Eight Markers in Perseus That Will Change DXing

with Appendix: ***Markers' Resolution in a Nutshell***

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Perseus software version 2.1h provides up to eight "markers" whose values can be saved to a log file. Nils Schiffhauer, DK8OK, describes what the markers are measuring and what you can do with the data. Incidentally, not only Perseus, but also some other receivers can record the signal level for use later in a spreadsheet. Ever since the first version of Perseus software, there have been markers available. They can be placed with a mouse click on any frequency within the large display. The value shown is the respective level. With software version 2.1h, there are now eight markers, whose values are optionally stored in the file named "markers.log". The concept of this marker is introduced in the following article, and their results over time are investigated further.

First, what is actually being measured accurately?

The units in Perseus' "Software Settings" permit you to choose between the input power (dBm) and the input voltage (dBuV) - see Figure 1.

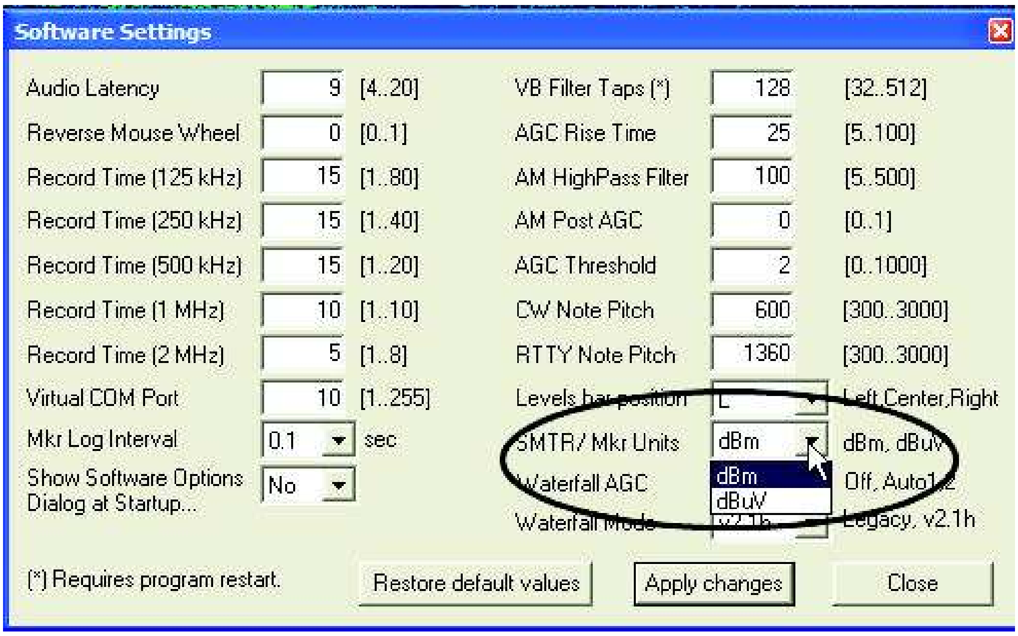


Figure 1: Under "Software Settings" is found the units for the signal meter and the markers: - dBm or dBmV.

For power, the reference of all calculations is 1 milliwatt (mW) at the antenna jack. The way to describe values other than 1 mW is the decibel/milliwatt (dBm): 10 dBm are 10 milliwatts, 100 milliwatts of power are 20 dBm, and -10 dBm are 0.1 milliwatts, thus -20 dBm corresponding to 0.01 milliwatts.

The value of S9 on the S-meter indicates -73 dBm input power.[1] A strong local station at the antenna can measure -20 dBm (S9 +50 dB on the S-meter). DX signals are often far below S9.

For voltage, the reference of all calculations is 1 microvolt (uV) at the antenna jack. The way to describe values other than 1 uV is the decibel/microvolt (dB/uV): 10 dB/uV are 3.16 uV milliwatts, 20 dB/uV are 10 uV of input voltage, and -10 dB/uV corresponding to 0.316 microvolts at the antenna jack.

The value of S9 displays on the S-meter when 50 microvolts input level is reached. Strong local stations on the antenna often reach 84 dBuV (S9 +50 dB on the S-meter) - see Figure 2.

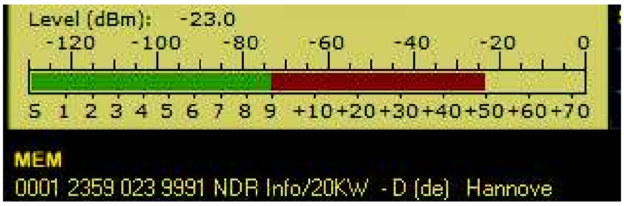


Figure 2: Local station can achieve a level of -23 dBm. Related to the filter bandwidth of 10 kHz, this corresponds to -63 dB/Hz, when the power is evenly distributed within the band.

The use of microvolts is a relic from the past; a professional will work with the input power.

Note: when referring to the voltage in microvolts, this refers to the voltage at the antenna jack. Don't mix it up with the field strength, which is given in microvolts/meter (uV/m) within several propagation programs, VoACAP among them. The field strength just describes the electromagnetic field. Simply put, a good antenna gets a high voltage out of this field, where a bad antenna recovers an only small voltage out of this field. The relationship between the field strength and the voltage actually measured at the antenna jack of the receiver is called "antenna factor". For most antennas, this antenna factor varies over frequency. But there are professional active antennas for measurement purposes which show a constant antenna factor over a very wide frequency range. (For SWLs, the DX-one professional is a good example.)

We will therefore primarily refer to the power in dBm at the antenna connector.

Note: Only with professional software-defined radios such as Perseus can the measured values be accurate within a frequency range! Almost all other receivers indicate weak signals lower than they really are, and strong signals are displayed too high. Most cannot even display properly an S9 value. Such inaccurate scales and meters are useless for displaying true signal levels, only trends of weakening or strengthening signals!

Signal levels depend on the bandwidth values displayed. The professional approach is to always refer to a bandwidth of one hertz: dBm / Hz or dBmV / Hz. Because of the way decibels are calculated, the conversion becomes easy for other bands. Let's take a DRM signal of 10 kHz bandwidth (10,000 hertz or 40 dB / Hz). So, if the input power (shown on S-meter display) when using a 10-kHz filter, is for example -50 dBm, then it is relative to 1 Hz. That results in a signal of only -90 dBm or -90 dBm / Hz.

The Perseus receiver can now indicate two measurements for signal display:

- The S-meter shows the signal level, as it lies within the chosen bandwidth. This level will vary within the filter - between the range of approximately 20 Hz and 50 kHz.
- The markers, however, reveal a different level on the display (regardless of whether the waterfall or spectrum is shown) - see Figure 3. This is called resolution bandwidth (RBW) and depends on sampling rate, chosen span, and zoom level. Thus it can be chosen indicate between 0.03 Hz and 1953.1 Hz.

Figure 3: The levels of the markers shows resolution bandwidth (RBW), which is displayed in Hertz in a window on the left of Perseus.

The best range to measure and normalize to 1 Hz also depends on the modulation of the signal. Here are a few considerations and recommendations:

AM (amplitude modulation) usually consists of a transmitted carrier with constant power plus the two sidebands. The latter cover 25 percent of the nominal power each at maximum (= peak modulation). Thus, if you set a marker on a carrier of such a signal (with peak search), it results in a level more or less corresponding to a bandwidth of 1 Hz (dBm/Hz) (independent from the actual bandwidth, which may be different, e.g. 50 Hz). In contrast, this is not applicable to noise and noise-like signals (such as DRM), where you have to normalize the measuring bandwidth to 1 Hz.

In SSB mode, the carrier is attenuated mostly to such a degree, not even seeable at the receiver. Here you have to rely to the modulation only. Thus, you must measure at a bandwidth, approaching the bandwidth of the modulation itself. As Perseus' widest measuring bandwidth (= resolution bandwidth/RBW) is 2 kHz, you should use this value. Especially with shortwave communications, (audio) frequency of considerably above 2 kHz, don't contribute too much to the signal strength, and can be omitted. Measuring the exact level of SSB signals seems difficult. This is just a coarse approach. Best is, to combine this with set "average" (AVG) quite high to get the peaks. On the other hand, you lose the influence of fading.

DRM is a noise-like signal with three pilot carriers. You measure a pilot carrier with a small marker (below 10 Hz), which corresponds to the display of a bandwidth of 1 Hz. Another way is to measure the noise-like part of the signal with the maximum RBW of 1953.1 Hz. Because this RBW represents only a fifth of the bandwidth of the whole signal (10 kHz wide), you have to add 3.7 dB to these values (because 1:5 = 3.7 dB). See Figure 6.

Noise can also be measured, to show the signal-to-noise ratio, for example. Here, the displayed power is always converted to 1 Hz.

Note: With narrow-band measurements, you should be aware of extremely deep, yet short dips in signal level. This is due to selective fading which runs through the signal like a deep trench. It can be shown best with noise-like signals, e.g. at DRM broadcasting stations.

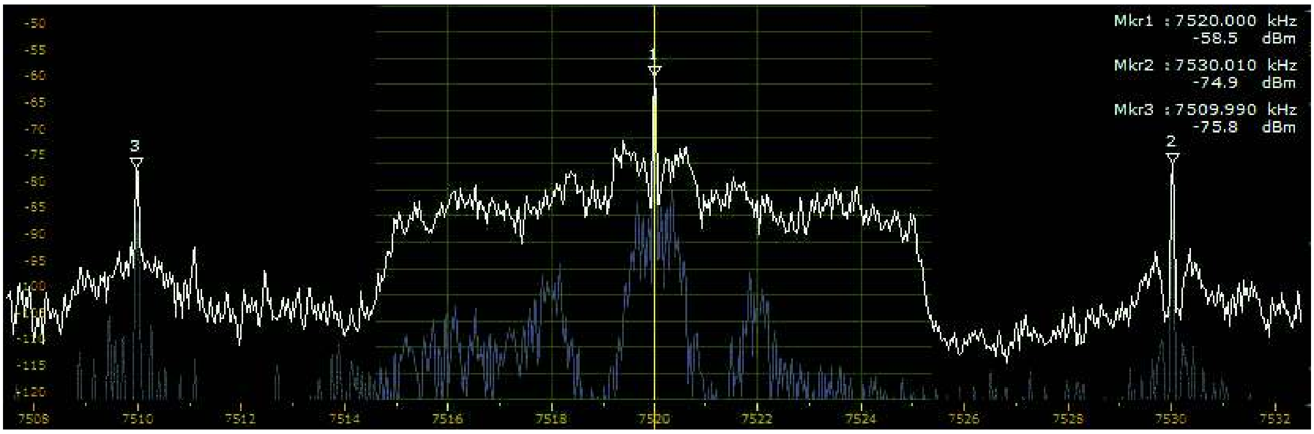


Figure 4: Radio Farda in AM from Thailand on 7520 kHz is broad and strongly modulated. An average shortwave AM signal is shown at Mrk2 (VOA Tinang). Many DX stations often produce a good signal, but are modulated so weak that they are barely audible - Angola 4950 kHz is a notorious example.

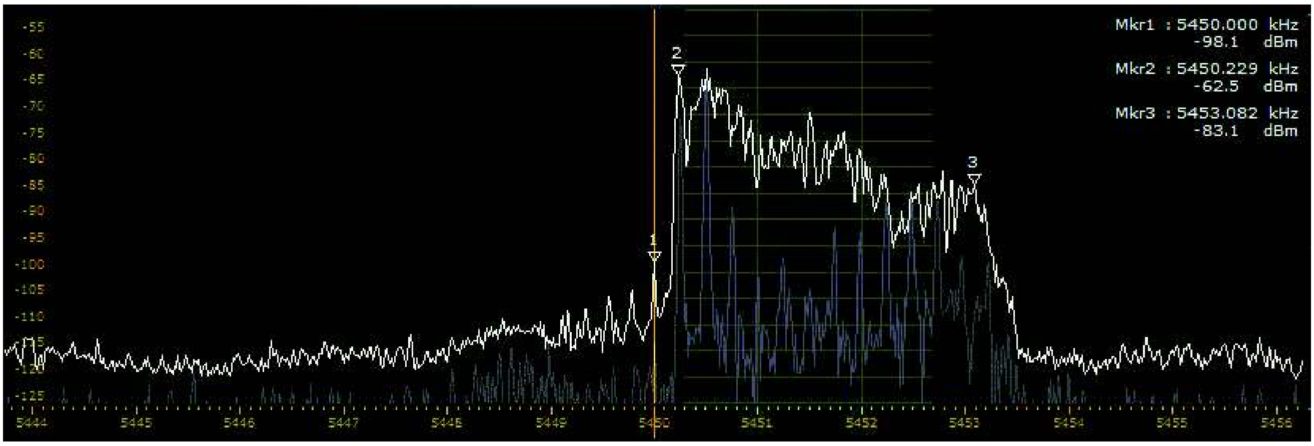


Figure 5: The signal of the RAF radio SSB transmitter in Drayton on 5450 kHz is in upper sideband. The carrier (Mkr1) is suppressed compared with the strongest modulation frequency (Mkr2) to 35.6 dB - an excellent value. The analysis of such signals can only succeed if we would put a 3 kHz wide marker (corresponding to the modulation width of the signal) in the midst of the signal, which here is the upper sideband. As Perseus provides roughly 2 kHz as widest resolution bandwidth, you should add 1.2 dB to compensate for the difference of 2 kHz to 3 kHz.

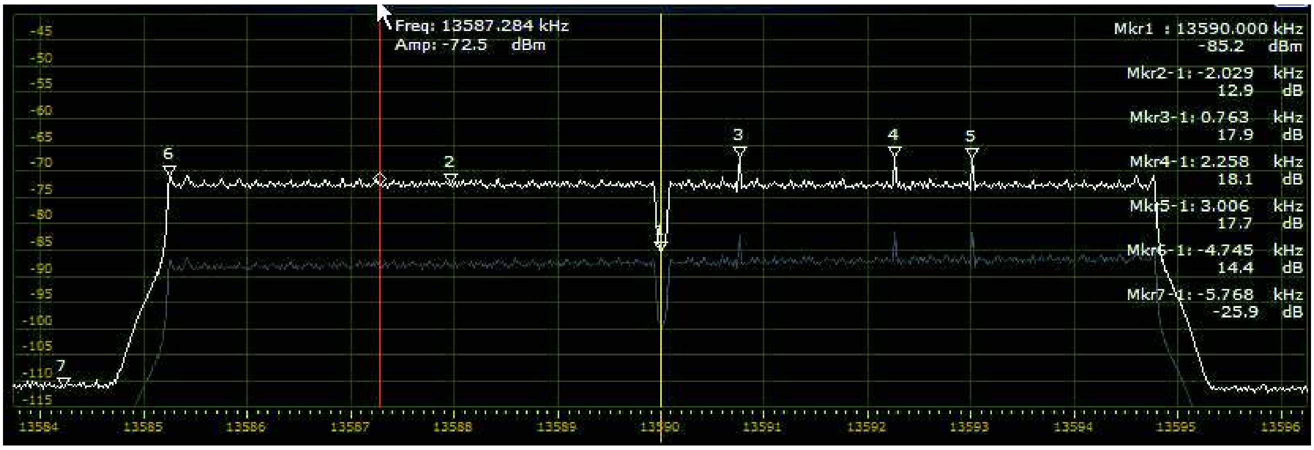


Figure 6: A DRM signal of the BBC / Sines on 13590 kHz, measured with 15.26 Hz RBW, shows the center frequency (Mkr1), the three pilot tones (Mkr3 to Mkr5) and the lower cutoff frequency. In addition, the average level of the PSK-modulated carrier (Mrk2) and the noise (Mrk7) is shown. Except for the last two markers, all equate to dBm / Hz values. But for the "noise markers" Mrk2 and Mrk7, you have to add 12 dB, to normalize their resolution bandwidth of 15.6 Hz to 1 Hz (for: 15.26 Hz/1 Hz correspond to this 12 dB). After adding this 12 dB, you have normalized the readings of these last two carriers to dB/Hz.

How often should you measure?

In addition to the frequency resolution, the time resolution is important. The software offers 2.1h (software settings / Mkr Log Interval) between 0,1 and 5 seconds practical ways to measure short-term changes, as well as long term - see Figure 7.

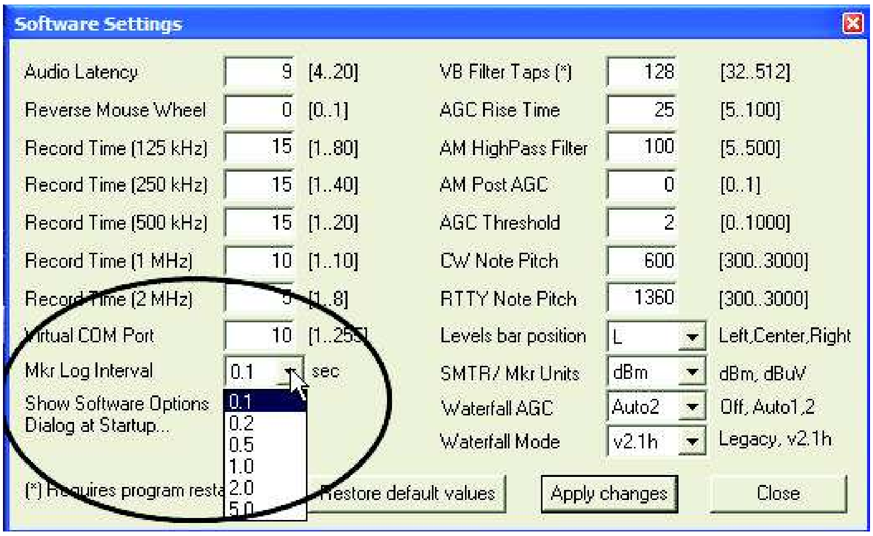


Figure 7: The time resolution can be selected in the software settings in the popup menu "Mkr log interval" between 100 milliseconds and 5 seconds.

When observing fade-in or fade-out using twelve readings per minute (i.e., every five seconds), this is almost too frequent. Very short-term detection, however, is important for the documentation of flutter fading, for example.

Notes: The smoothing function of the main display (slider: AVG Main) also has some impact on the screen and in the stored values of the "markers.log" file. With short sample times, you should turn off the AVG Main slider, because otherwise the "Software Settings" set time resolution will be overruled. Any smoothing can be made later in other programs, with controlled and traceable results.

The AGC setting (Fast / Med / Slow / Off) has no consequences on the data. All right, is it all set up correctly? Yes, then we can start! Either from live reception, or even from a WAV recording:

- With the mouse on the appropriate signal, click the right mouse button in succession to set up to eight markers. If you have enabled the button "PeakSrc', the marker will automatically be within a certain capture range and it gets set to the strongest frequency. This is ideal if you want to observe the carrier of an AM radio station.
- Press the button "MkrLog", and a Save to File window opens for markers.log - see Figure 8. Click "OK", and the file markers.log will be filled with the appropriate values. The display "MkrLog" lights up at this time.
- To turn off the logging feature: click the MkrLog button again. The "marker saved to file" markers.log opens; then click "OK".

Note: the log will then again start to function, and the previous file will be overwritten without warning!

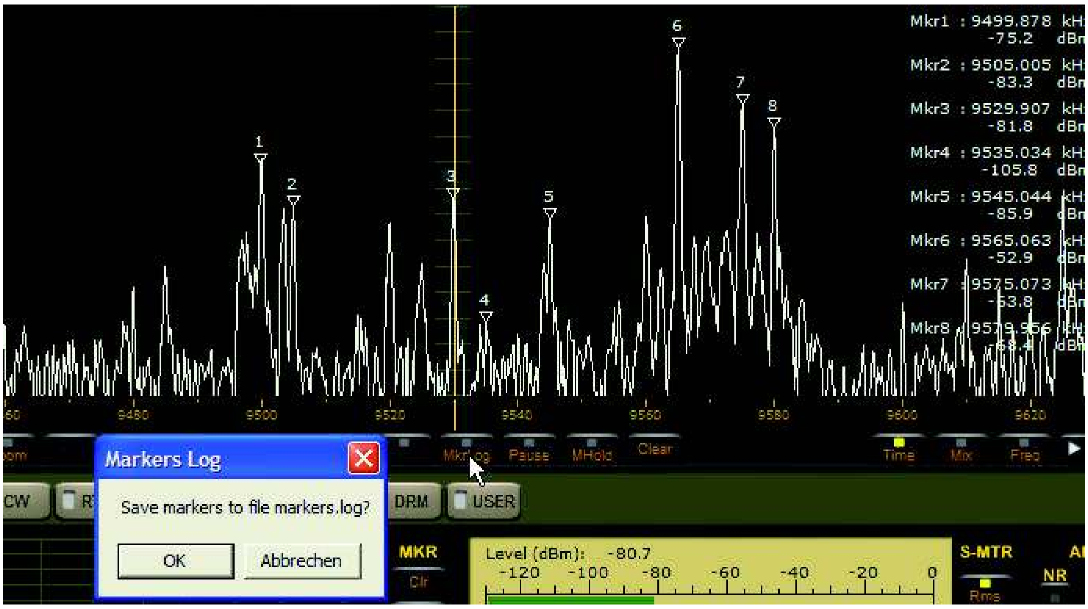
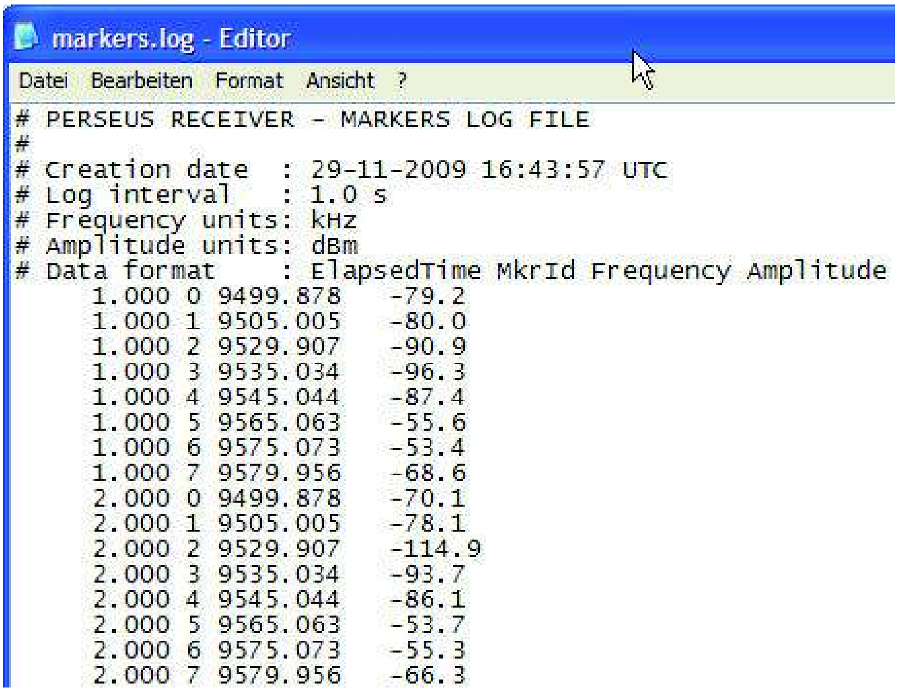


Figure 8: Eight markers are prepared for logging. Your current frequencies and levels are right. At the same time their carriers 1 to 8 characterized in the spectrum. Click again on "OK" and then press the "MkrLog" button. The MkrLog indicator lights up - starts the recording.

What do you do with it now?

So now we have a log file with the markers. What are you supposed to do with it? The possibilities are endless and depend on your interest and knowledge. But two things you will inevitably end up with: a visual representation and a thinning of the data using statistical methods. The deeper meaning is to find some patterns, hidden in a vast amount of data; not just thinning, but thinning by the sense of a known algorithm. Thus, one has to try pattern recognition by statistical methods. I would like to give some examples of both and also avoid obstacles in the way, such as the formatting of the data - see Figure 9.


markers.log - Editor

Datei Bearbeiten Format Ansicht ?

```
# PERSEUS RECEIVER - MARKERS LOG FILE
#
# Creation date  : 29-11-2009 16:43:57 UTC
# Log interval   : 1.0 s
# Frequency units: kHz
# Amplitude units: dBm
# Data format    : ElapsedTime MkrId Frequency Amplitude
     1.000 0 9499.878   -79.2
     1.000 1 9505.005   -80.0
     1.000 2 9529.907   -90.9
     1.000 3 9535.034   -96.3
     1.000 4 9545.044   -87.4
     1.000 5 9565.063   -55.6
     1.000 6 9575.073   -53.4
     1.000 7 9579.956   -68.6
     2.000 0 9499.878   -70.1
     2.000 1 9505.005   -78.1
     2.000 2 9529.907   -114.9
     2.000 3 9535.034   -93.7
     2.000 4 9545.044   -86.1
     2.000 5 9565.063   -53.7
     2.000 6 9575.073   -55.3
     2.000 7 9579.956   -66.3
```

Figure 9: When you open the file "markers.log" with a text editor, it is clear that eight markers (0 to 7) were recorded every second.

I decided to use the markers.log with the free software SciDAVis.[2] It has Windows, Mac, and Linux versions available and is easier to work with than Microsoft Excel. But in principle you can use any spreadsheet with a statistics function. So even Microsoft Excel (or Sun Open Office), Apple Numbers, and above all the Origin software probably offers the most options.[3]

The easiest way is to import a log file with only one marker. Once there is more than one marker, all markers are listed under the same sample-time one after another. They are marked from "0" for marker 1 to "7" for marker 8 in the column "MkrId". - Figure 10 shows the import with the appropriate settings, and Figure 11 is a section of an on-going recording of "markers.log" in "SciDAVis" imported record.

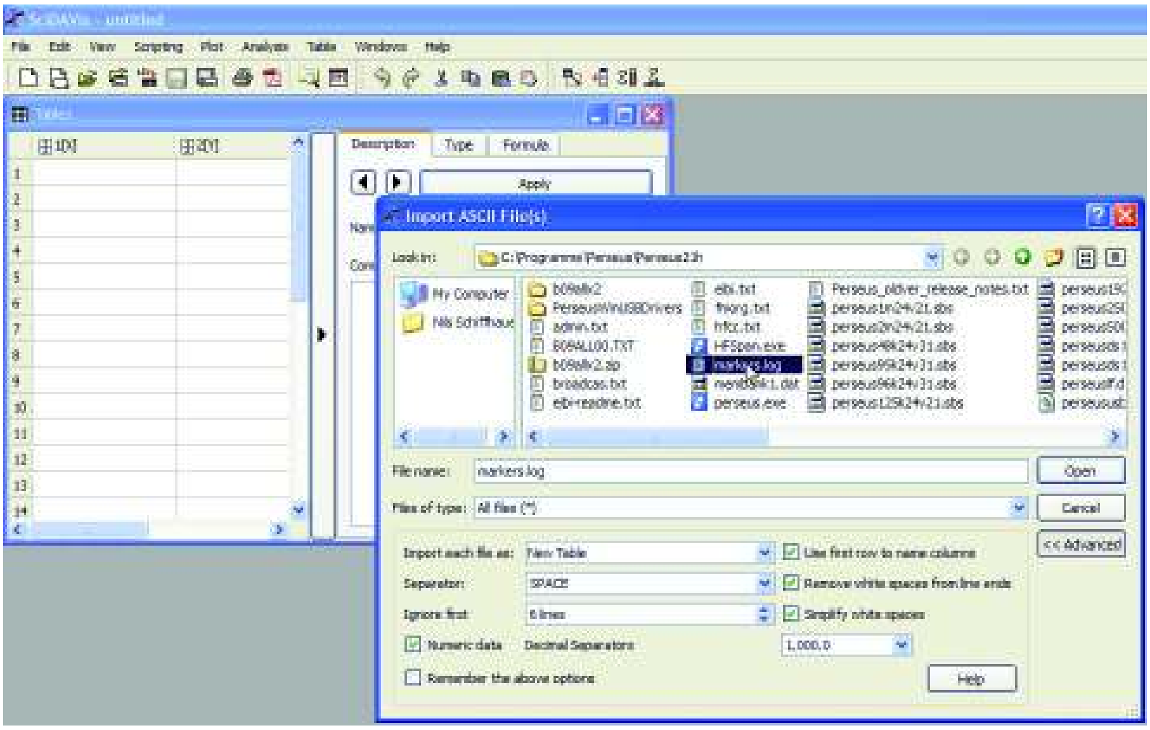


Figure 10: With SciDAVis you can even import data from the log file while playing a recording. While ignoring the first six rows and select the Separator "SPACE" option.

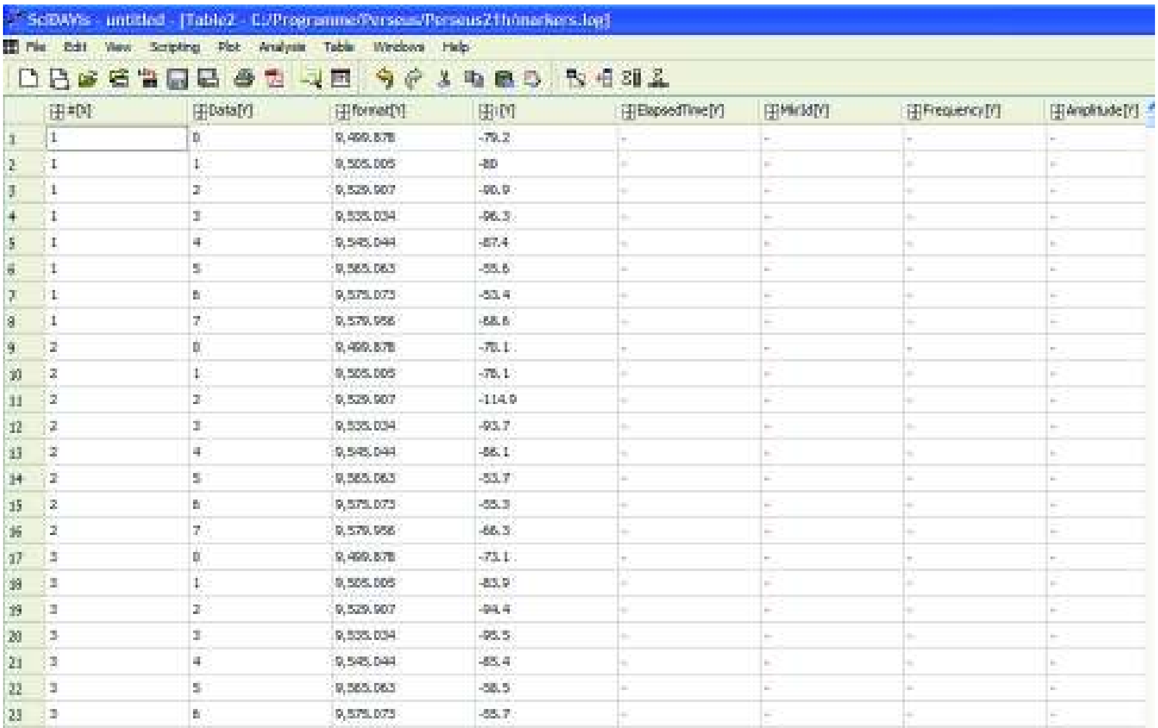


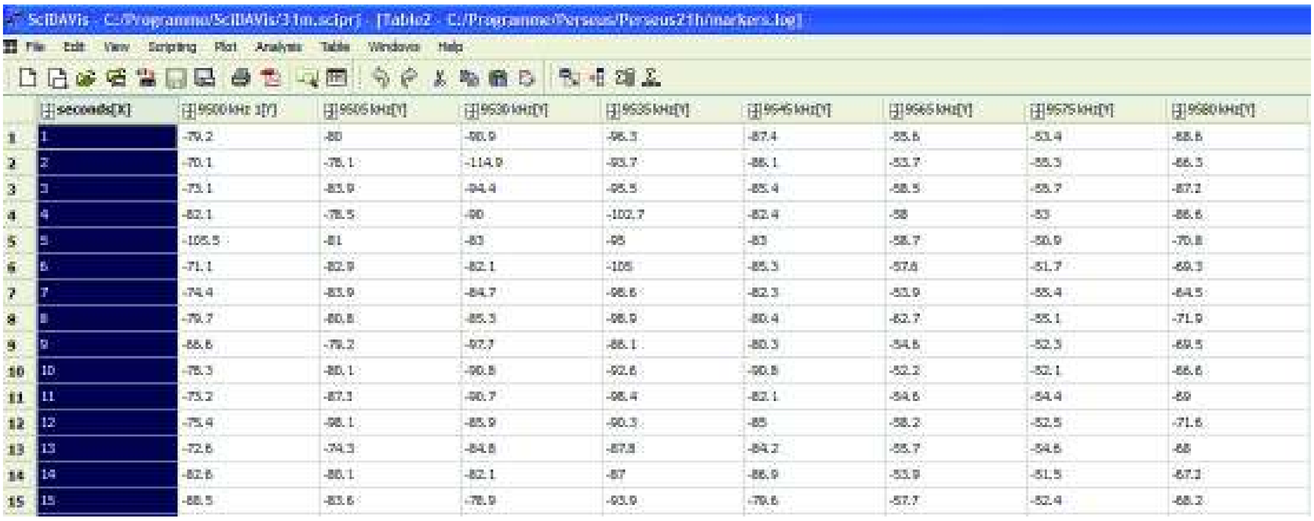
Figure 11: How the results look in SciDAVis, which admittedly still needs editing.

This in turn allows data to be separated, so you can copy the values separately for each marker into a separate column. To sort the table according to the marker numbers:

- select the whole table (all columns and rows)
- Click menu: Table > Sort Table
- Sort columns: "Together"
- Order: "Ascending"

Leading Column: the one containing the number of the Markers (Marker ID, max. from 0 to 7)

This will sort all complete rows according to the marker numbers, e.g. all (!) values for marker 0 are followed by all values for marker 1, and so forth. Then you need to copy the values of all other markers other than marker 0 into the neighboring columns. Thus, you have for each time sample (= row) the values of the different markers also in this row, but in different columns. After that – and naming the titles of the columns appropriately – the table should look like what is shown in Figure 12.


SciDAVis - C:/Programme/SciDAVis/31m.sciprj - [Table2 - C:/Programme/Perseus/Perseus21h/markers.log]

File Edit View Scripting Plot Analysis Table Windows Help

	seconds[X]	9500 kHz 1[Y]	9505 kHz[Y]	9530 kHz[Y]	9535 kHz[Y]	9545 kHz[Y]	9565 kHz[Y]	9575 kHz[Y]	9580 kHz[Y]
1	1	-79.2	-80	-90.9	-96.3	-87.4	-55.6	-53.4	-68.6
2	2	-70.1	-78.1	-114.9	-93.7	-86.1	-53.7	-55.3	-66.3
3	3	-73.1	-83.9	-94.4	-95.5	-85.4	-58.5	-55.7	-67.2
4	4	-82.1	-78.5	-90	-102.7	-82.4	-58	-53	-66.6
5	5	-105.5	-81	-83	-95	-83	-58.7	-50.9	-70.8
6	6	-71.1	-82.9	-82.1	-105	-85.3	-57.6	-51.7	-69.3
7	7	-74.4	-83.9	-84.7	-98.6	-82.3	-53.9	-55.4	-64.5
8	8	-79.7	-80.8	-85.3	-98.9	-80.4	-62.7	-55.1	-71.9
9	9	-86.6	-79.2	-97.7	-88.1	-80.3	-54.6	-52.3	-69.5
10	10	-78.3	-80.1	-90.8	-92.6	-90.8	-52.2	-52.1	-66.6
11	11	-73.2	-87.3	-90.7	-98.4	-82.1	-54.6	-54.4	-69
12	12	-75.4	-98.1	-85.9	-90.3	-85	-58.2	-52.5	-71.6
13	13	-72.6	-74.3	-84.8	-87.8	-84.2	-55.7	-54.6	-68
14	14	-82.6	-80.1	-82.1	-87	-86.9	-53.9	-51.5	-67.2
15	15	-88.5	-83.6	-78.9	-93.9	-79.6	-57.7	-52.4	-68.2

Figure 12: The data is adjusted, the levels of the marker are next to each other, and the headers are filled with the frequencies. Now we can proceed!

Note: The Perseus markers log function records in seconds, but not the absolute time. Therefore, I prefer to replace the values in the "time" column (e.g. 5.001, 10.003, 15.019 …) just by the numbers of the row (reading: 1, 2, 3 …):

- Select the first column
- Menu: Table > Fill Selection with > Row Numbers

After that, you can let SciDAVis calculate even the absolute time by inserting a formula for all row numbers in the first column:

- Select the column
- Open "Formula"

- Insert the appropriate formula. Example: If you have sampled every 5 seconds, e.g. row 12 will represent the value for 1 minute after start, and row 720 will represent the value 1 hour after start. Thus the formula "col(1)/12" will return the minutes, whereas "col(1)/720" will return the hours. Of course they are in decimal notation. To get the absolute time, you have to add to the formula the number of minutes/hours since midnight.

I recorded for six minutes, giving 6 x 60 = 360 values per station. Eight markers result in a total of 2880 numbers. That’s a huge number, calling for a visualization or overview. This is done by just a click on the menu "Plot", shown in Figure 13.

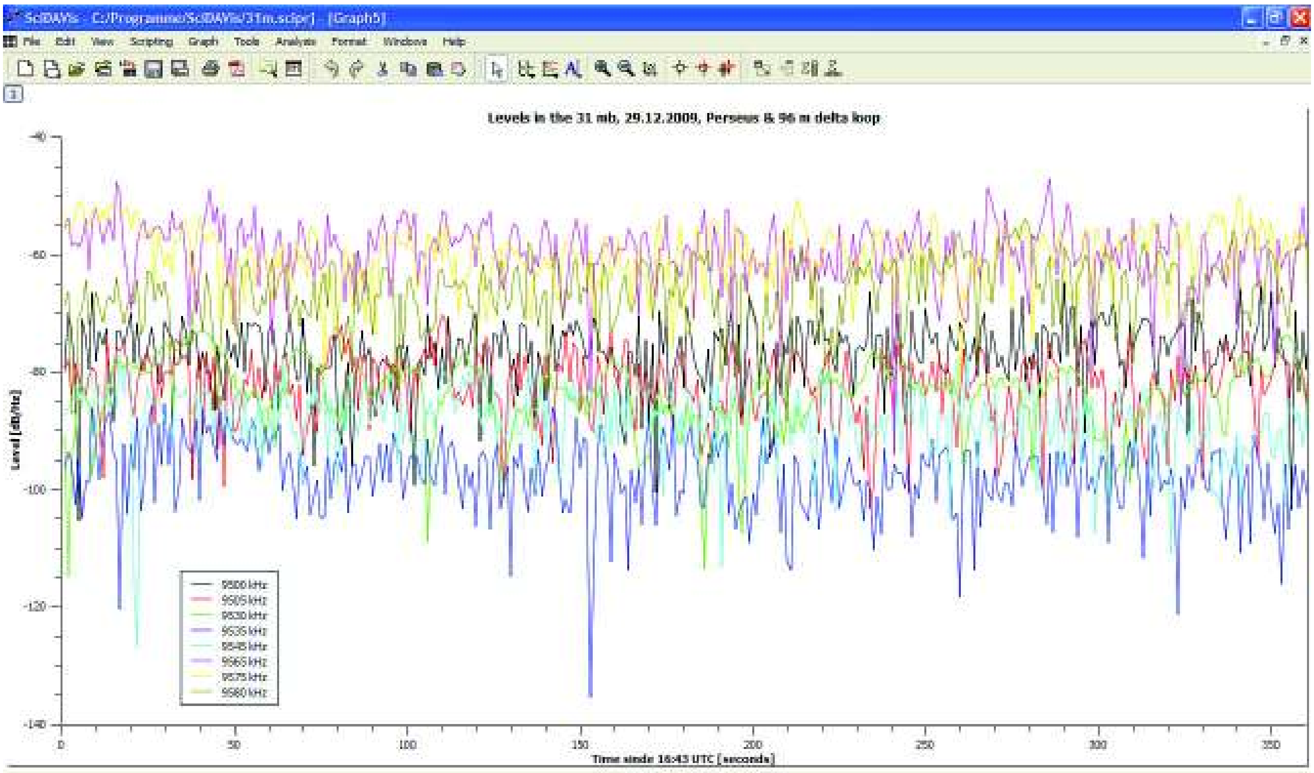


Figure 13: Eight new channels recorded over six minutes in the 31 mb. Pretty confusing.

This is actually too much information. We need to reduce or average it in a meaningful way. This done with the help of statistics. It's not math trickery, but actually highlights the important data from the unimportant data, and shows trends. First, I converted the data from image 13 into a "box plot". This is done with just a click of a button in SciDAVis (Plot > Statistical Graph > Box Plot); see Figure 14.

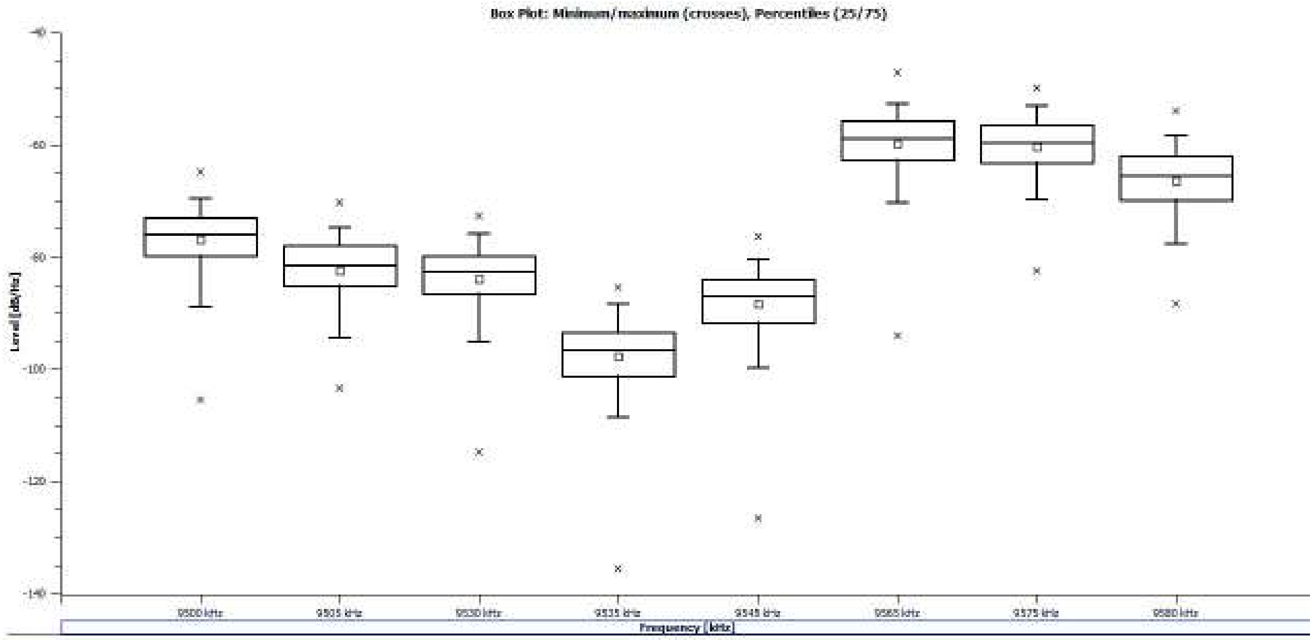


Figure 14: The Box Plot is a statistical method that creates order. For details see text.

The level characteristic of each frequency in each case is summarized in a column at the bottom of the X-axis, corresponding to the frequency. 360 values at each frequency are each divided into several groups:

- Minimum and maximum of each signal within the six minutes is marked by an upper and lower "X"
- The rectangle (box) itself includes all the values that lie at ± 25 percent around the mean value. This is marked by the small square. Upper and lower sides of the box denote the 25 and 75th percentiles
- The top and bottom short, horizontal line segments mark the 5 and 95th percentiles

Is the information clearer to us? Yes, we can assess the reliability of the reception since we get an overview about the fading, even with selective fading. For example, this seems particularly meaningful on 9535 kHz, since the distance from the highest to lowest value in just six minutes is about 50 dB. We thus get an overview not only for a moment, but with a reliable view of the overall period. These are insightful methods which have never been available before to shortwave listeners or radio amateurs.

If this diagram seems too crowded (Figure 13), you can show each trace separately or any traces combined. Figure 15 shows this for the two traces from 9.505 kHz (flat fading) and 9535 kHz (vivid fading). But take care: in this diagram, all levels have been "normalized". This is: the levels don’t represent their absolute value in dB, but their relative values. The highest value of each trace is "1", whereas the lowest value shows "0". Whether "1" means -20 dBm (and a local station) or -80 dBm (a DX station) cannot be seen from such "normalized" traces. However, there is a big advantage of normalized values: for you can compare the structure of the fading, regardless of the absolute level of the signals.

SciDAVis can normalize only positive numbers. As we face negative numbers (like -73 dBm), we have to add to each level the number of the lowest level of each marker. Example: The values for the marker range between -

50 dBm (maximum) and -70 dBm (minimum)-- you have to add 70. Thus, -70 dBm will become "0", and -50 dBm will become "20". After normalization, "0" leaves "0", whereas "20" will get "1". And "-60 dBm" will get "10" in the first stage, and after normalization 0.5.

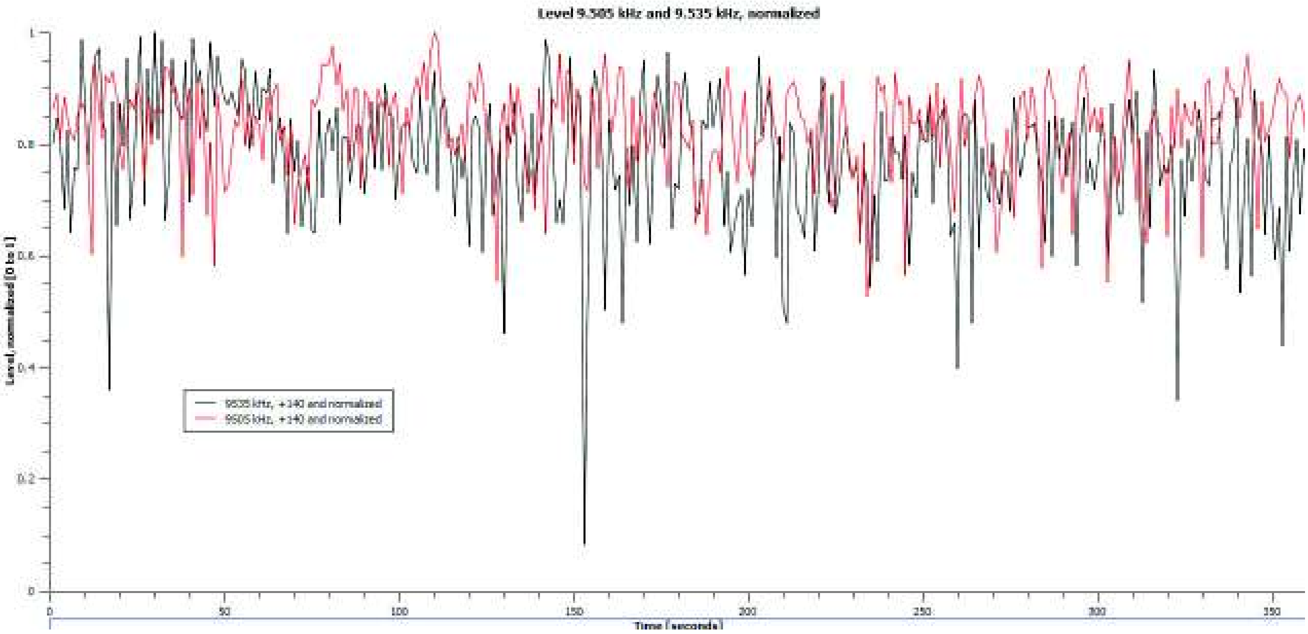


Figure 15: The normalized axis does not exhibit the absolute level, but a level relative to each on a scale from 0-1.

But the image is still too detailed. That’s the right circumstance where "smoothing" comes into play. Just imagine it as median values of a defined number of neighboring values. If you include only two neighboring values, smoothing is weak. The bigger the number of neighboring values, the stronger the effect of "smoothing", showing not details, but the general tendency of fading. Figure 16 shows this for six neighboring values, namely 0 to 5. At "0" there is no smoothing effect, whereas at "5" it is quite strong, as seen in Figure 16.

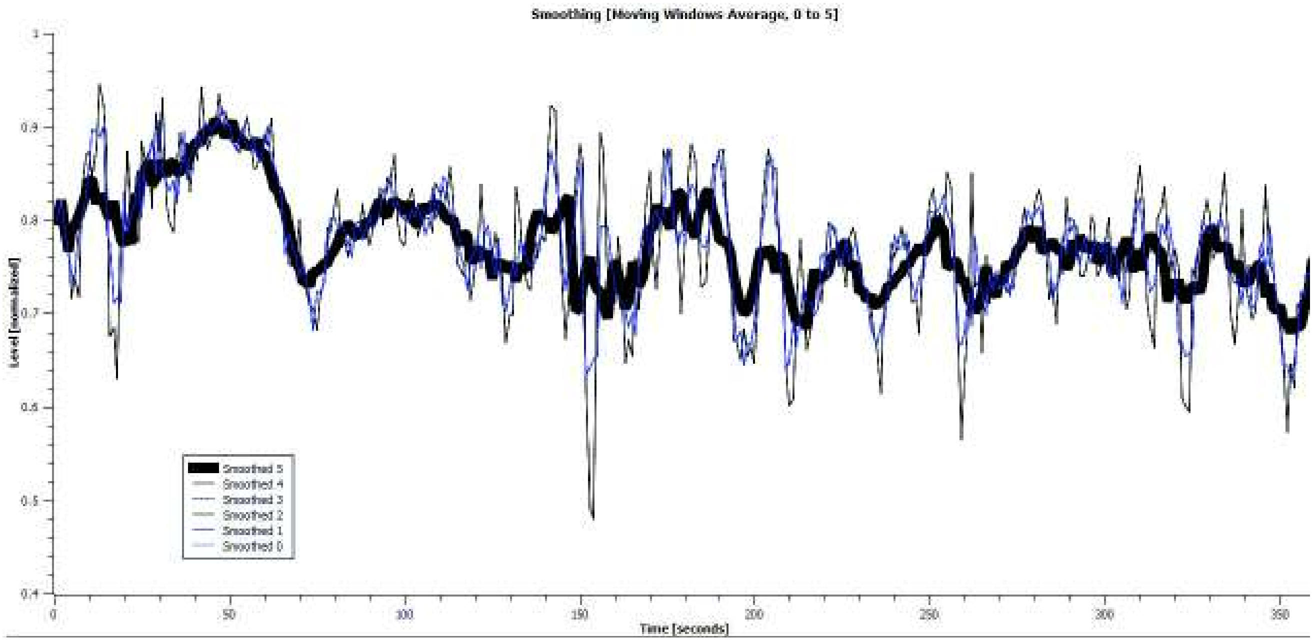


Figure 16: The original curve "Smoothed 0" will be smoothed at various strengths. Details are progressively lost, but fading tendencies and patterns emerge more clearly.

With this approach you can easily compare various smoothed curves, and understand the differences.

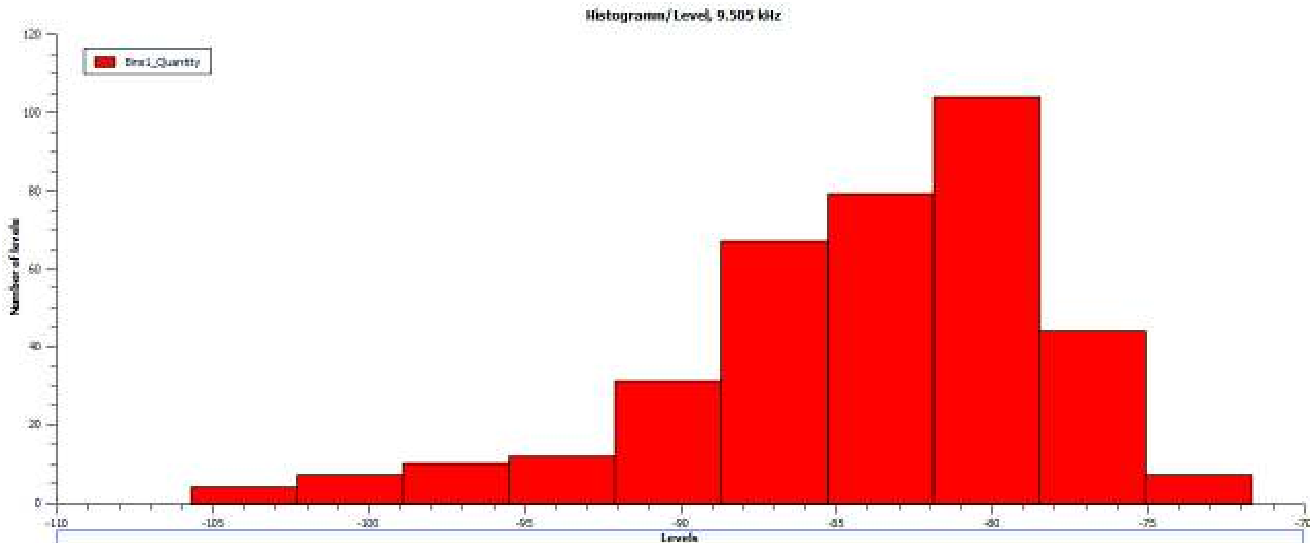


Figure 17: Here we find many relatively small signals, as shown in this histogram.

The histogram is an interesting curve for these comparisons. Here is a diagram showing the frequencies and the signal level groupings (ten in this case). Figure 17 shows a wide range of smaller signals; the reception here is less stable than the signal shown in the histogram of Figure 18. A completely stable signal would have only a single column.

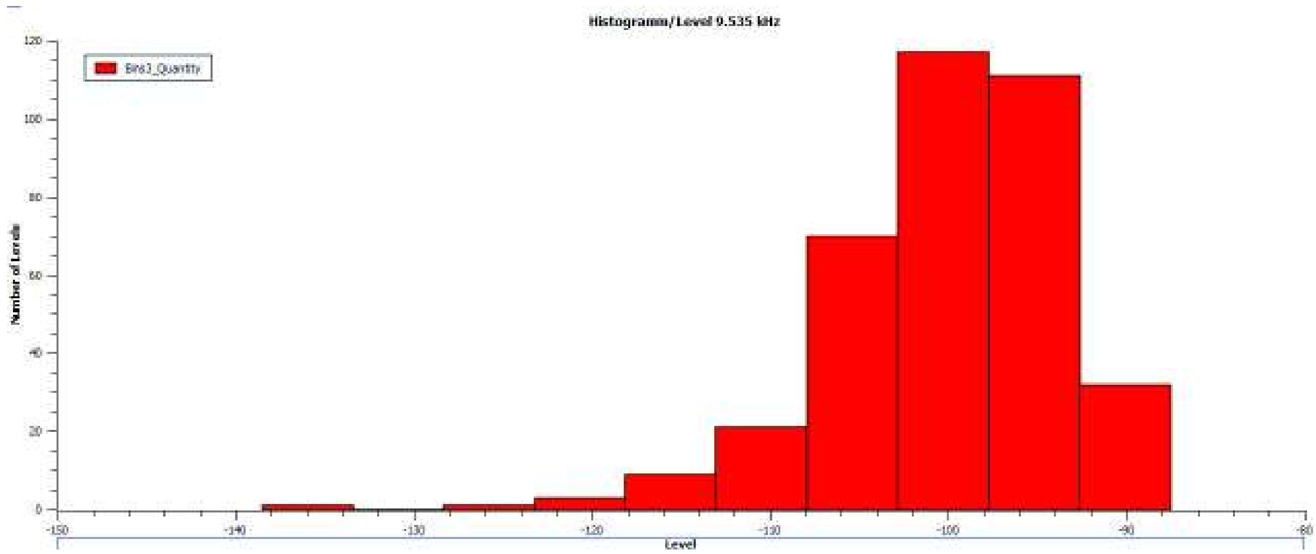


Figure 18: In this more stable signal, the larger level is concentrated in a smaller width.

The distribution of the level is different from the famous bell-shaped Gaussian curve (all values randomly distributed around a mean to give the symmetrical appearance of a bell). When it comes to fading though, we have a flatter profile in the direction of lower signal strength and a steeper profile in the direction of strong signals. But why do the signals appear on the left side of unlimited flat discontinued and limited to the right side?

This depends on the fact that most signals arrive at least two different ways to us. At the receiver, there are two extreme options: they mingle "in phase" (then the signal is doubled (+6 dB), or they mingle with "opposite phase" (then they absorb each other). They are attenuating each other, in effect totally extinguishing the whole signal, thus the attenuation is "infinite dB". This extreme is occurring only if the phase of two paths differs by exactly 180° plus each path delivering exactly the same level to the antenna jack. However, both conditions almost never converge into one moment. In practice, the attenuation rarely is infinite, but in the region of some 10 dB. But it is approaching "infinite dB" asymptomatically. On the other hand, the upper limit is an exact figure: +6 dB, when two paths are exactly "in phase", and of the same strength. This type of distribution (one side asymptomatically, the other steep with a fixed end) is called "Rayleigh distribution". There are several siblings of this distribution, but in general we encounter Rayleigh distribution when describing the character of multipath fading.[4]

Such things are indispensable to the professional planning of short-wave broadcasts. DXers are more interested in whether a signal is heard, and for how long, and when the signal is the best. Again, the markers provide every possibility.

Thus we see in Figure 19 the course of the winter signal WWCR / Nashville 5070 kHz and Radio Rebelde / Cuba 5025 kHz between 0600 UTC and 1200 UTC, shortly after WWCR sign-off. The sunrise at the receiver in Northern Germany is 0730 UTC, the sunrise in Cuba is 1155 UTC, and in Nashville, the sun even goes on until about 1259 UTC. We see that both signals start almost equal, but then the more northerly Nashville strengthens compared to Cuba. Even before sunrise at the receiving location, the signal from Cuba travels a long distance in daylight, and its more subdued signal is evident. In Figure 20 (from DX-Atlas), one can also see the December 30th grayline 1000 UTC.

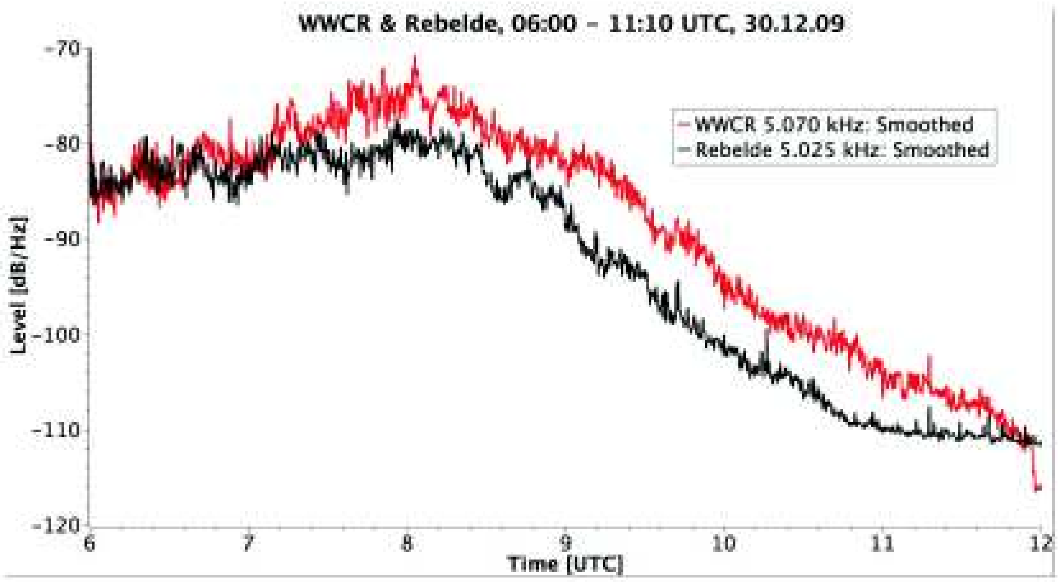


Figure 19: Shows the smoothed levels of Nashville and Habana over time. They start at almost same signal strength. But around receiver's sunrise, they separate from each other. As Habana takes a more southerly path, this signal is more influenced by the attenuating D-layer, building up due to sunshine. A bigger part of this path lies under the sun.

Figure 20: Shows the position of the grayline on December 30th at 1000 UTC, globe projection. Nashville and Habana are shown by pushpin icons, and the receiver location is indicated by a Yagi antenna icon.

If such experiments do guide us to exceptional DX, they are very much welcomed by even the average DXer. They can provide a useful trace where you can see the times with best signal/noise ratio at a glance. Figure 21 is a clear example.

Figure 21: The reception of SIBC Honiara on December 24, 2009 at 1500 UTC shows the optimum reception time.

On Christmas Day 2009, DXer Wolfgang Bueschel announced that SIBC Honiara / 5019.7 kHz was heard once again, after a transmitter repair. When I read the news in Christoph Ratzer's A-DX list, I immediately pressed the record button of Perseus and captured 1330 to 1900 UTC in WAV files. Right from the start SIBC was audible, and it increased to 1500 UTC, and faded shortly after 1600 UTC. The signal strengthened a bit after that, but never reached its prior level. My local sunset was 1509 UTC, almost exactly the time of the strongest reception.[5]

These were just a few possibilities and ideas on using the markers and marker.log file in Perseus. Your other ideas are welcome! German **Text & Images © 2010: Nils Schiffhauer, DK8OK**

Footnotes

Footnote 1: http://www.giangrandi.ch/electronics/radio/smeter/smeter.html
Footnote 2: http://scidavis.sourceforge.net/
Footnote 3: http://www.additive-net.de/software/origin/index.shtml
Footnote 4: For further examples: http://www.cliftonlaboratories.com/signal_statistics.htm
Footnote 5: Two Samples 14:00 to 15:00 UTC: http://web.me.com/nils.schiffhauer/Website/Monitoring

APPENDIX

Markers' Resolution in a Nutshell

For (semi-) scientific purposes it is important to know, what exactly you are measuring by the markers. They have two dimensions:

- *time* and
- *level*

For both, *resolution* depends on a couple of factors, some of them interdependent.

In general, the marker's log documents what you see on the screen in the big window, spectrum preferred over waterfall.

Regarding *time*, Perseus' "Software Settings" do offer a choice from 0.1 to 5 seconds. Obviously, the actual time resolution also depends from the "Span", and the "Resolution Bandwidth/RBW". Let's show this effect, when receiving time signal station MSF on 60 kHz.[1] Each "normal" minute starts with "at least 100 ms 'off' and ends with at least 700 ms carrier", as the fact sheet of the National Physical Laboratory puts it.[2] *Figures A* to *D* have all been made with a resolution of 0.1 seconds (Perseus' Software Settings). Please refer to the captions.

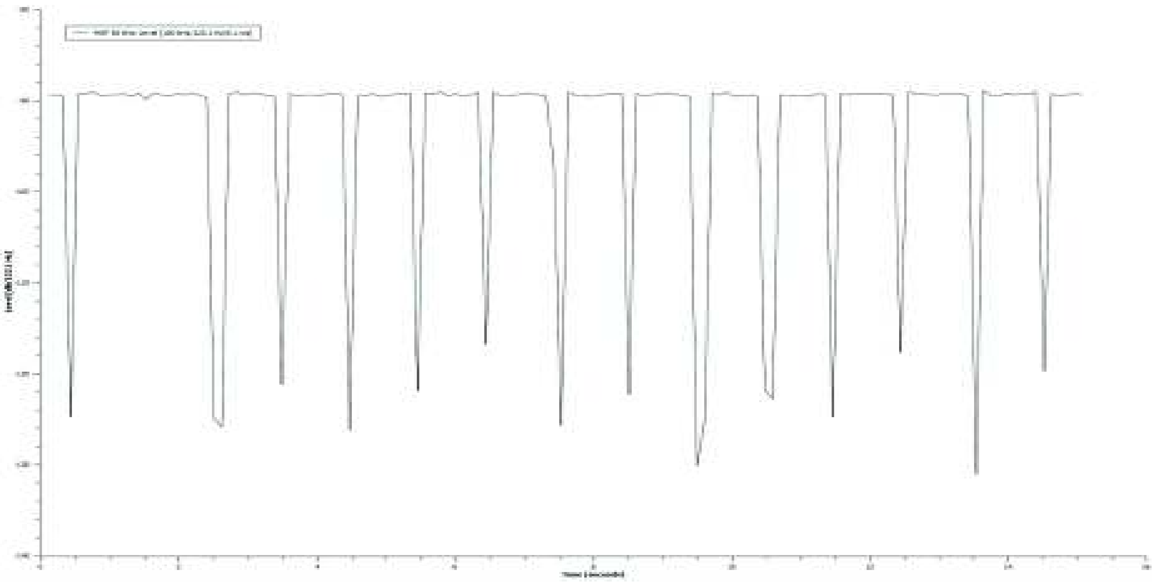


Figure A: *This is the diagram, we do expect from a time signal station on long wave. We clearly see the seconds, marked by "carrier off" for at least 100 milliseconds. The data refer to a "span" of 100 kHz, and a "resolution bandwidth" of 122 Hz. If we magnify this diagram, this leads us to …*

[1] http://www.npl.co.uk/science-technology/time-frequency/time/products-and-services/msf-radio-time-signal
[2] http://www.npl.co.uk/upload/pdf/MSF_Time_Date_Code.pdf

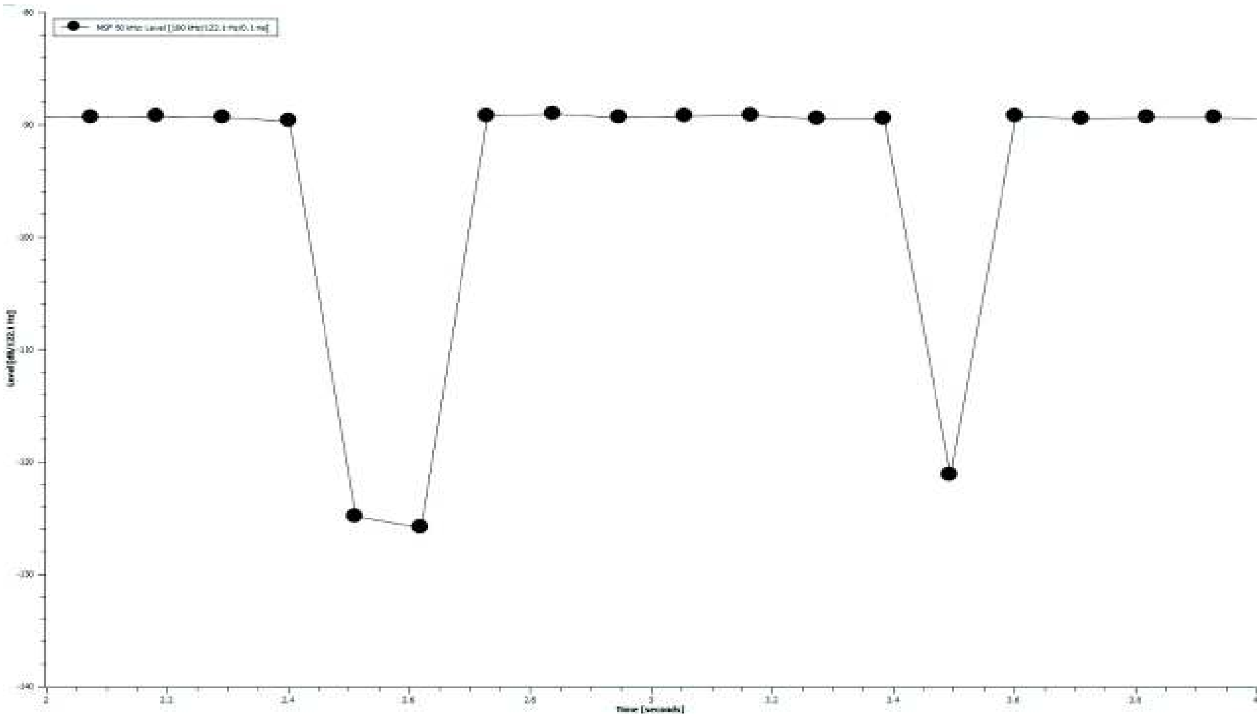


Figure B: *… where each 100-millisecond-sample is marked by a bullet. Because starting of the 100-ms-samples cannot be synchronized with the time of transmitting, you sometimes see more than one bullet marking a "carrier-off-time" of exactly 100 ms.*

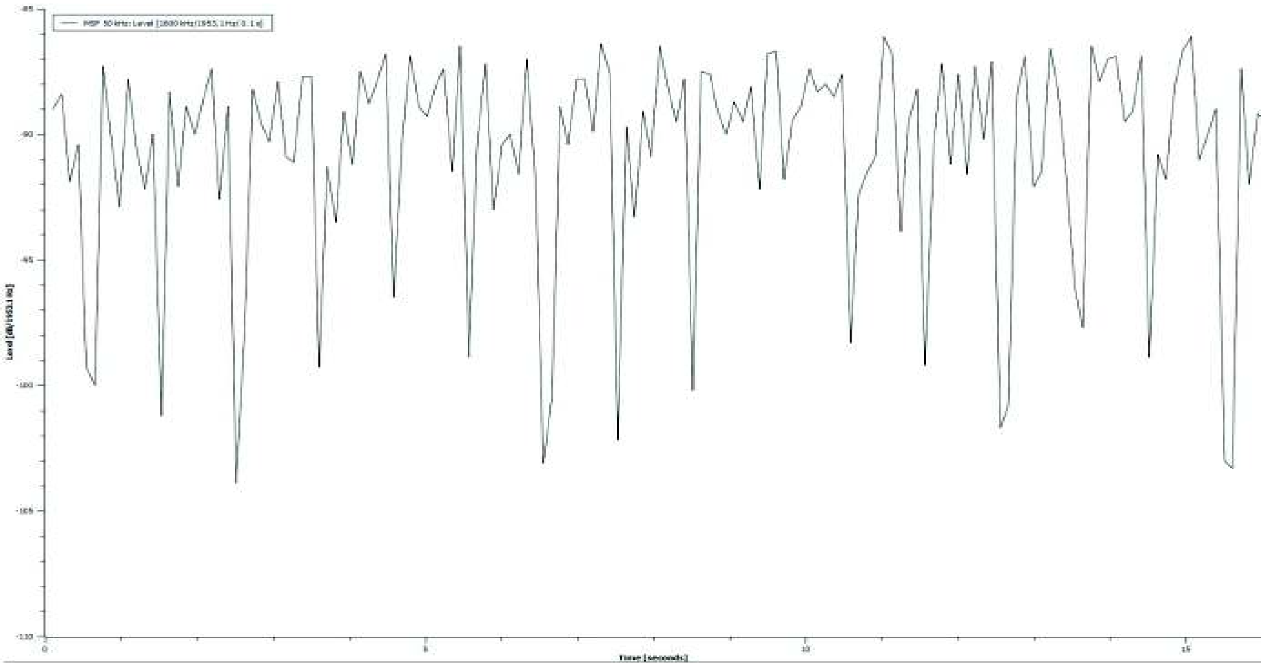


Figure C: *Exactly the same situation, as shown in Figure A. But recorded with a "span" of 1600 kHz, and a "resolution bandwidth" of 1953,1 Hz. This obviously provides us with a better time resolution.*

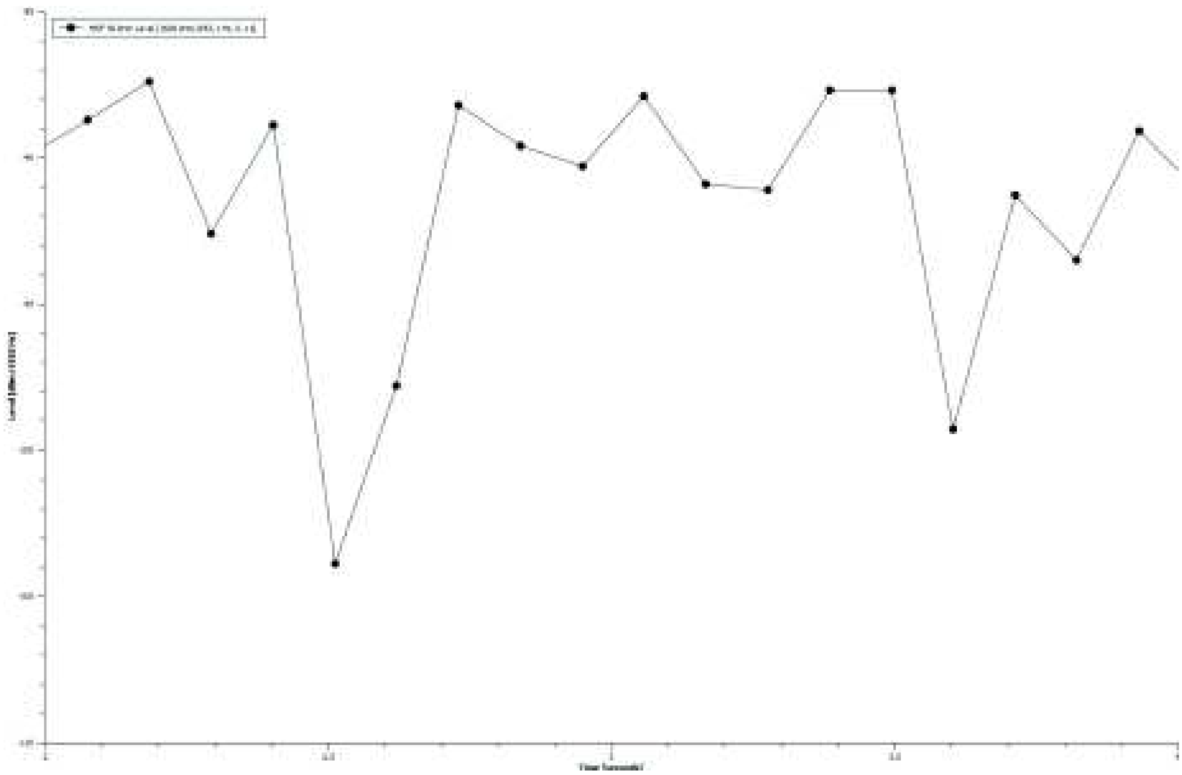


Figure D: *A magnified part of Figure C, showing a better time resolution. See for some dB of fading even during the 900 milliseconds of "carrier on".*

The figures show that the bigger the span and the bigger the resolution bandwidth, the greater is the *resolution in time*.[3]

The next step was to find out, what a sampling rate of e.g. "5 seconds" really means: Will it return the average level (power of voltage) over five seconds, or will it give just a flashlight picture each five seconds?

Obviously, Perseus is collecting samples via the flashlight-method. Otherwise, *Figures E* and *F* won't show samples of such low levels. Again, I received MSF time ticks. Over five seconds, its carrier should be "on" for at least four seconds or 80 % of the time. Thus, when averaged, the distribution of the sample would be within just a couple of dB, but not up to 50 dB. Thus, the diagrams seem to show the synchronization between the time, where the samples are "flash lighted", and the second ticks of the transmitter. If it would be possible to synchronize the start just within "carrier off", the diagram would show almost a simple line around -100 dBm. In case, started within "carrier on", it would show almost a line between -90 and -80 dBm.

[3] Sorry for don't providing the underlying math; will have to ask Nico for that.

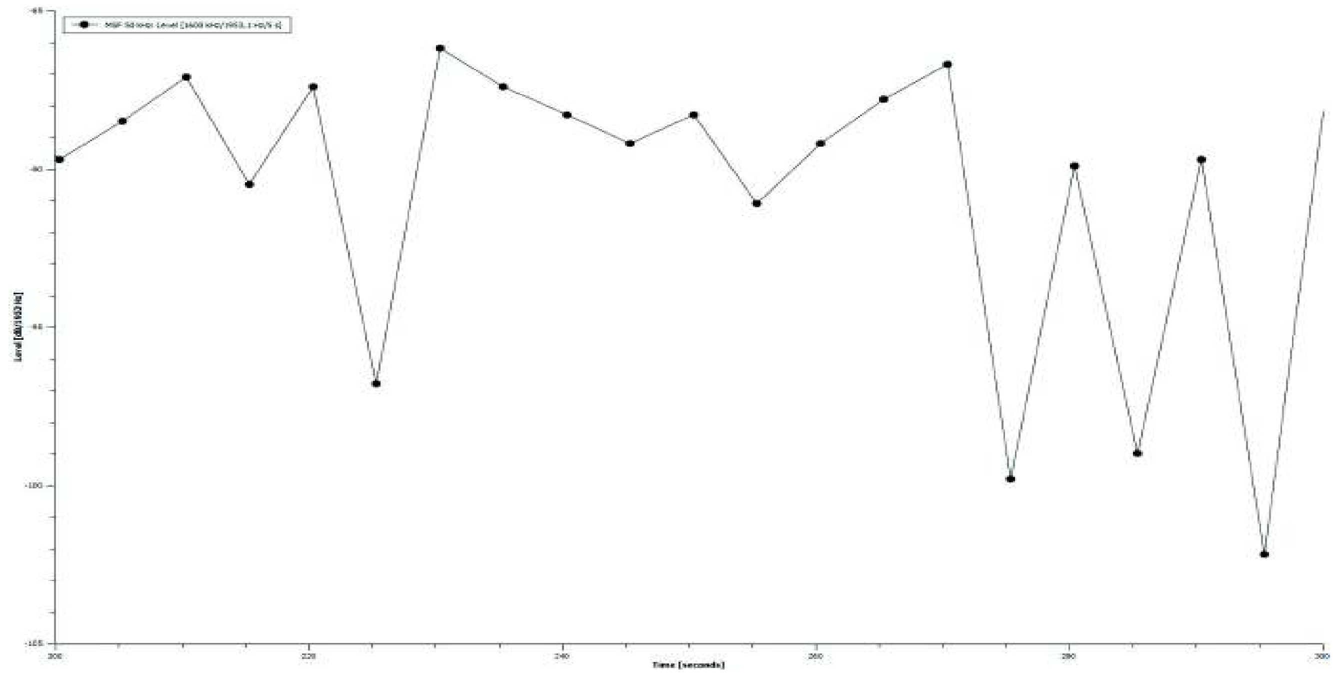


Figure E: When sampled MSF with five seconds, a span of 1600 kHz and a RBW of 1953 Hz, the differences of the samples come up to more than 15 dB. This suggests that each five seconds, the software places a flashlight onto the signal. Sometimes, at this moment, it sees a carrier (-90 dBm), sometime the carrier is off.

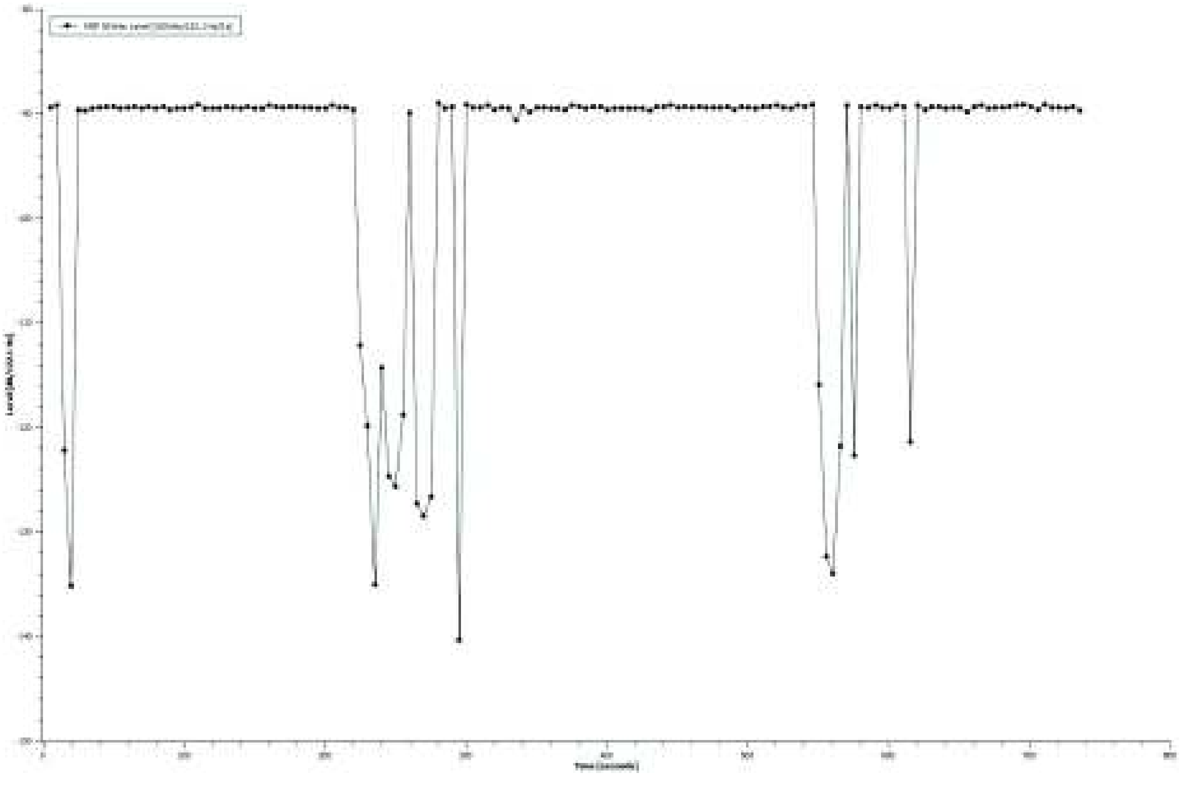


Figure F: Shows the effect of synchronization, 800 seconds, 100 kHz span and 122 Hz resolution.

Averaging the signal level, will give us more realistic results. This can be done by the slider “AVG Main”. You can see the effect from *Figure G*, comparing with *Figure E*.

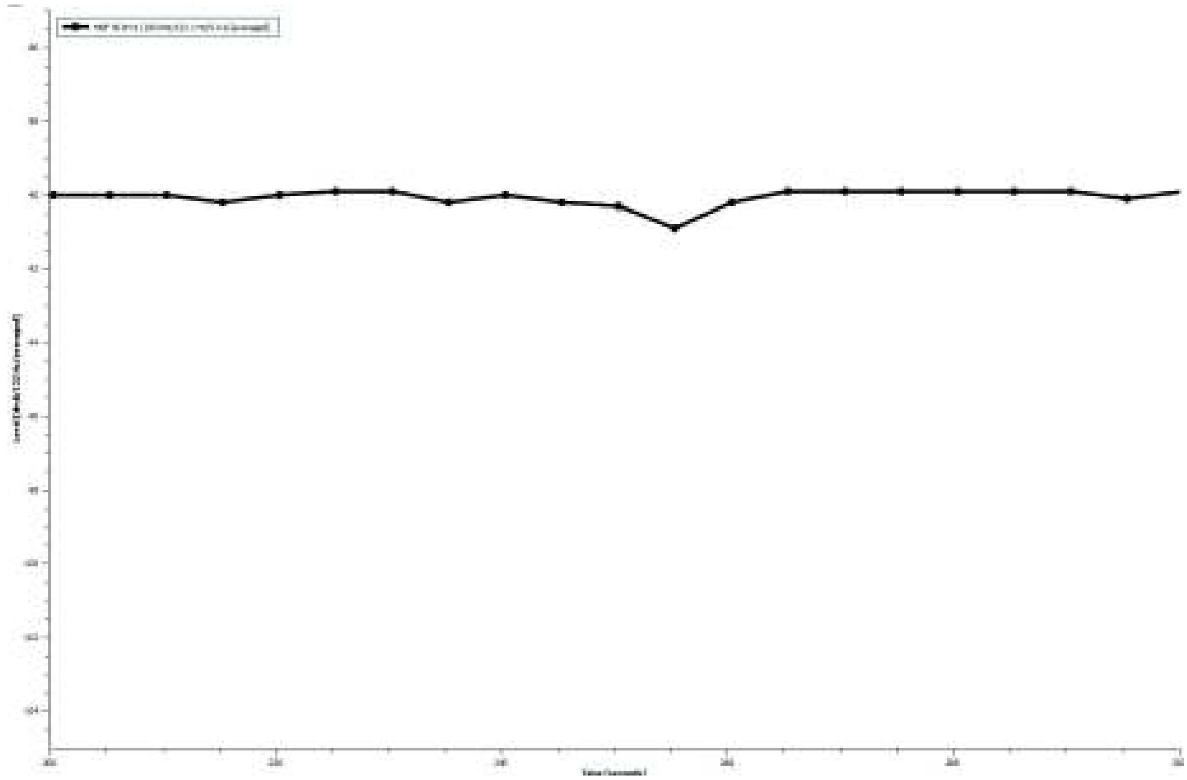


Figure G: Averaging shows the average level of the time signal station for 100 seconds at the same scale (Level/Time) as Figure E.

As we don’t know by exact numbers the effect of this averaging, a more precise averaging can be also done by statistical methods (e.g. “Averaging Window”).

So much for “times and samples”. Now for the markers’ “level”. As laid out in the article, the level depends on – of course – the signal and on the “resolution bandwidth/RBW”. Signals with a constantly transmitted carrier, which is strong compared to the modulation (as with most broadcasting stations), are easily to measure: largely not influenced by the resolution bandwidth, the marker (set onto the carrier: PkSrc) automatically shows the level in dBm or dBuV at 1 Hz.

To measure noise or noise-like signals (like DRM), you have to take the “resolution bandwidth” into account. This is not always as simple as just adding or subtracting dB, in order to “normalize” a bandwidth to that of 1 Hz. Most often on shortwave, you have to take into account the factor of *selective* fading.

Figure H shows the levels of the three pilot carriers of a DRM signal. They are *transmitted* with the same *constant power*. But we *receive* them with often *different levels*.

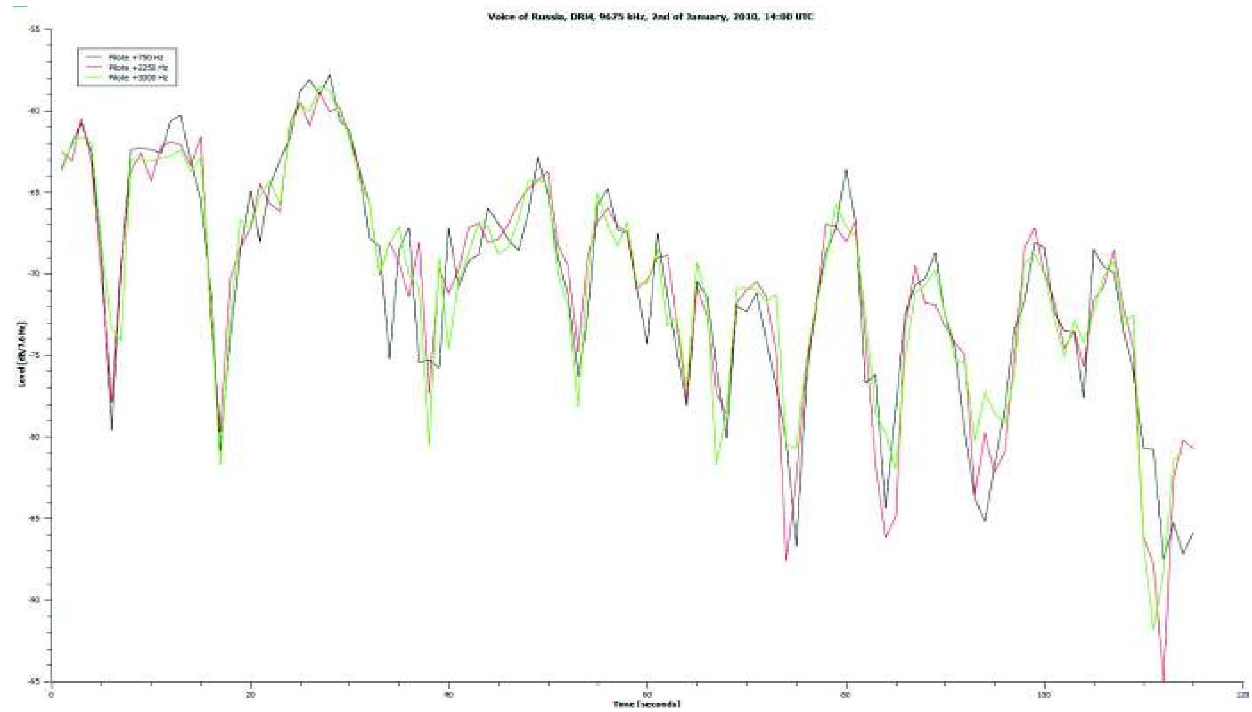


Figure H: The three pilot carriers of a DRM signal at +750 Hz, +2250 Hz and +3000 Hz (in reference to the carrier frequency) have a similar shape, but not exactly the same. Due to selective fading, they differ a bit in time, as well as in level.

Even measuring pilot carriers, with DRM signal, you have to observe the resolution bandwidth, see Figure I.

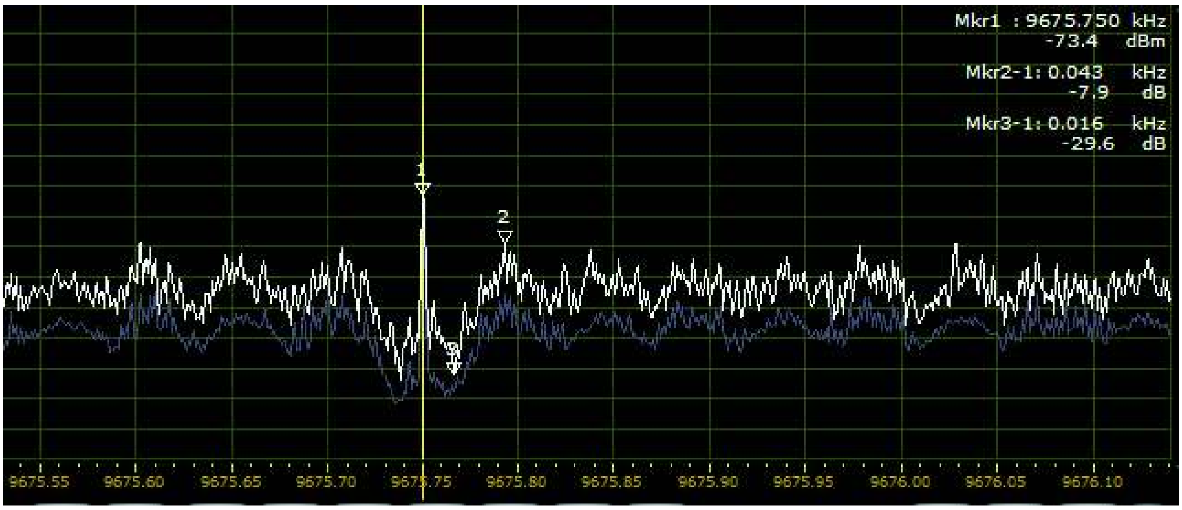


Figure I: One DRM pilot carrier under the microscope (Mkr1). It is only roughly 8 dB stronger than the other PSK carriers (Mkr2), peaking in a distance of only ±43 Hz. Thus, in such an environment, one should measure the carrier-only at a "resolution bandwidth" lower than about 30 Hz – Mkr3 marks two "notches" 16 Hz apart from the pilot carrier. As a sharp selective fading can lead to a pilot carrier well below (some 10 dB) below the PSK carriers, you never know, what exactly you are measuring with a wider "resolution bandwidth".

The graphical (not: numerical) setting of markers is very easy and intuitive to do, but leaves us with two problems in rather special cases:

- to measure e.g. a DRM signal with several markers of a wide “resolution bandwidth” (they cannot be placed exactly)
- to measure at very low “resolution bandwidths”, e.g. separate carriers on one medium wave channel, differing by only a few Hertz. Tried to separate e.g. Urumchi, BKSA Ryadh and Gold UK from each other on 1521 kHz, but failed to do so.

RTTY signals (FSK) should be measured with a “resolution bandwidth”, wider than their shift.