ITU Workshop
Spectrum Monitoring Today and Tomorrow.
Tasks, Problems and Solutions
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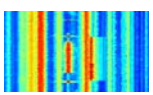
Frequency Channel Occupancy measurements (ITU SM.1793) using Frequency Band Registrations (SM.1809)

By: Henk Stel

©  Spectrum Monitoring Technology Advisors

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Frequency Channel Occupancy Measurements (ITU SM.1793)

Content:

- Frequency channel and band measurements
- Reasons for FCO
- Measurement methods
  - continuous
  - Systematic
  - Monte Carlo
- Important parameters
- Philosophy
- Increase of re-visit time
- Data collection using ITU SM.1809
- Process measured field strength
- Occupancy in:
  - color plot
  - table
  - HF bands
- Occupancy verses availability
- Demo FCO/website

Frequency Channel and Band Measurements

frequency **band** occupancy measurements (FBO) means:

Measuring a frequency band from F-start to F-stop in a number of steps (bins).

Frequency distance between consecutive frequency steps (channels) is always the same.

(See previous presentation ITU SM.1809)

Frequency Channel and Band Measurements

Frequency **Channel** Occupancy (FCO) measurements means:

The receiver is measuring a number of channels. The frequency distance between the consecutive steps is not necessarily the same.

Frequency Channel Occupancy Measurements

Six reasons for FCO:

Measure Occupancy to

- Serve new customers for new frequency
- Verify complaints (co-channel users)
- Determine spectrum is used efficiently
- Detect trends in spectrum usage (repeat)
- Publish traffic figures spectrum usage
- Check emergency channels not being used for other purposes.

Frequency Channel Occupancy Measurement Methods

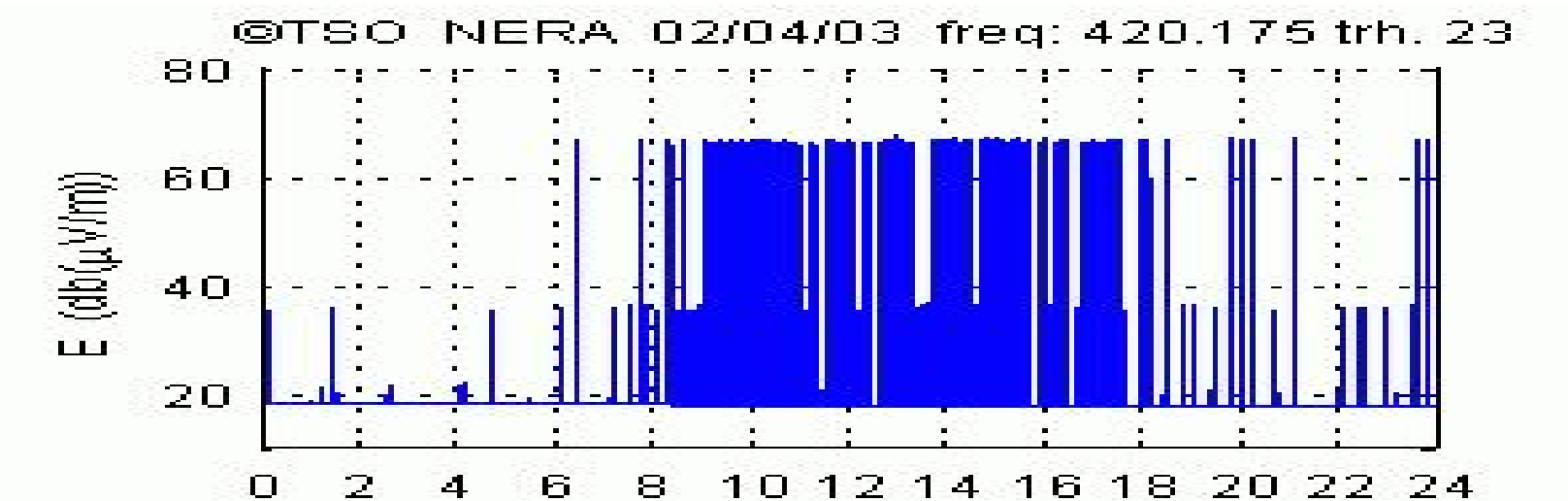
1. Continuous Measurements.
2. Systematic Measurements.
3. Random (Monte Carlo) Measurements.

1. Continuous Measurements
(on one channel)

- You get the exact occupancy during the measurement.
- You can predict the future occupancy, but of course the reliability of that is not 100%.
- Using one measurement device, you can only measure one channel at a time.

1. Continuous Measurements

example of continuous measurements on one channel



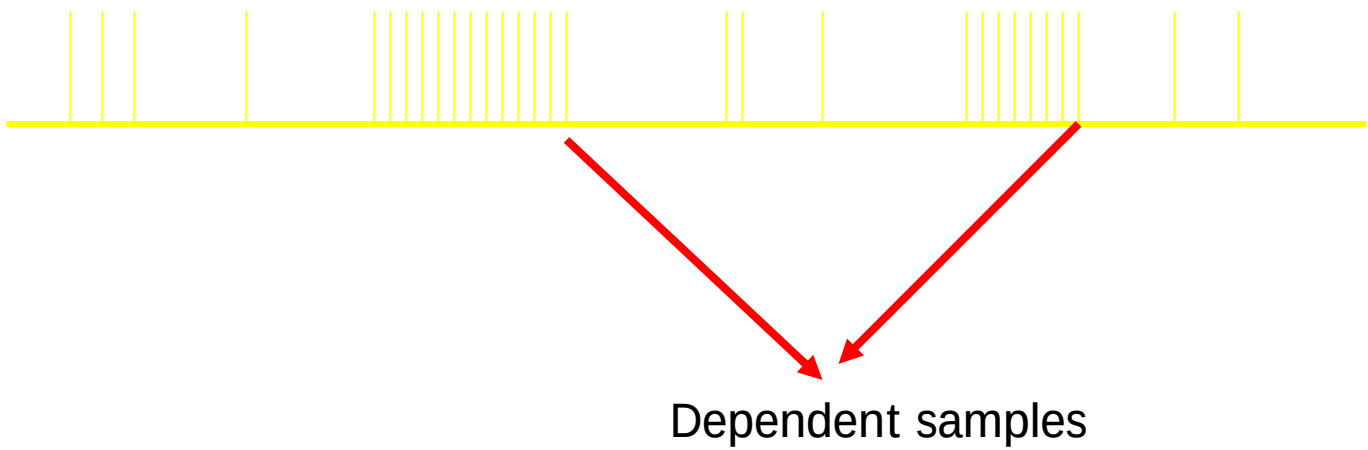
Two users active !

2. Systematic Measurements

- You can measure lots of channels in the same time period but lose some reliability.
- With short revisit times, successive measurement results are dependent, in other words the measurements are not done efficiently.
- Moreover the reliability of the occupancy estimation changes with the mean transmission time and therefore it will be unknown in most cases.
- With large enough revisit times, the measurements are independent, but if the revisit time is too large you might lose too much reliability.

2. Systematic Measurements

dependent and independent



2. Systematic Measurements

- To achieve a certain accuracy with a certain confidence level a certain number of samples is required. If the occupancy of a channel is 100%, just a few samples are required to determine this with a good accuracy. At low occupancies a larger number of samples is needed to achieve the same accuracy and confidence level.
- Fortunately, from spectrum management point of view, accurate measurement of low occupancies is not so critical.

3. Monte Carlo

- Channels are chosen randomly, which means samples are **in**dependent.
- Increase of number of channels with same accuracy.

Not further discussed in this presentation

Important Parameters

Important parameters:

- Threshold level
- Observation time
- Re-visit time (systematic measurements)
- Transmission length
- Duration of monitoring
- Resolution of measurements
- Accuracy

FCO ITU-R SM.1793

Re-visit time:

The time taken to visit all the channels to be measured (whether or not occupied) and return to the first channel

(1 second is often a good re-visit time for ITU-R SM.1536 measurements)

Sometimes also called: sweep or scan time

Frequency Channel and Band Measurements

Example of Frequency Channel Occupancy Measurements using ITU SM.1536:

Channel 1: 118.450 MHz

Channel 2: 465.125 MHz

Channel 3: 142.200 MHz

Channel 4: 118.475 MHz

Channel 5: 162.520 MHz

Channel 6: 162.500 MHz etc

Philosophy

Collect as much as data as possible by means of frequency band registrations and let software do the work.

- Processing
- Converting data into information
- Analysing
- Presentation

Use frequency band registrations for determining Frequency Channel Occupancy

Increase of Re-visit time

Traditional FCO as described in ITU-R recommendation SM.1536 (is also in line with Handbook section 4.4) recommends a very short re-visit time in order to achieve good accuracy . Preferable about 1 second (Nyquist rule)

99% is possible depending on transmission length and occupancy

Increase of Re-visit time

Do we always need a 99% accuracy or can 95 % also be sufficient?

The answer is that in most cases a little less accuracy is no problem

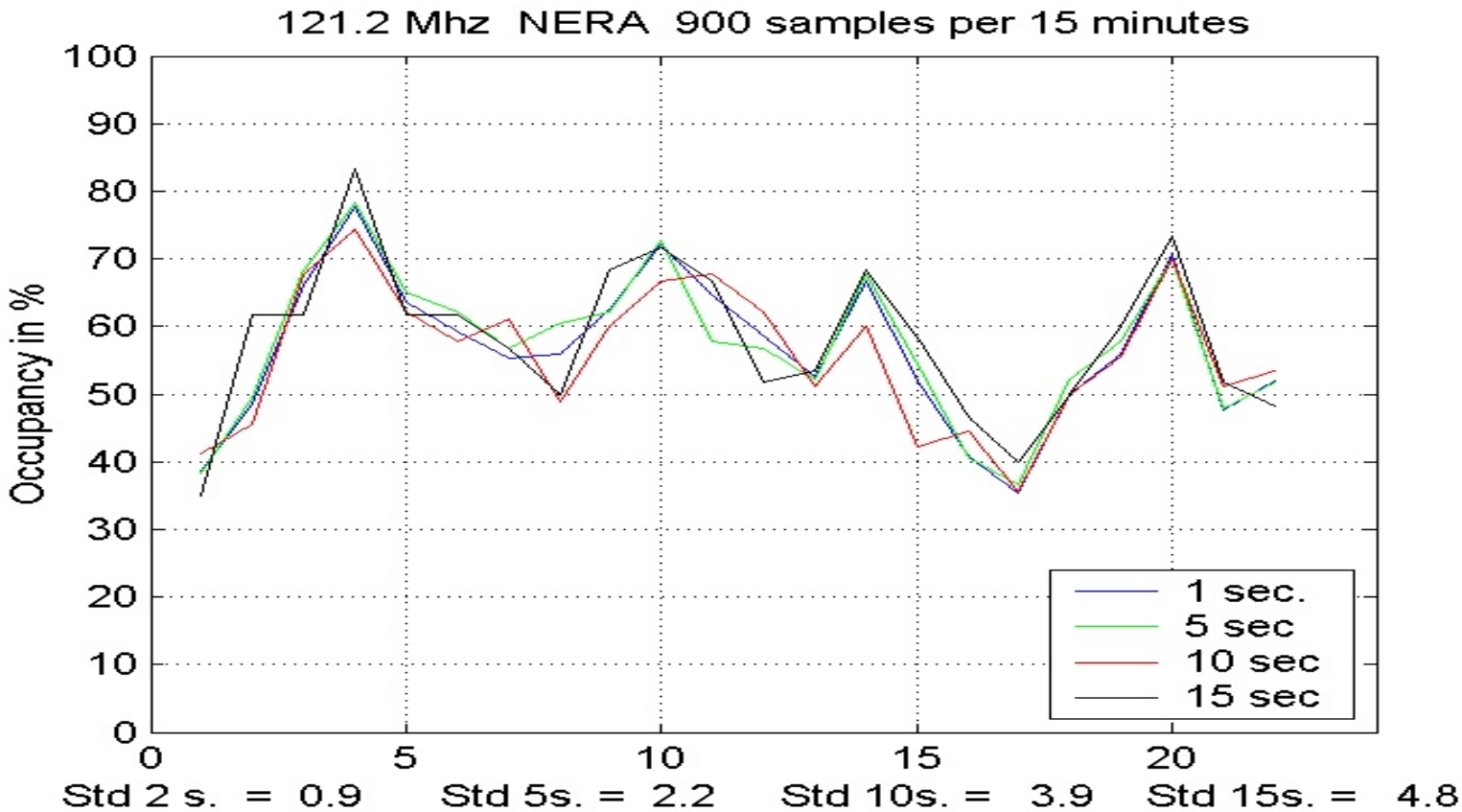
Increase of Re-visit time

Test measurements to determine effects of increased re-visit time by sampling with 1 second and simulating other re-visit times by skipping 1, 2, 5 ,10 samples.

1 Aeronautical channel (short transmission)

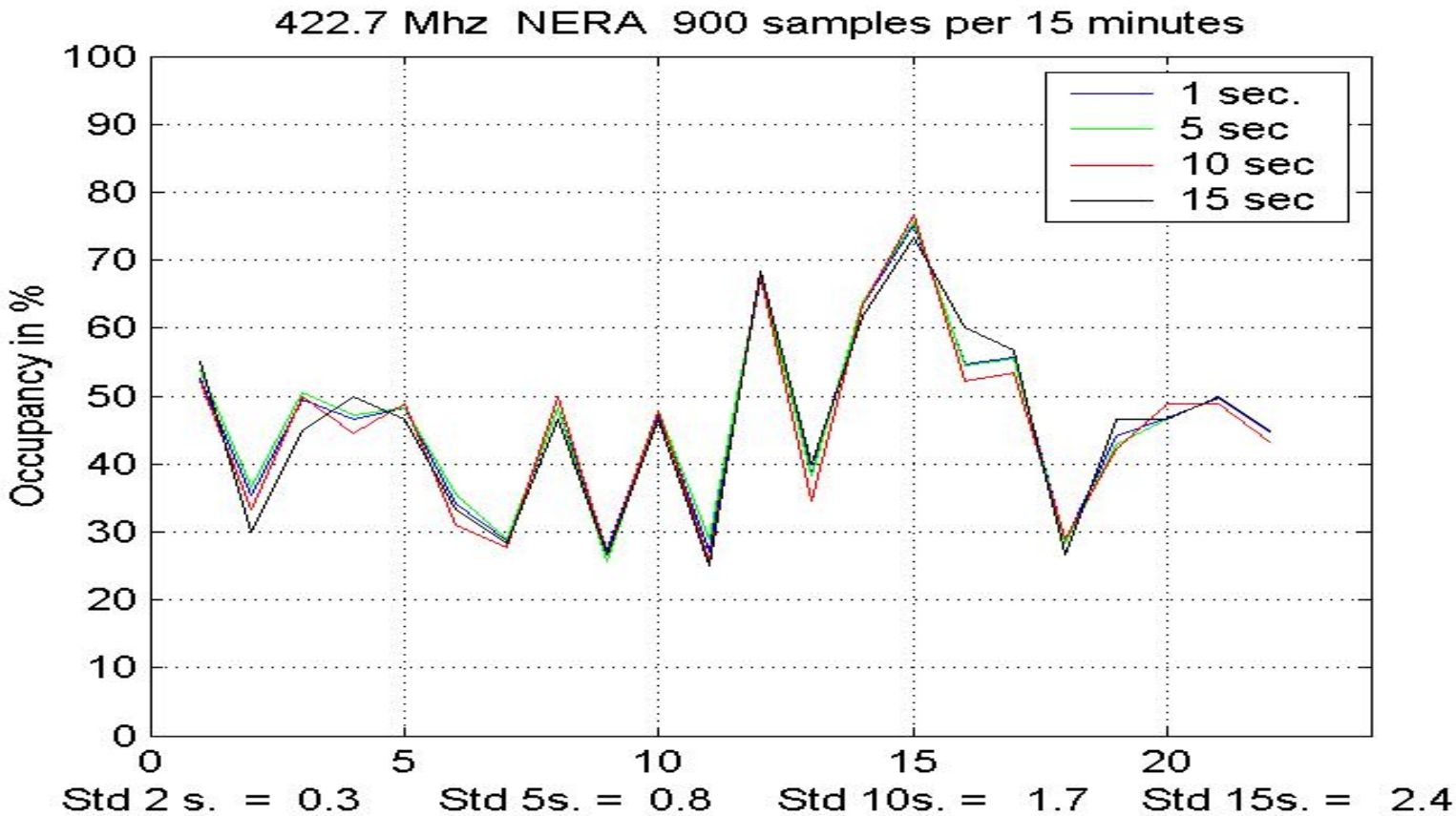
2 Duplex channel (long transmission)

Increase of Re-visit time



Aeronautical channel: short transmissions

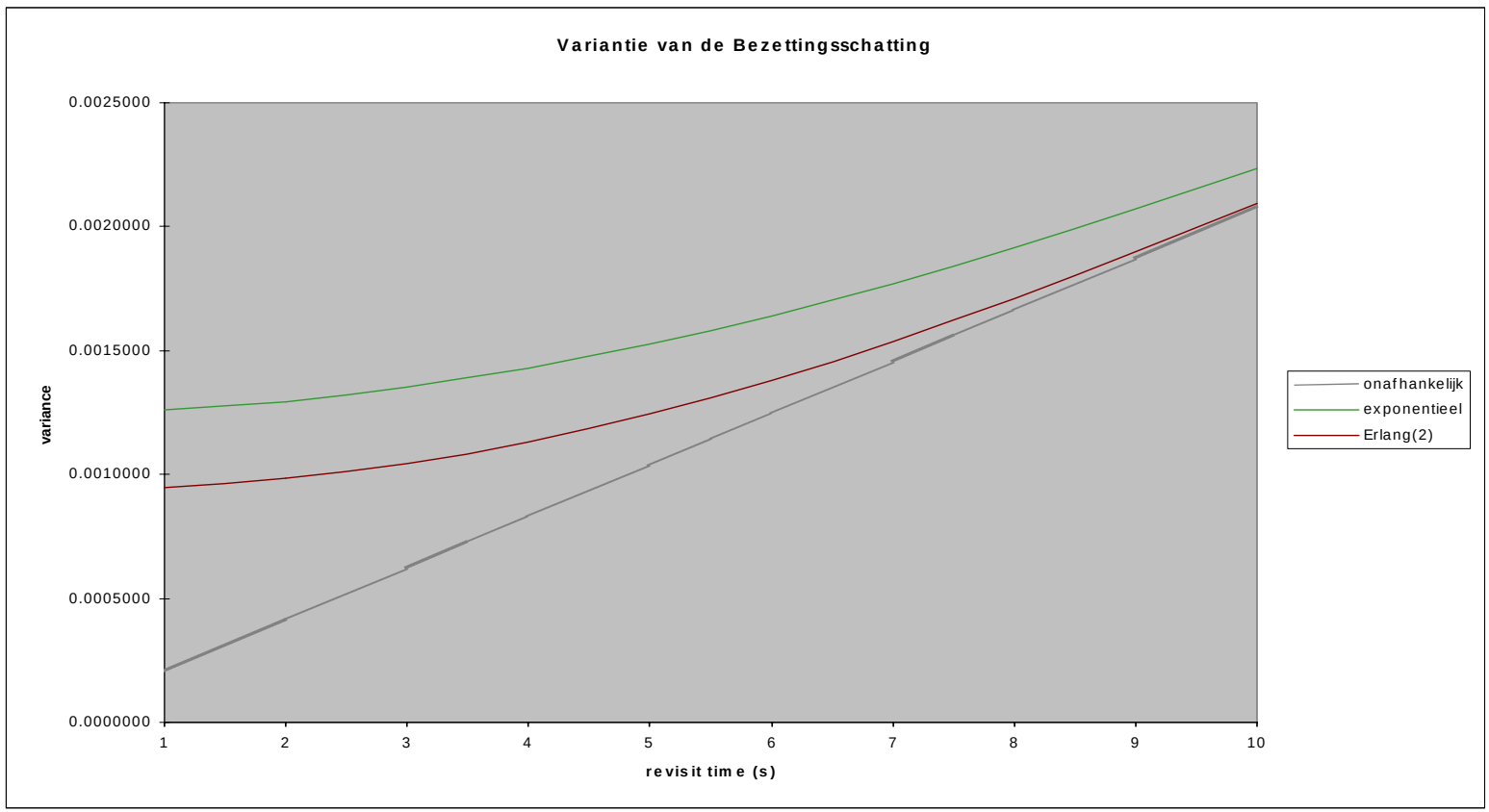
Increase of Re-visit time



Duplex channel: long transmissions

Increase of Re-visit time

Relation re-visit time and variance not linear



Increase of Re-visit time

Conclusion:

The re-visit time can increase considerable

without affecting the accuracy too much, so

Frequency Band registrations according ITU SM.1809 can be considered as Frequency Channel Occupancy measurements

See ITU SM.1793

With 1000 channels i.s.o. 125 for SM.1536

SM.1793 = 8 x SM.1536 (max.)

Data Collection using ITU SM.1809

Frequency band registrations

- Sweeptime 10 seconds
- Frequency steps (channels)1000 per scan
- Size of frequency band: depends
- Duration of monitoring: 24 hours

= Frequency Channel Occupancy measurements on 1000 channels in stead of 125 (HB 4.4)

Link to example file

Data collection

Aeronautical bands channel separation is 25 kHz

Channel 1	118.000	MHz
Channel 2	118.025	MHz
Channel 3	118.050	MHz
Channel 4	118.075	MHz
.....		
Channel 999	142.950	MHz
Channel 1000	142.975	MHz

Data collection

Strong relation between:

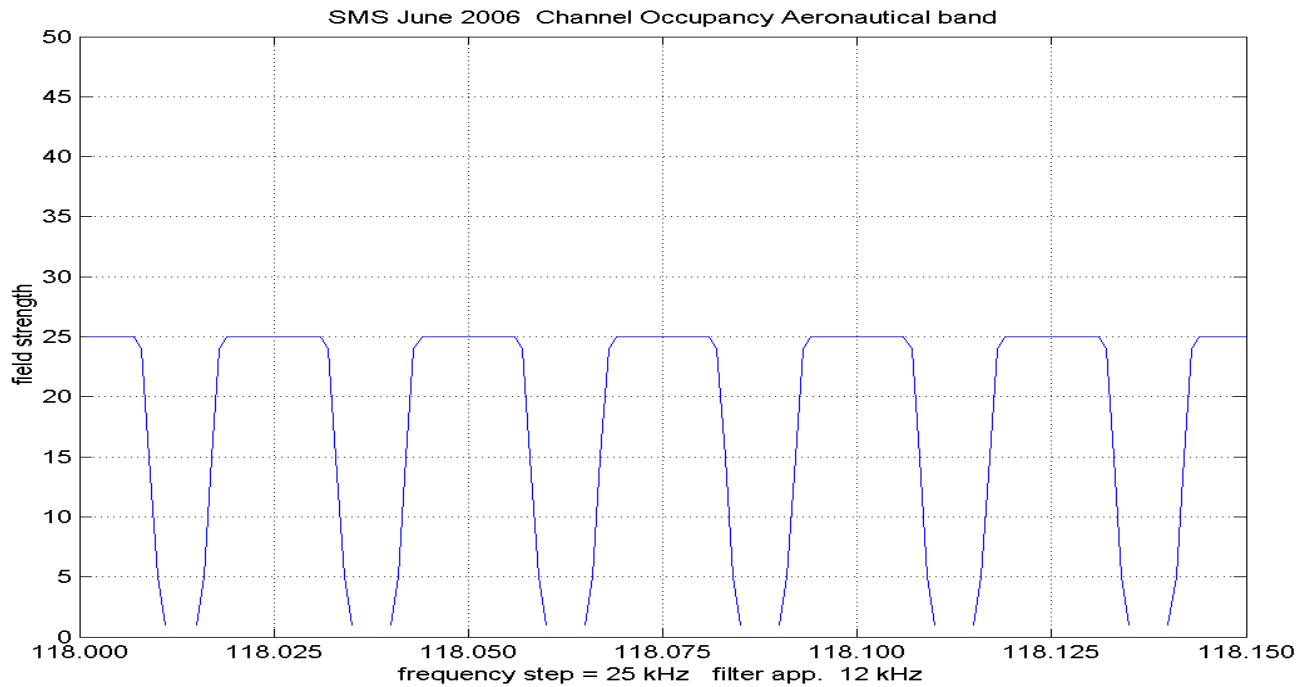
Size and shape of filter (channel or Gaussian) and

Occupied bandwidth of systems in band to be measured

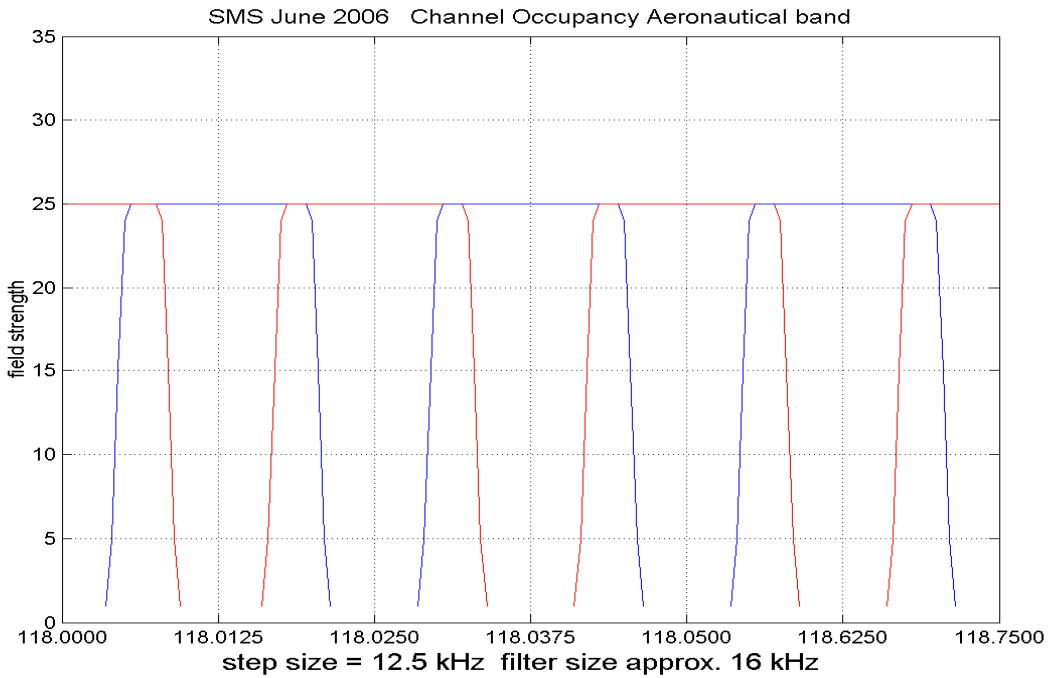
To avoid occupancy caused by stations in the neighboring channels it is better to skip one frequency step (channel)

Data collection

Relation filter(15 kHz) and stepsize (25 kHz)



Data collection



Step size 12.5 kHz, only process red “steps” (500 channels)

Data collection

	118.000	118.0125	118.025	118.0375	118.050	118.0675	118.075	118.0875	118.100	118.1125	118.125	118.1375	118.150	118.1675	118.175
00:00:00	63.8	61.7	51.8	32.3	35.0	33.7	31.3	39.6	52.8	64.9	72.2	65.0	51.7	41.2	37.6	50.1
00:00:10	63.9	61.3	51.5	32.0	35.6	33.8	31.6	39.1	52.9	64.8	72.3	65.5	51.9	41.8	37.7	50.8
00:00:20	61.7	61.7	50.8	32.9	35.3	32.9	31.9	39.8	52.1	65.4	72.7	65.4	51.9	42.2	37.6	50.9
00:00:30	63.3	61.9	52.7	31.5	34.6	33.7	31.0	40.6	52.8	65.2	72.1	66.0	51.1	41.7	37.0	49.5
00:00:40	63.8	62.0	51.3	32.3	35.0	33.7	30.6	39.9	52.5	64.9	72.8	65.5	52.7	41.2	38.3	50.7
00:00:50	63.1	62.3	51.8	32.8	35.7	33.4	31.3	39.6	53.1	64.3	72.2	64.9	53.7	41.3	37.6	50.1
00:01:00	64.8	60.7	50.0	32.1	36.1	33.1	31.8	39.3	52.8	64.2	72.6	65.0	51.6	40.9	37.8	50.4
00:01:10	62.8	61.9	51.9	33.0	35.0	34.2	31.9	39.1	52.3	64.1	72.3	65.2	51.5	41.8	36.6	50.7

Link to example file

Process Measured Field strength

In case of traditional FCO (ITU SM.1536) the channel is considered to be occupied (=1) in case the measured field strength exceeds the threshold level, regardless the real measured field strength.

Next plot both transmissions cause 25% occupancy

Process Measured Field strength

Process Measured Field strength
ITU SM.1793

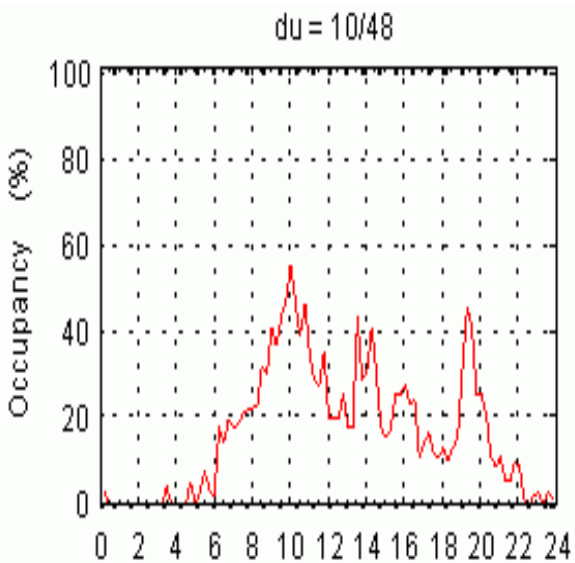
For every channel there are > 8600 samples available over 24 hours
(sweeptime = re-visit time = 10 seconds)

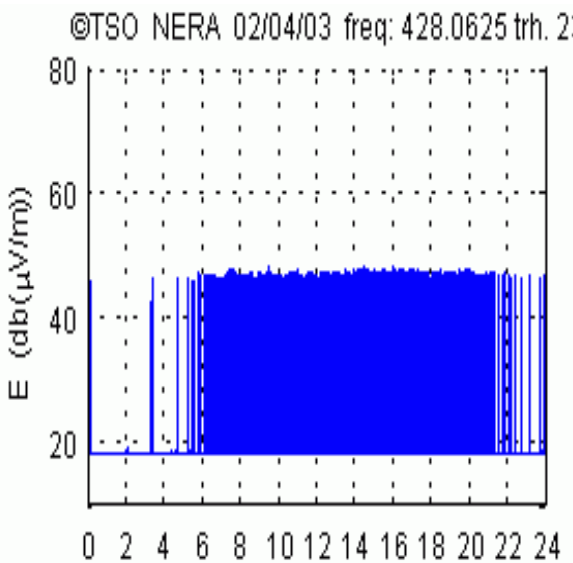
These 8600 are processed per 15 minutes,

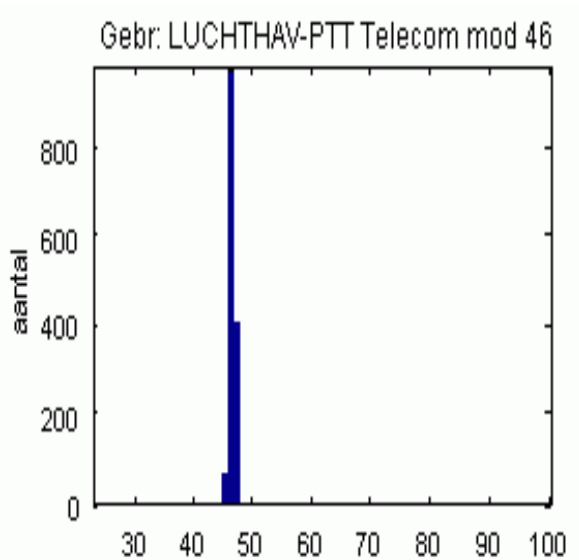
This means that for every 90 samples (15 minutes) the average is calculated

Process Measured Field strength

One user active on this channel

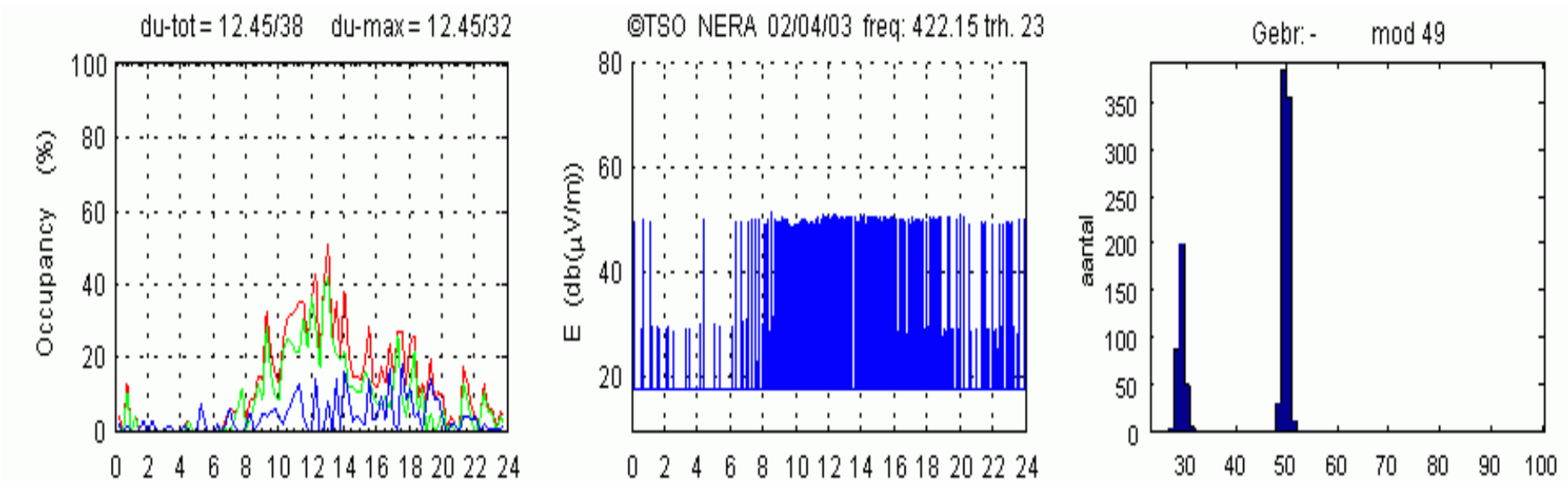






Process Measured Field strength

Two users active on this channels

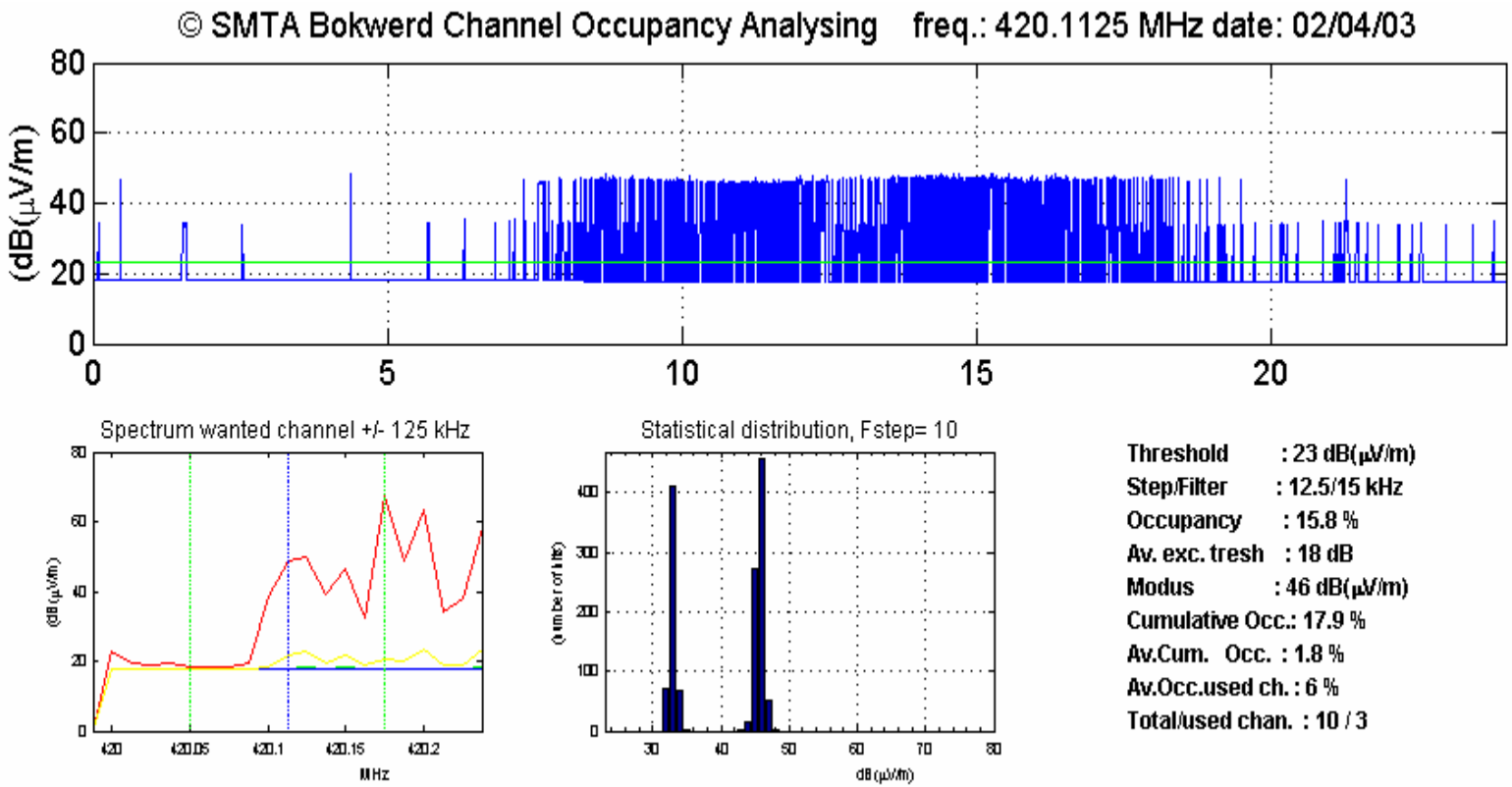


Process Measured Field strength

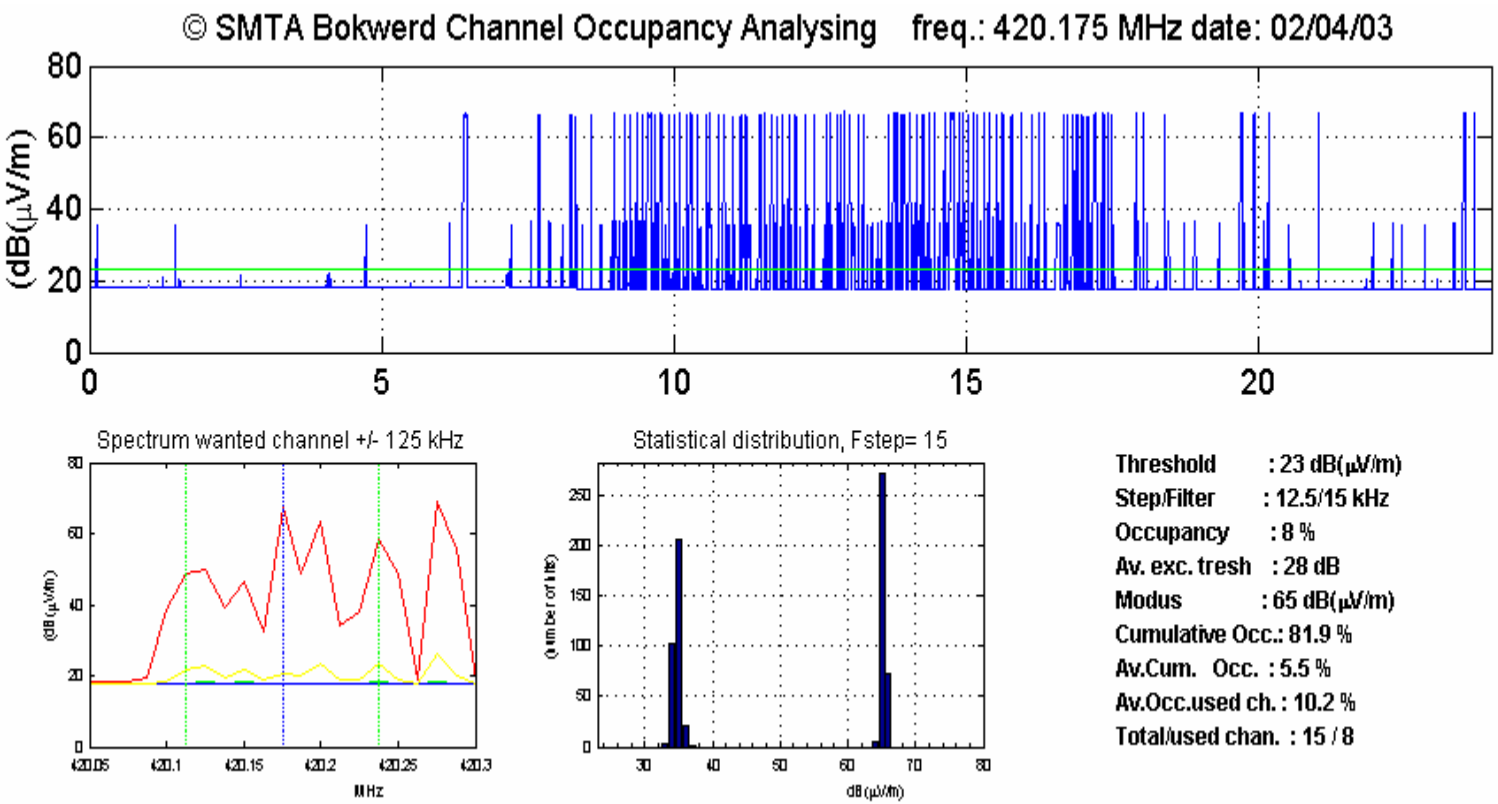
- Red curve : total occupancy, all users)
- Green curve: occupancy most active user in plot user with 49 dBuV/m
- Blue curve: occupancy other users

  In plot user with 29 dBuV/m

Process Measured Field strength Analysing (420.0-432.5 MHz)



Process Measured Field strength Analysing (420.0-432.5 MHz)



Occupancy in color plot

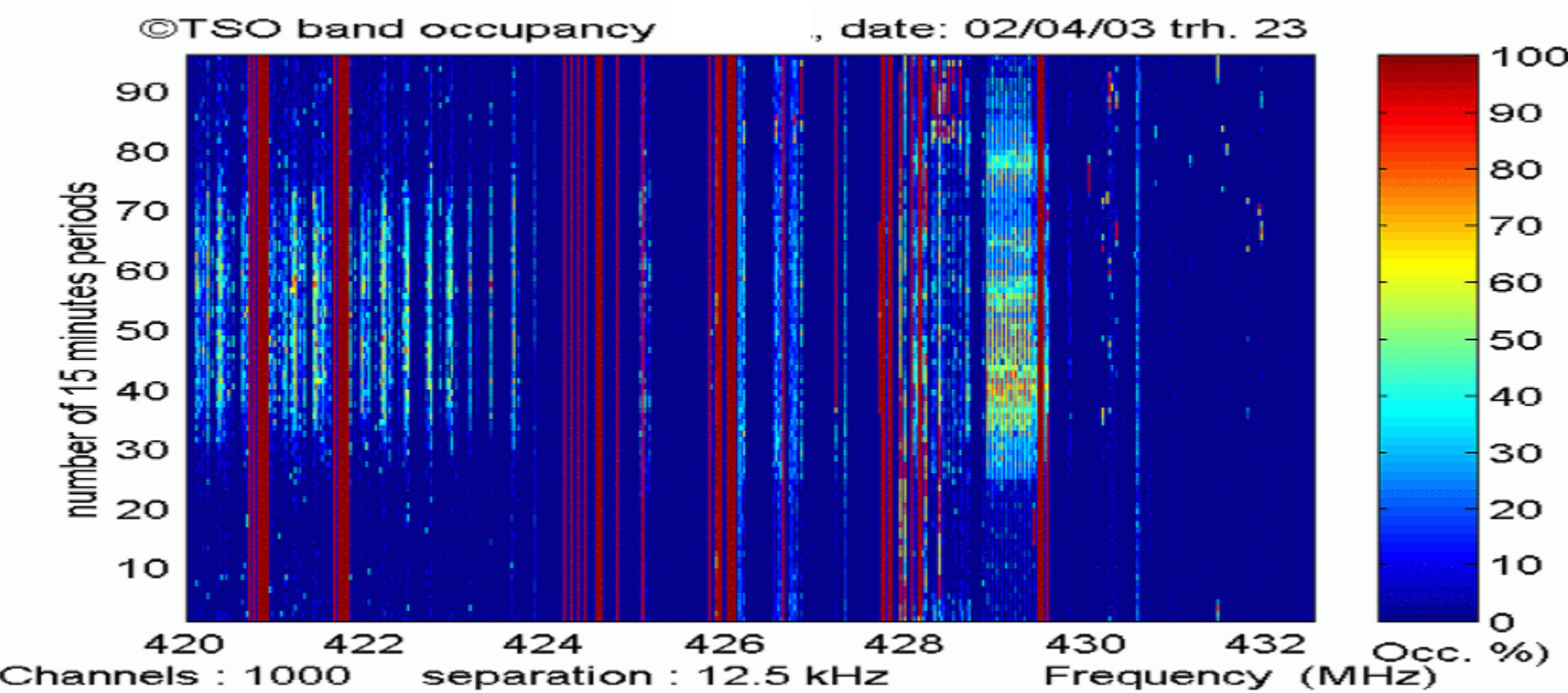
Next plot shows the occupancy presented by colour according colour bar. Red = 100%, Blue 0% (this is not a spectrogram!!)

96 periods of 15 minutes per 24 hours.

Gives a quick overview of occupancy in measured band (420-432.5 MHz)

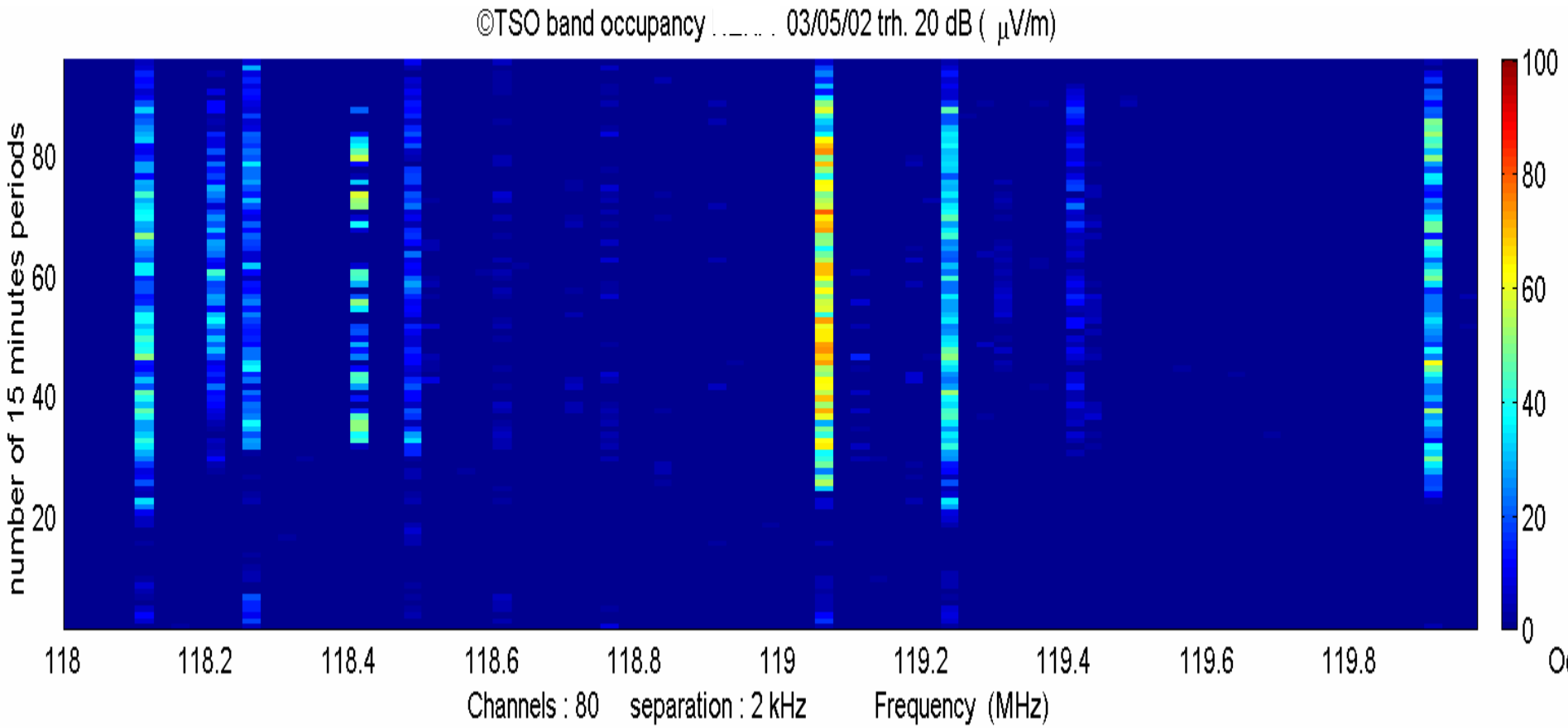
Occupancy in color plot

12.5 MHz Band



Occupancy in color plot

2 MHz band



Occupancy table

The results are also presented in a table.

The user information, from a simple ASCII help file, is automatically added.

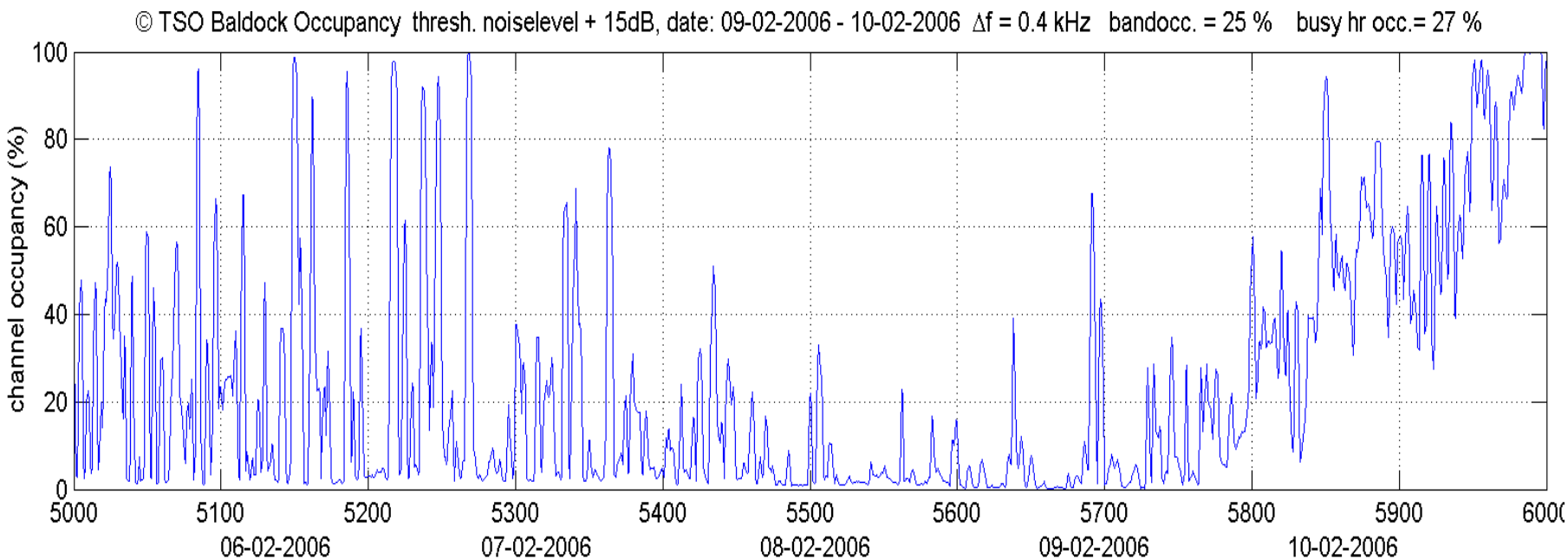
example of tabel

Occupancy table external ASCII file

- 118,050;Brussel;
- 118,100;Schiphol(tower, secondary);
- 118,125;Moenchengladbach;
- 118,150;Parijs;
- 118,200;Rotterdam (tower);
- 118,225;Vliegtuigen;
- 118,250;Brussel (arrival);
- 118,300;Dusseldorf;
- 118,400;Schiphol (arrival);
- 118,475;London tower;
- 118,500;Woensdrecht;
- 118,550;Toulouse;

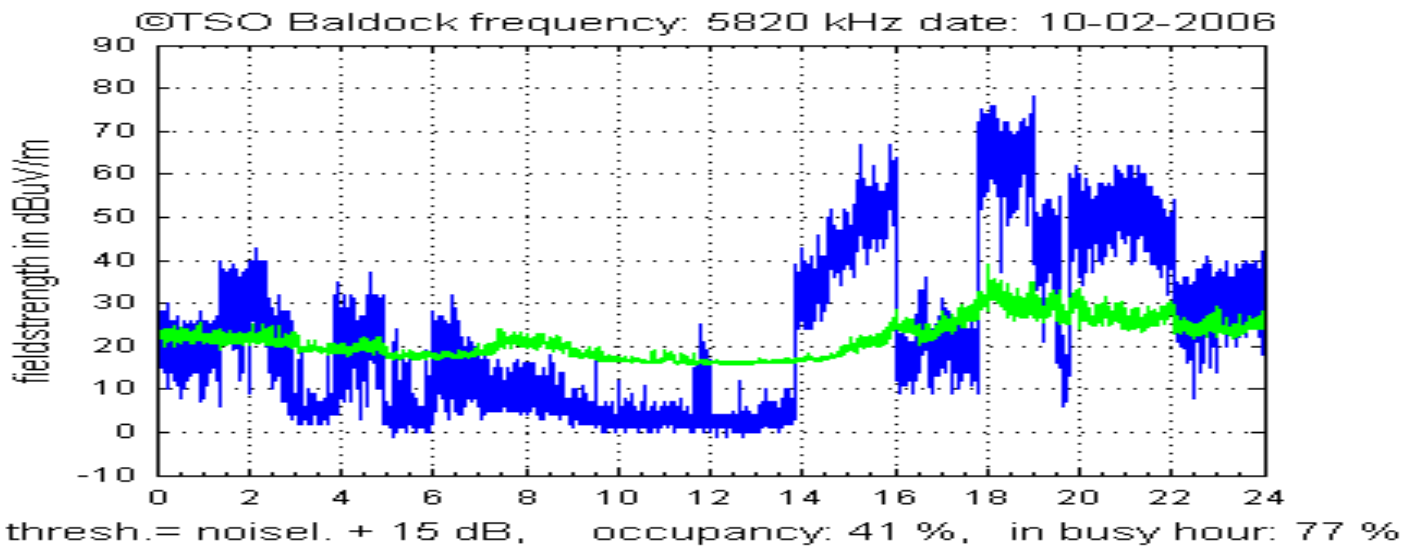
Occupancy in HF bands

Also the occupancy in the HF bands can be measured



Occupancy in HF bands

Occupancy measured on a broadcasting channel with varying threshold due to propagation diferrences during 24 hrs.



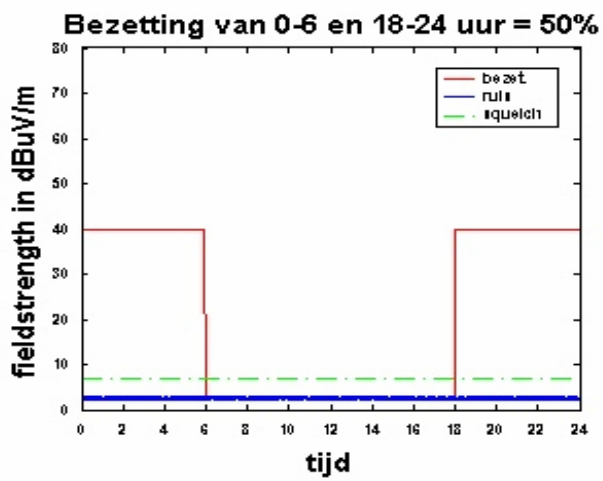
Occupancy verses availability

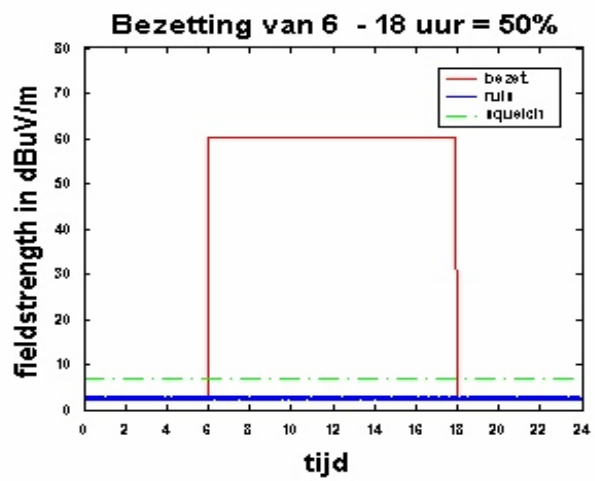
A channel is occupied for 50%

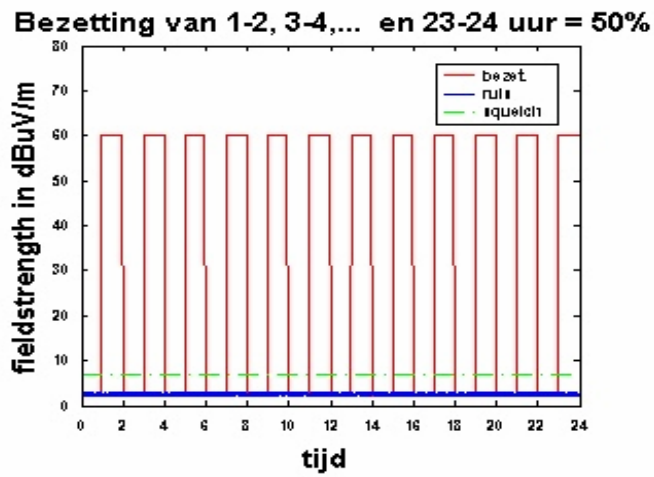
Does that mean that this channel is available 50%?

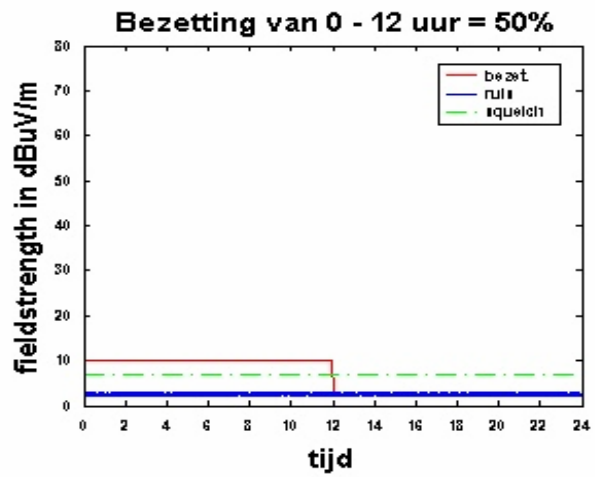
This is under study in ITU-R SG-1 WP1C (new Question)

Occupancy verses availability









Spectrum Monitoring Training Lichtenau April 2007

- Demo presentation aeronautical bands, 4 years, 5 measurements including trends. (link)

- Demo presentation overall (link)