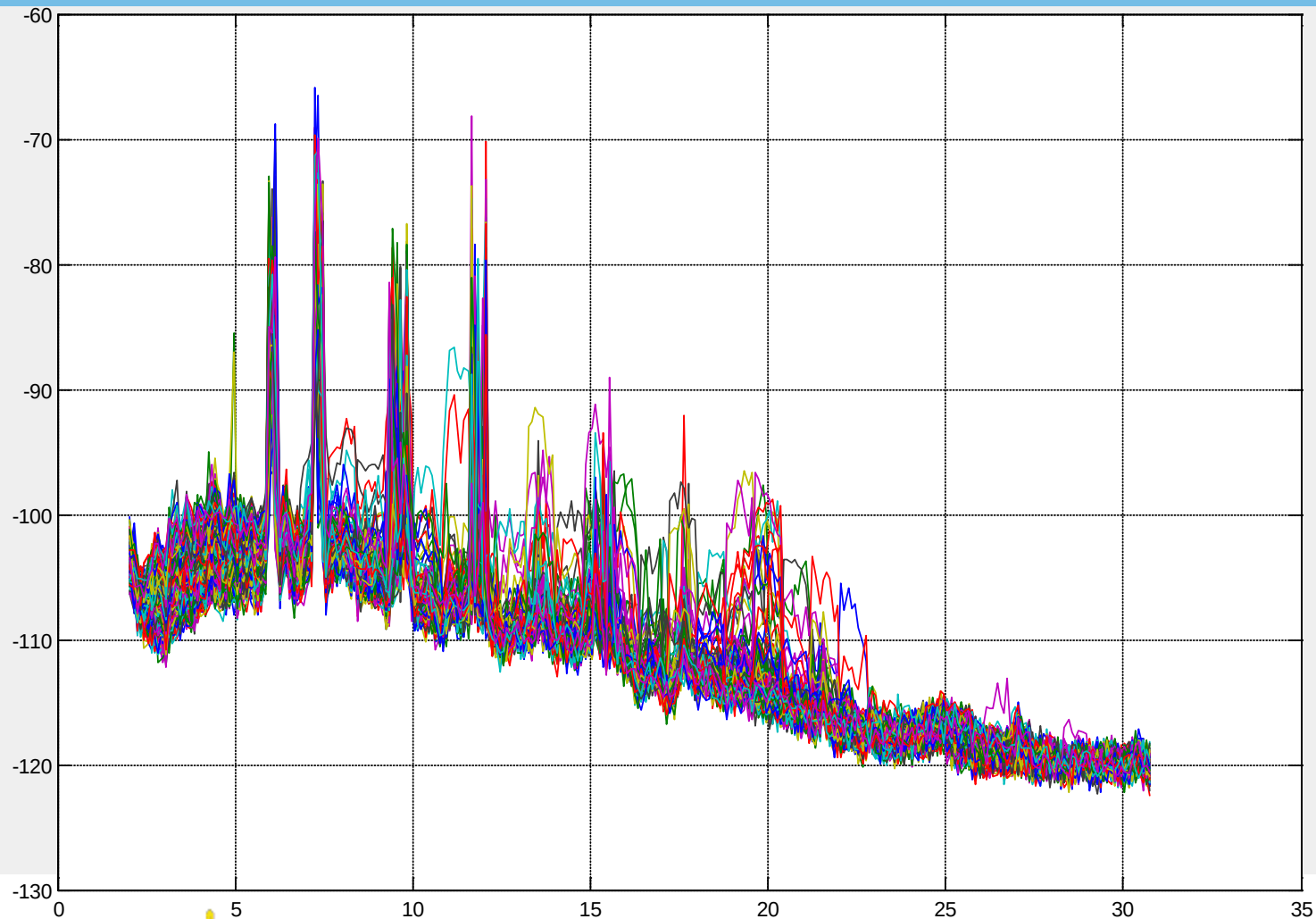
- Laycock-Gott congestion model still valid. By adding a “translation module” (Congestion → Occupancy) it will be a useful tool in simulation of HF net in Northern Europe
- A receiver in a noisy environment will classify more channels as unoccupied compared to a receiver at a quiet location. In an adaptive system algorithms must take this problem into account.
- Difficult frequency planning for fix frequency 24 kHz channels

Questions?

Measurement system



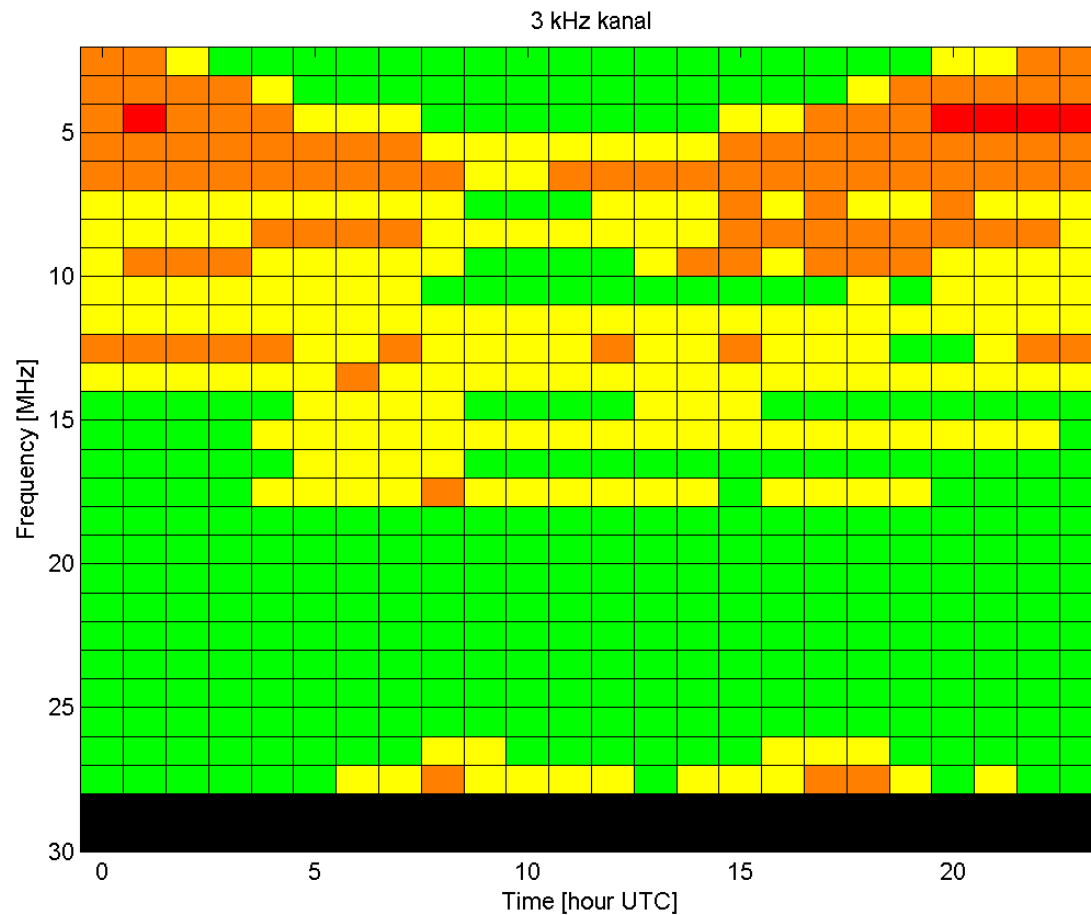
BD Noise estimation





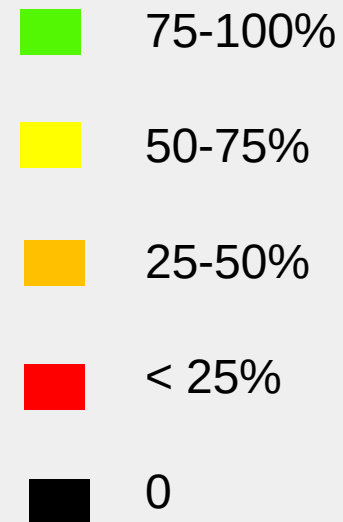
Unoccupied 3 kHz Channels

Fixed and Mobile, Horizontal, Linköping



Each block
1 MHz * 1 hour

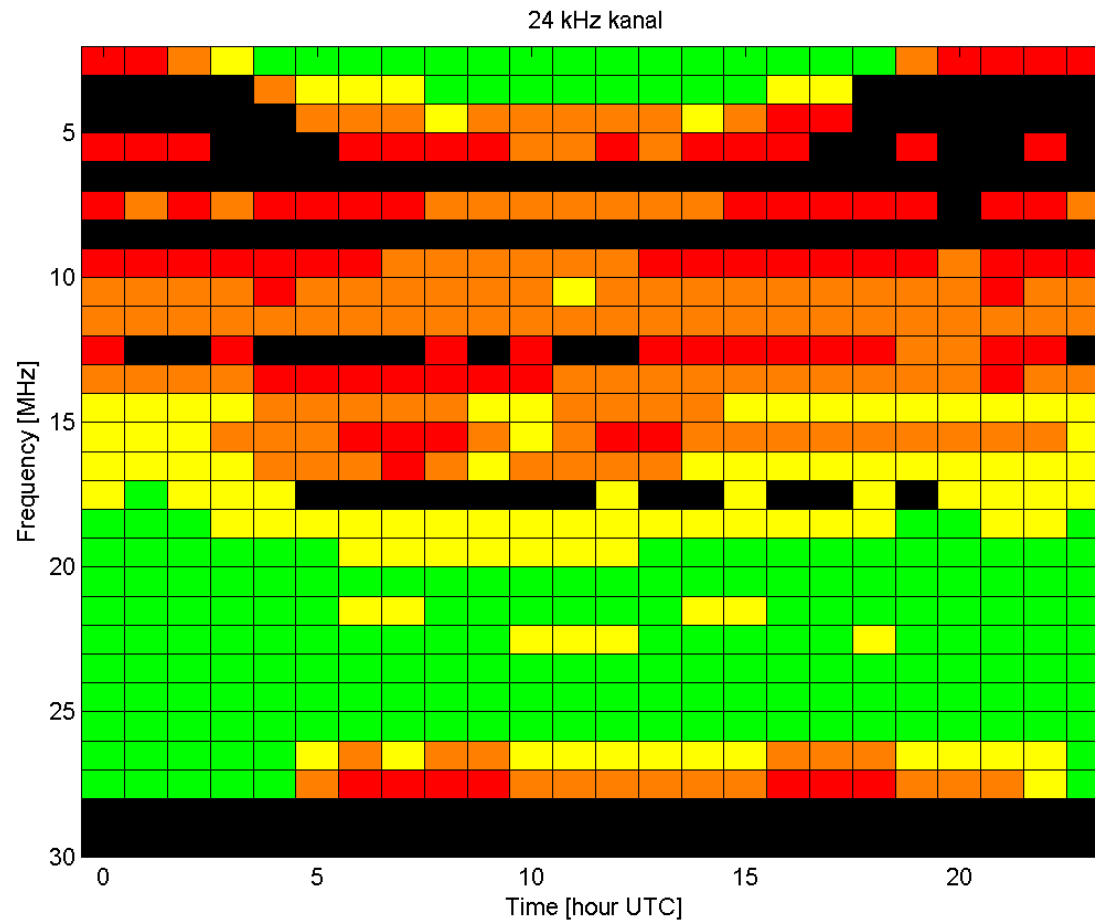
Unoccupied
channels





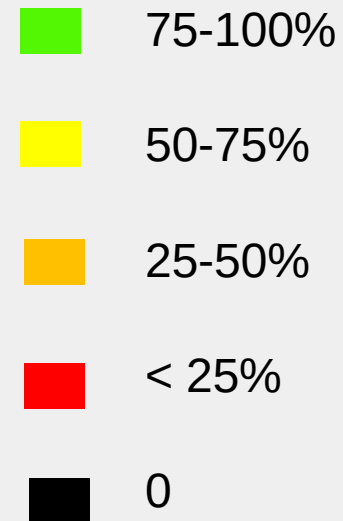
Unoccupied 24 kHz Channels

Fixed and Mobile, Horizontal, Linköping



Each block
1 MHz * 1 hour

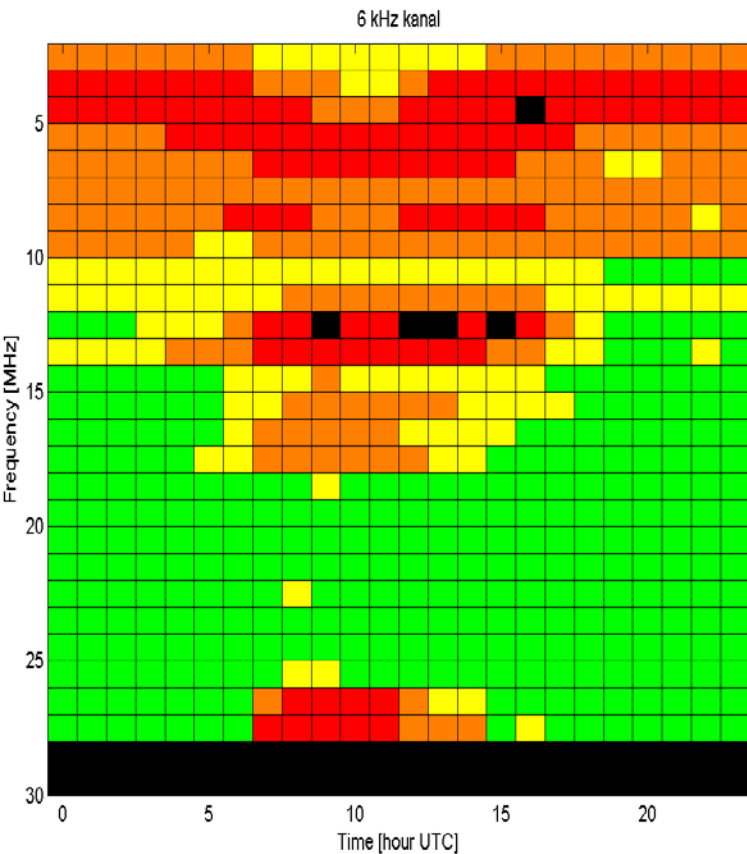
Unoccupied
channels



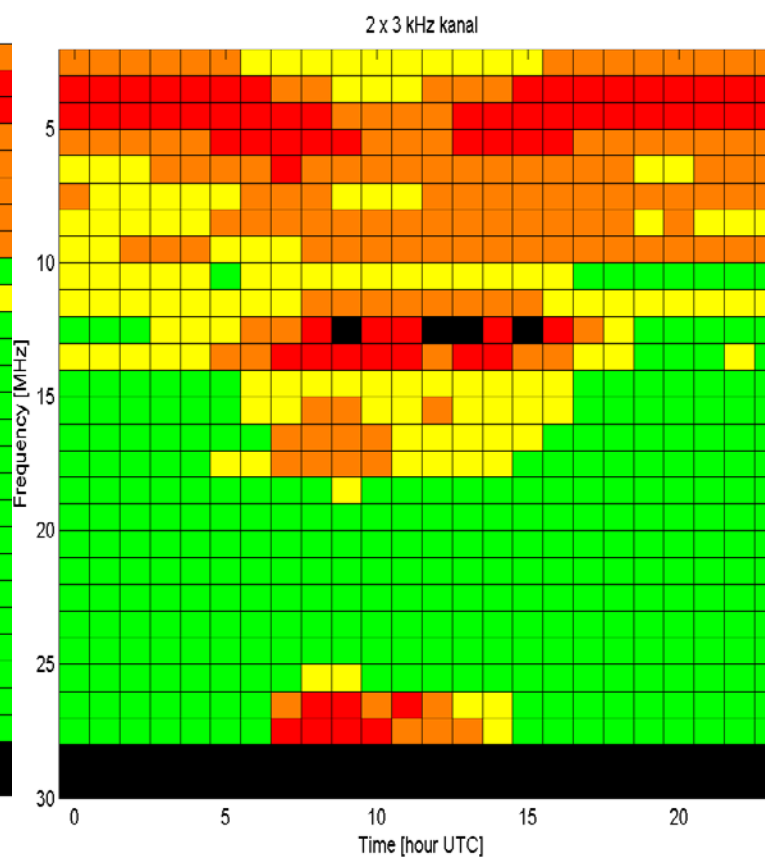
Unoccupied 6 kHz Channels

Fixed and Mobile, Horizontal, Stockholm archipelago

Contiguous

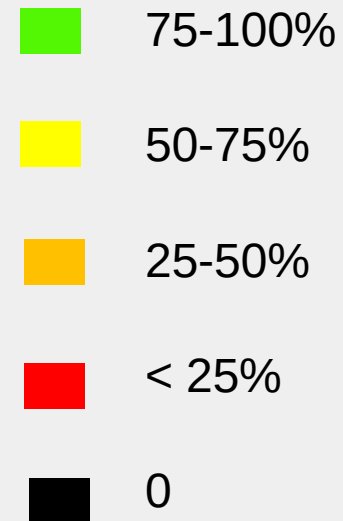


Channel-bonded over 24 kHz



Each block
1 MHz * 1 hour

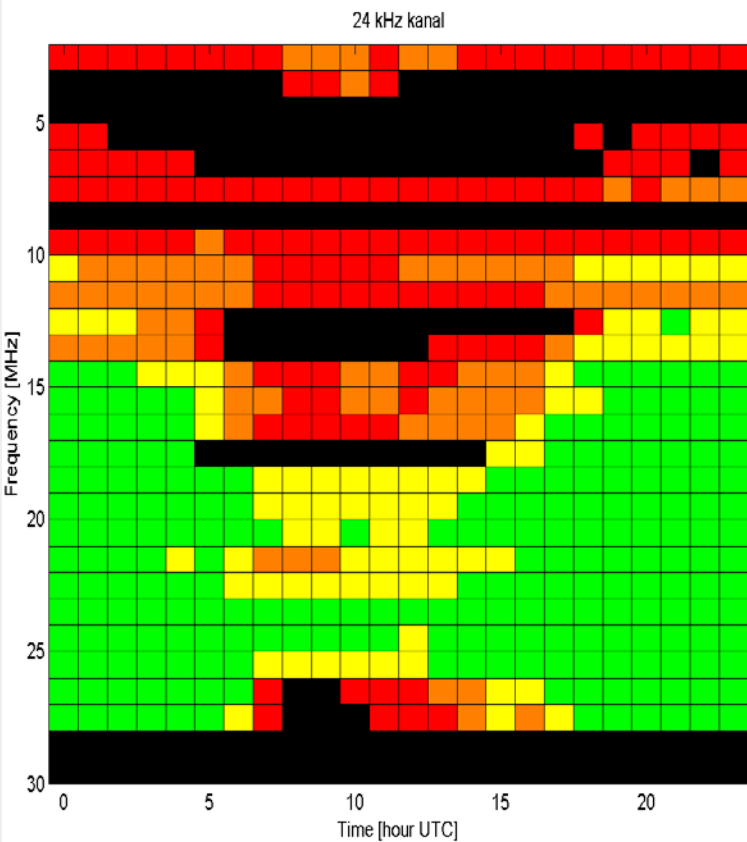
Unoccupied
channels



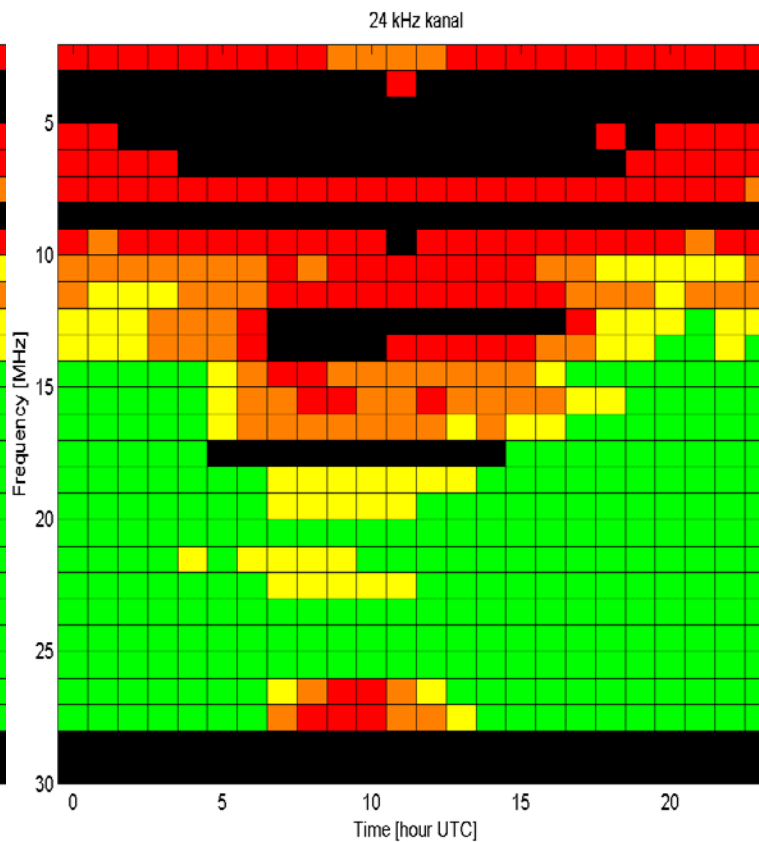
Antenna, 24 kHz Channels

Fixed and Mobile, Stockholm archipelago

Horizontal

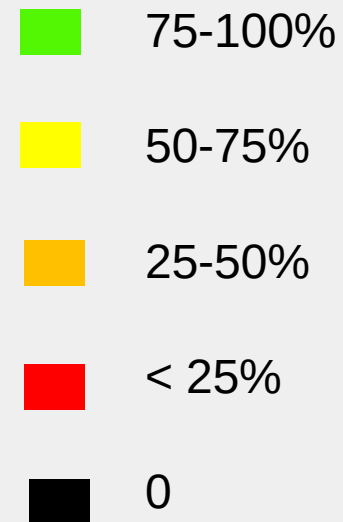


Vertical



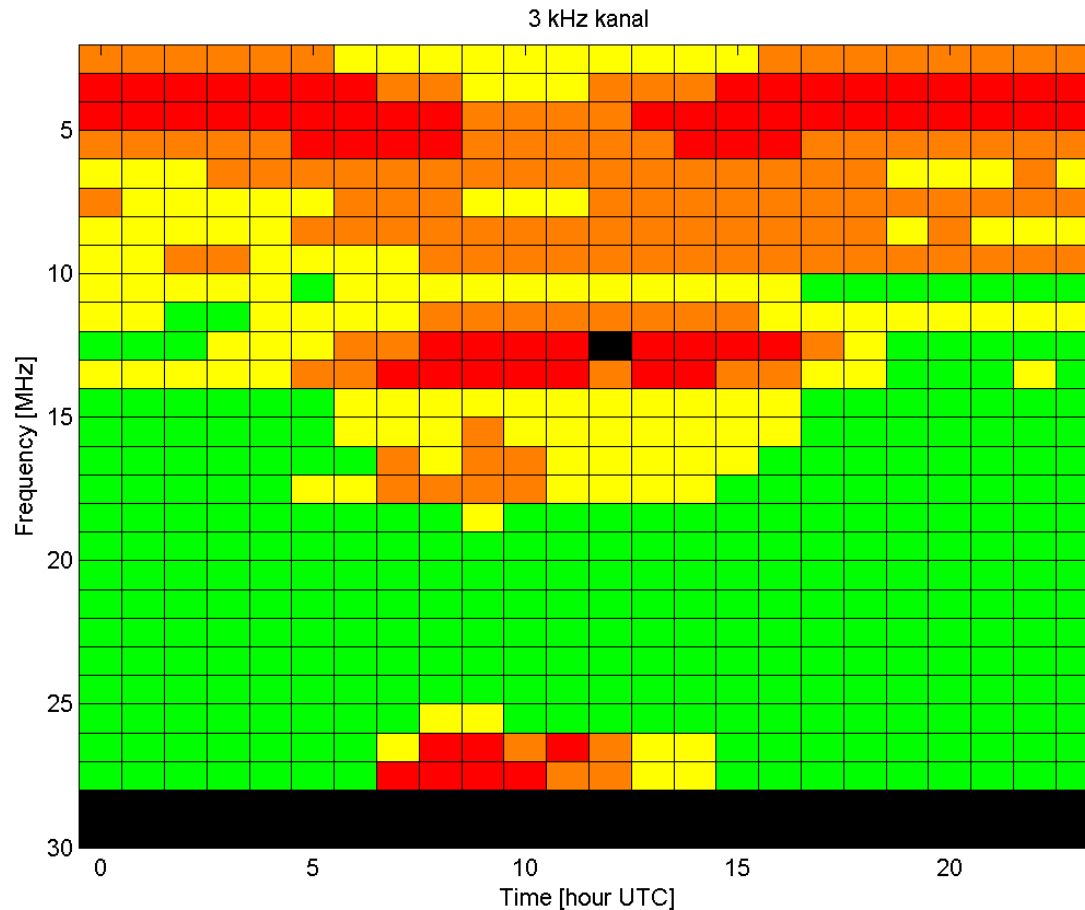
Each block
1 MHz * 1 hour

Unoccupied
channels



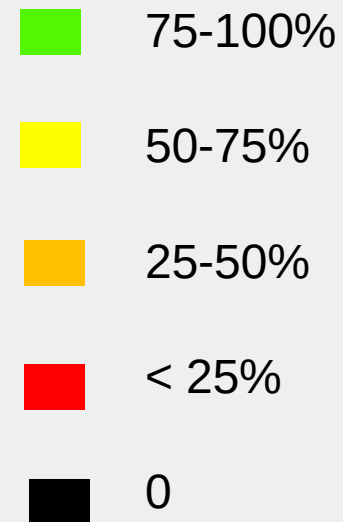
Unoccupied 3 kHz Channels

Fixed and Mobile, Horizontal, Stockholm archipelago



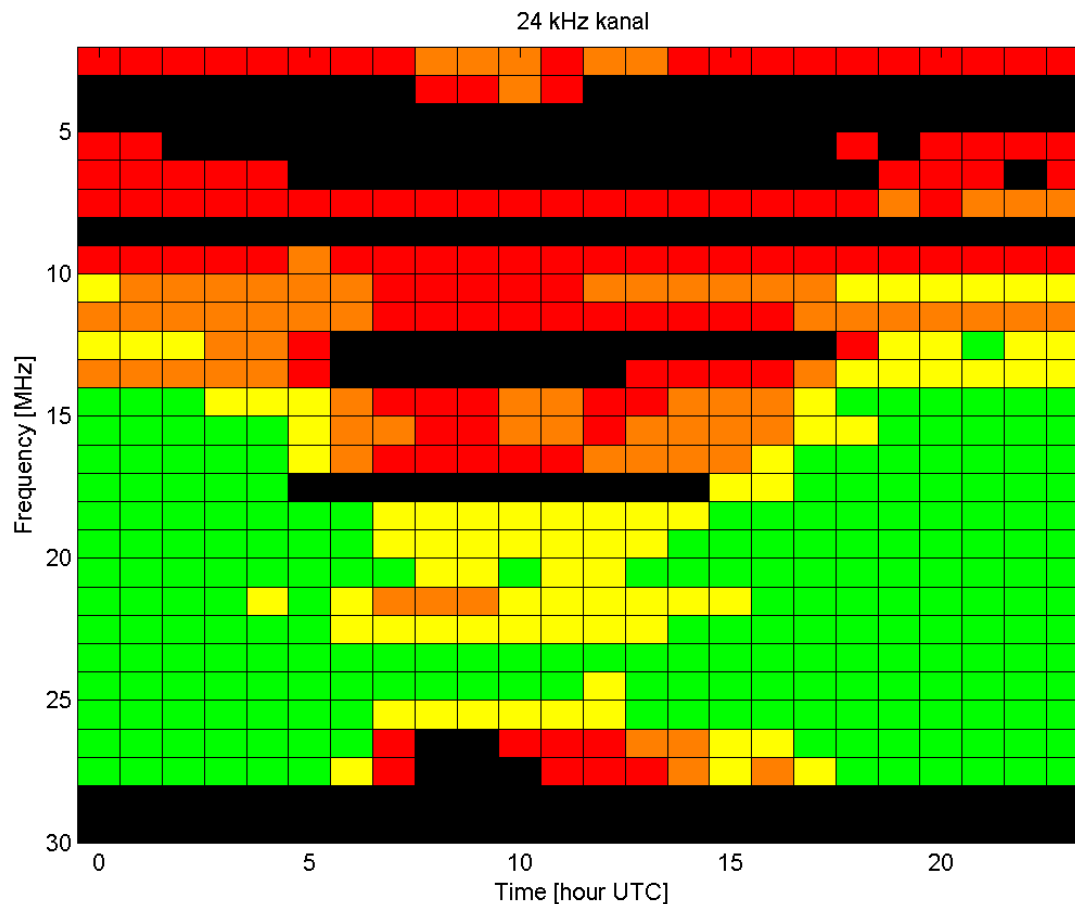
Each block
1 MHz * 1 hour

Unoccupied
channels



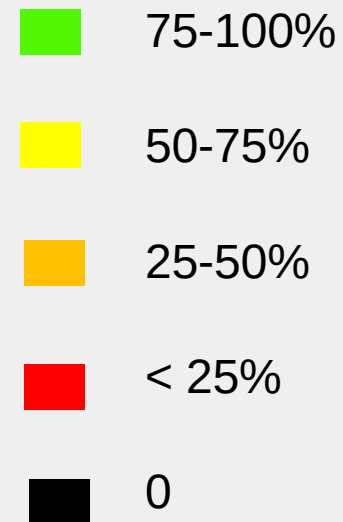
Unoccupied 24 kHz Channels

Fixed and Mobile, Horizontal, Stockholm archipelago



Each block
1 MHz * 1 hour

Unoccupied
channels



STANAG 4538 Occupancy detection

(NU) TABLE 4.6.4-1. Synchronous-mode occupancy detection requirements

Waveform	AWGN 3 kHz SNR (dB)	Minimum Required Detection Probability
2G-ALE	0	50%
	6	90%
Robust LSU (BW0)	-9	50%
	-6	95%
HDL (BW2)	0	30%
	6	70%
single sideband (SSB) Voice	6	50%
	9	75%
MIL-STD-188-110 or FED-STD-1052 PSK modem	0	30%
	6	70%
STANAG 4285 or STANAG 4529 PSK modem	0	30%
	6	70%

PERSEUS specifications

Technical specifications

Frequency Coverage	10 kHz - 30 MHz (tunable 0 - 40 MHz)
Modes	Software-defined, AM, S-AM, SSB, RTTY, CW, FMN and more
Sensitivity	0,39 µV in SSB at 10 dB S+N/N
Selectivity	Software-defined, Stop Band attenuation >100 dB
Image Rejection	90 dB
Input IP3	+31 dBm
Dynamic Range (IMD3)	100 dB (SSB, 2.4 kHz); 104 dB (CW, 500 Hz)
Spurious free Dynamic Range	110 dB
Blocking Dynamic Range	125 dB (CW, 500 Hz)
MDS (Minimum Detectable Signal)	-131 dBm (bandwidth 500 Hz, Preamp On) -124 dBm (bandwidth 2.4 kHz, Preamp On)
ADC Clipping	-3 dBm, resp. -6 dBm (Preamp On)
Attenuator	0, 10, 20, 30 dB

Low pass filter	0-1.7 MHz
Band pass filters	1,7-2,1, 1,1-3,0, 3,0-4,2, 4,2-6,0, 6,0-8,4 8,4-12,0, 12-17, 17-24, 24-32 MHz sowie OFF (0-40 MHz im Breitband-Modus)
ADC (Analogue/Digital-Converter)	14 bit, 80 Ms/s with internal Dither Generator
DDC (Digital Downconverter)	FPGA (Xilinx Spartan III XC3S250E)
PC-Schnittstelle	USB2.0, 480 Mbit/s
Sampling Rate(Output)	125 Ks/s, 250 Ks/s, 500 Ks/s, 1 MS/s, 2 MS/s
Output-Bandwidth	100/200/400/800/1600 kHz (bei Alias-Unterdrückung von 130 dB)
Output Signal	24 bit/sample I-Q/Pair
PC-Requirements	2,5 GHz Dual Core Processor, 1 GB RAM
Power Supply requirements	+5V DC +/-5% - 700 mA
Universal-Power Supply	f. 110/240V AC (included)
Cabinet	Aluminium Enclosure, 110 x 36 x 185 mm (B x H x D)
Operating Temperature Range	0-40 °C
Frequency Accuracy	±1 ppm after calibration
Weight	380 g