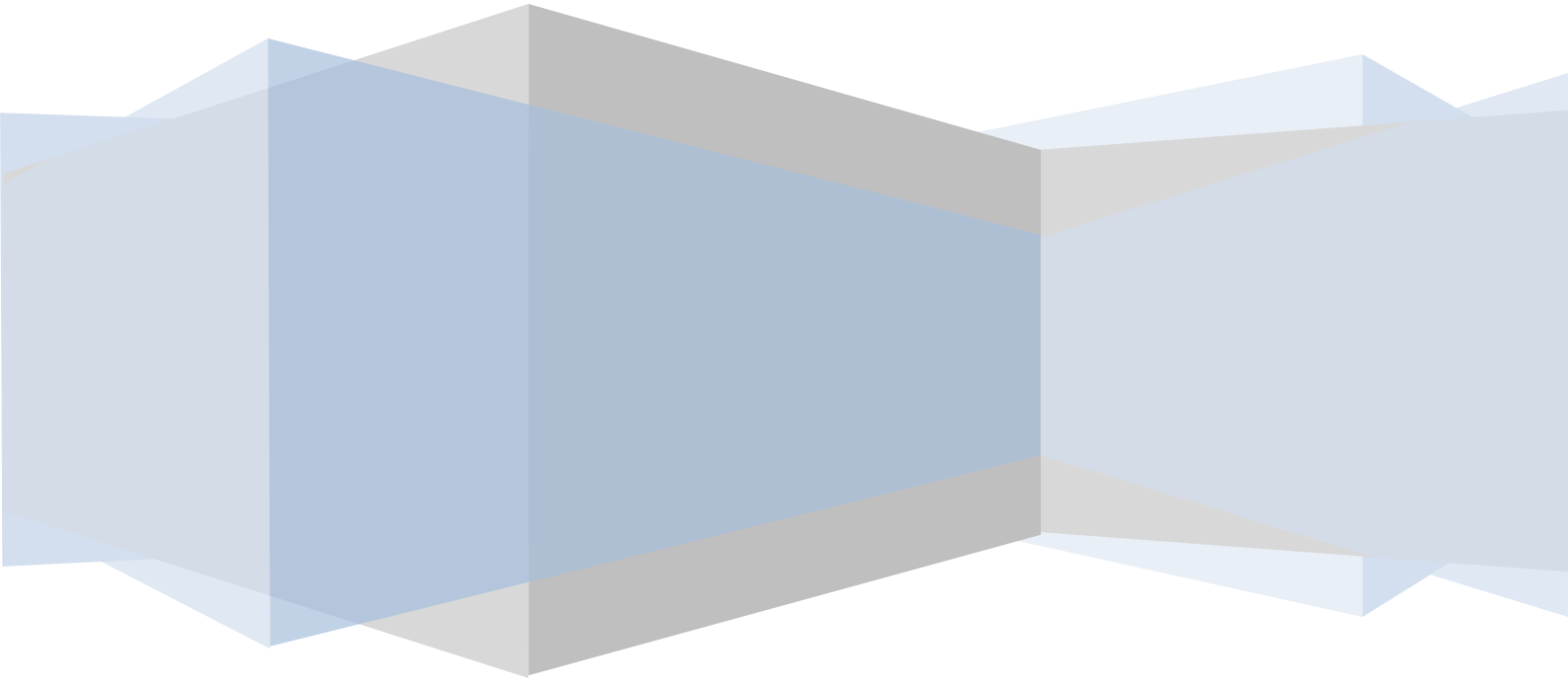
October 2011

Ground Gain Measurement Procedure

Addendum to the article “Ground Gain in Theory and Practice” published in DUBUS 3/2011

Gaëtan Horlin, ON4KHG



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1. Introduction

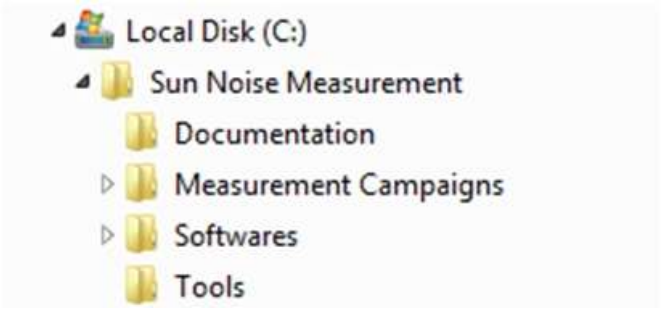
As an addendum to the article "Ground Gain in Theory and Practice" published in the magazine **DUBUS 3/2011**, this document describes the measurement protocol steps to be performed in order to assess one's own Ground Gain geometry and magnitude or in a more general way one's own antenna elevation pattern in presence of ground effects. The emphasis is on 144 MHz but it could be applicable to other bands through some customization.
The following equipment is required :

- A SSB capable receiving chain with an AGC disabling capability.
- A computer ; any current one will do the job.
- A soundcard, either embedded in the computer or external.
- A link between the receiving chain audio output and the computer soundcard input (Line IN), with a way to adjust the audio level in between.

2. Preparation

2.1. Step 1 : extract the package content

Unzip the content of the package to the root directory C:\. Don't do it somewhere else (i.e. in another directory), otherwise the Excel macros devoted to data processing will fail to work.
You will get a directory with the following structure :

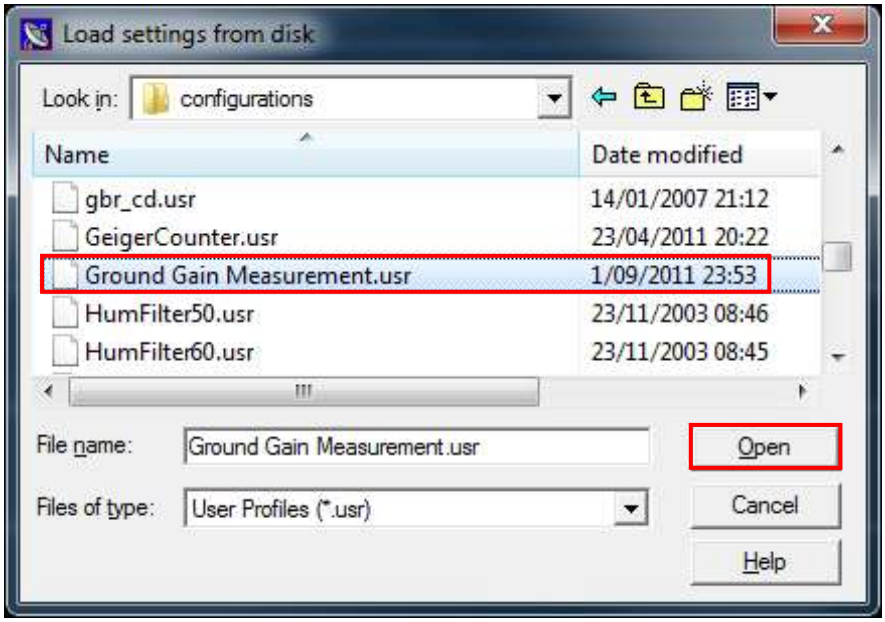


In the different directories, you will find :

- ***Documentation*** :
  - The present document, *Ground Gain Measurement Procedure v1-0.pdf*
  - Precedings of the IRE - Scatter Propagation Issue – Part 1, *IRE 1955 Part 1.pdf*
  - Precedings of the IRE - Scatter Propagation Issue – Part 2, *IRE 1955 Part 2.pdf*
- ***Measurement campaigns*** :
  - Examples of real measurements
- ***Softwares*** :
  - Spectrum Lab v2.76 b8 (by DL4YHF), *Spectrum Lab 2-76.zip*
  - Configuration file *Ground Gain Measurement.usr* for Spectrum Lab
  - GJTracker (by W7GJ), *GJTRACKER.zip*
- ***Tools*** :
  - *Ground Gain Geometry and Magnitude Calculator File.xlsm* which is a theoretical simulator (MS Excel 2007).
  - *Ground Gain Sun Noise Measurement Processing File.xlsm*, the file (MS Excel 2007) to process the sun noise measurement data records and its desktop shortcut.

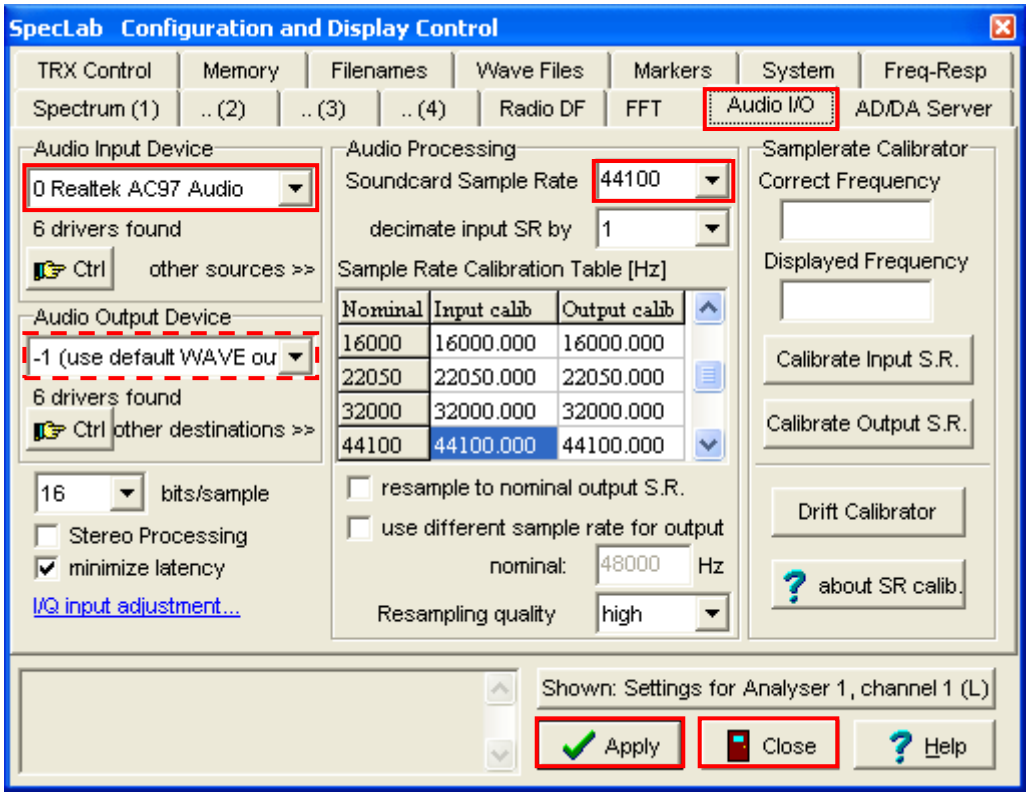
2.2. Step 2 : install and configure Spectrum Lab

- Install Spectrum Lab in whatever directory (this one not necessarily C:\). I'm using Spectrum Lab under MS Windows XP SP2.
- In the directory where Spectrum Lab is installed, create the following sub-directories :
  - ***Captures***
  - ***Logging***
- Move the file *Ground Gain Measurement.usr* provided in the measurement package to the sub-directory ***configurations*** of Spectrum Lab.
- Start Spectrum Lab (icon on desktop).
- In the menu toolbar, select **File > Load Settings From.. :**
  - Go to the sub-directory ***configurations*** and choose the file *Ground Gain Measurement.usr*.
  - Click on **Open**.

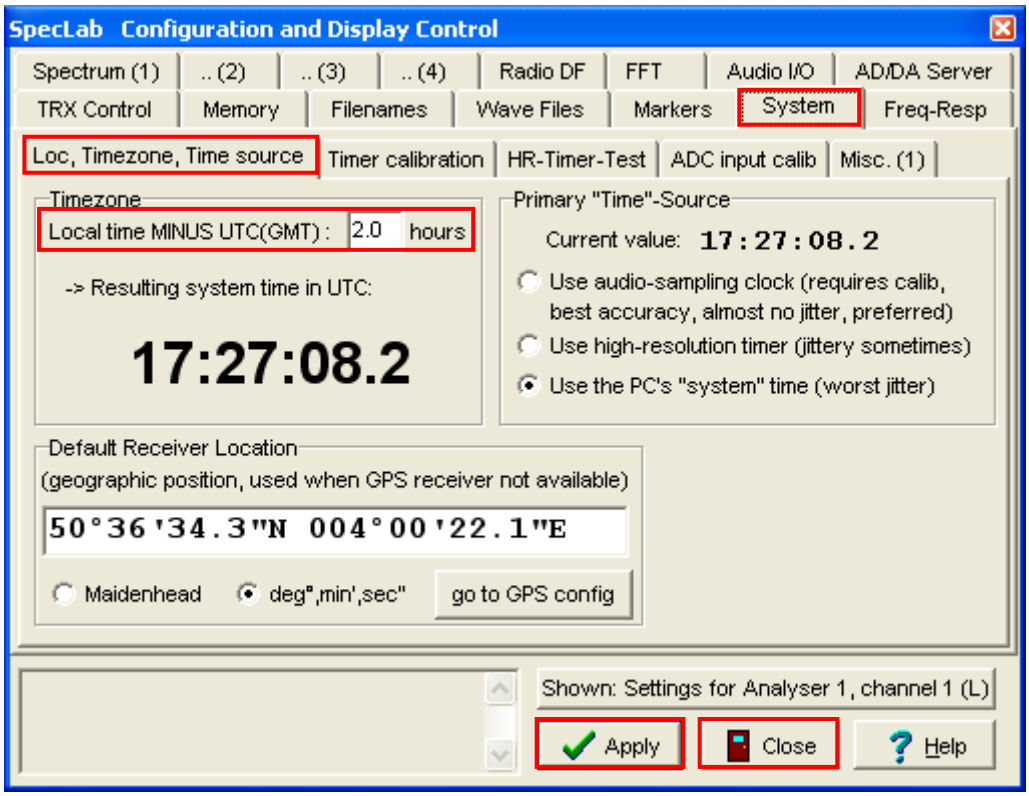


This file contains the customized configuration required for the measurement. You need however some more own customization.

- In the menu toolbar, select **Options > Audio settings, I/O device selection** :
  - In the tab **Audio I/O** of the new window, select your own particular soundcard (**Audio Input Device**) amongst the list. According to your particular soundcard, it could be required to change also the **Soundcard Sample Rate** (e.g. 11025 Hz instead of 44100 Hz as for mine).
  - If you also want to listen (but it will just be noise), select the **Audio Output Device** too.
  - Click on **Apply** and **Close**.

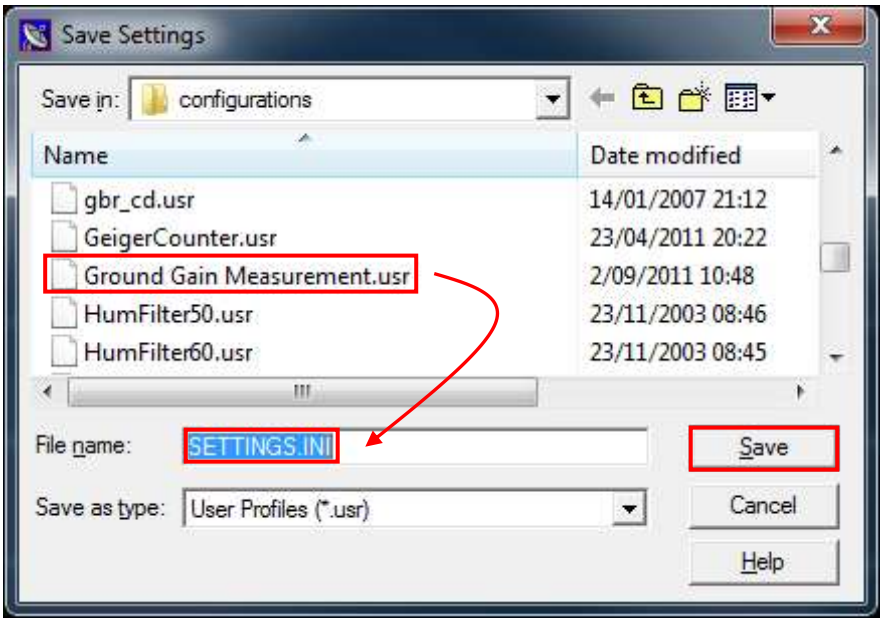


- In the menu toolbar, select **Options > System settings > Timezone, Time source, Timer Calibration** :
  - In the tab **Loc, Timezone, Time source**, set **Local time MINUS UTC(GMT)** according to your location.
  - Click on **Apply** and **Close.**



For example in Belgium in winter, we are at UTC+1h local time (UTC+2h in summer) ➔ e.g. UTC is 12:00, local time is 13:00 in winter (14:00 in summer). So, **Local time MINUS UTC(GMT)** is **1** (13-12) in winter and **2** in summer.
The computer must be synchronized on a NTP time server (there are many softwares to achieve this, e.g. D4, Chronos, Meinberg,…).

- Finally, in the menu toolbar, select **File > Save Settings As.. :**
  - Replace *SETTINGS.INI* by *Ground Gain Measurement.usr* chosen in the list.
  - Click on **Save**.

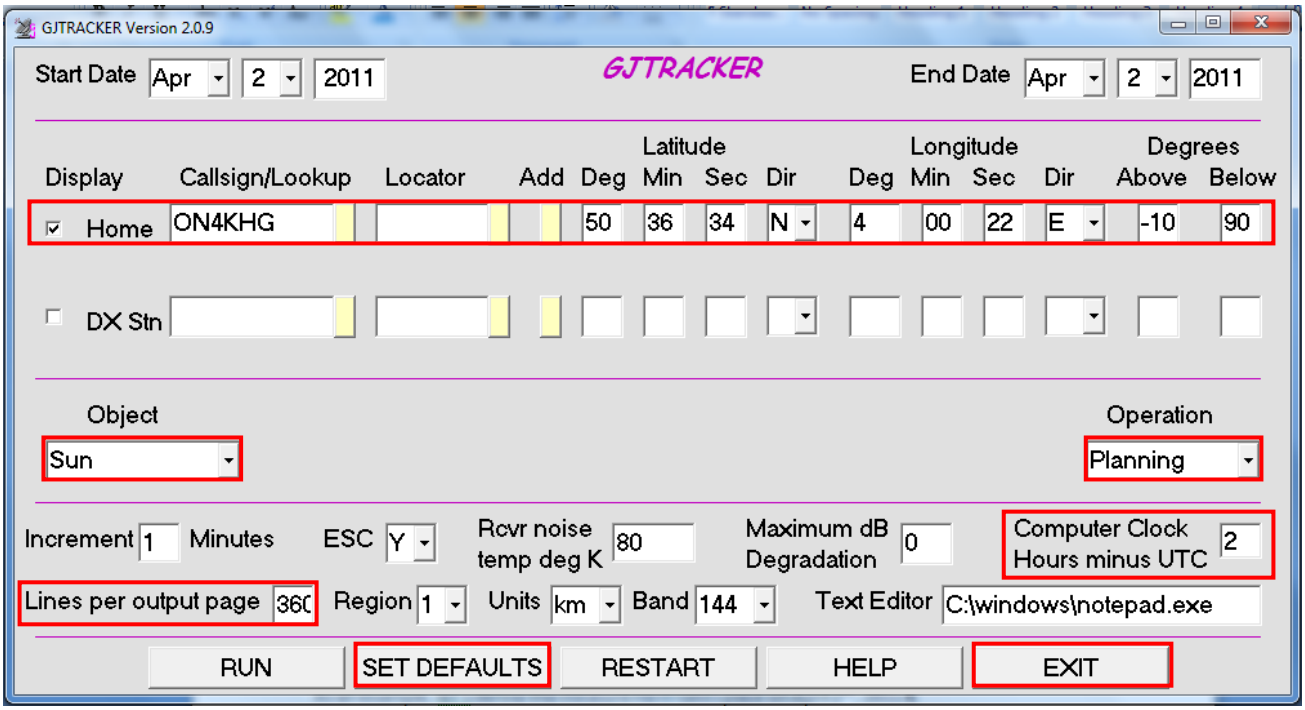


That is all, don't change anything else ; FFT, noise measurement formulas,… are already included in the *Ground Gain Measurement.usr* file.

- **Close** Spectrum Lab. For the subsequent measurements, Spectrum Lab is now configured once and for all.

2.3. Step 3 : install and configure GJTracker

- Install GJTracker (provided in the measurement package) on your computer, wherever you wish (in any directory).
- Start GJTracker and configure with your own data according to the following screenshot :



  - **Lines per output page** : set to “3600” (to ease subsequent processing work).
  - **Computer Clock Hours minus UTC** : set in the same way as for Spectrum Lab, explained in section 2.2.

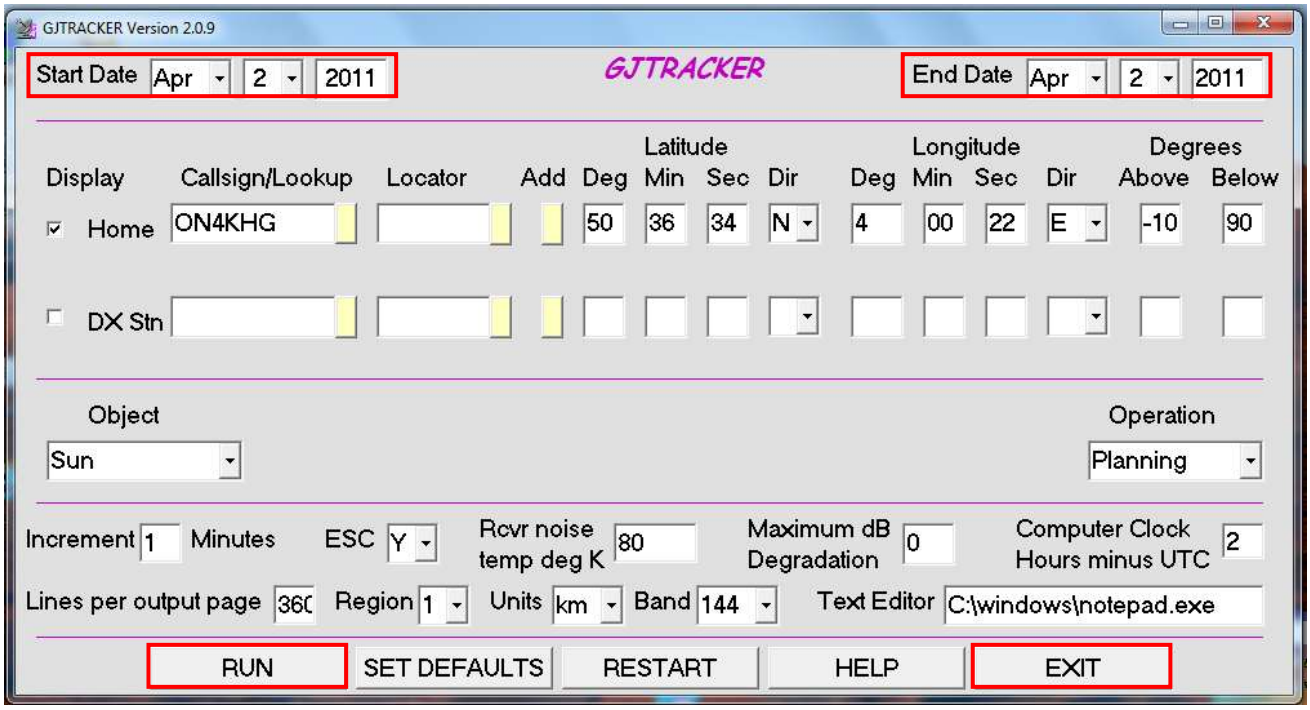
- Click on **SET DEFAULTS**, so that at next start all but the date will remain the same. GJTracker is now installed once and for all.
- **Exit** (close) GJTracker.

3. Measurement

3.1. Step 1 : plan the measurement

As an example, let's define the measurement takes place on April 2nd, 2011.

- Open GJTracker.
- Set **Start Date**, then **End Date** to "Apr 2 2011".
- Click on **RUN.**



- Here is an extract of the output text file :

```
APR  2, 2011              POSITION OF Sun FROM ON4KHG              50 ° 36' 34" N
SATURDAY                                                           4  ° 0 ' 22" E
JD: 2455653.5                                                        (QTH:JO10xo)

UTC     AZIMUTH     ELEV      DEC     RT ASCN
====    =======     ====     =====    =======

0420      69.8      -9.9      4.8      0H 44M
0421      70.0      -9.8      4.8      0H 44M
0422      70.2      -9.6      4.8      0H 44M
0423      70.4      -9.5      4.8      0H 44M
0424      70.6      -9.3      4.8      0H 44M
0425      70.8      -9.2      4.8      0H 44M
0426      71.0      -9.0      4.8      0H 44M
0427      71.2      -8.9      4.8      0H 44M
0428      71.4      -8.7      4.8      0H 44M
0429      71.6      -8.6      4.8      0H 44M
0430      71.8      -8.4      4.8      0H 44M
0431      72.0      -8.2      4.8      0H 44M
0432      72.2      -8.1      4.8      0H 44M
0433      72.4      -7.9      4.8      0H 44M
0434      72.6      -7.8      4.8      0H 44M
0435      72.8      -7.6      4.8      0H 44M
0436      73.0      -7.5      4.8      0H 44M
0437      73.2      -7.3      4.8      0H 44M
```

- **Save** this file under the name *Sun Az-El.txt* in the directory C:\Sun Noise Measurement.

It is important to respect the naming convention given here (both directory and file names), otherwise the processing macros in Excel won't work !

- **Exit** (close) GJTracker.

On April 2nd, 2011 for my location, the sun rises at 05:24 UTC (azimuth 82.4°) and sets at 18:12 UTC (azimuth 277.9°).

3.2. Step 2 : equipment warm-up

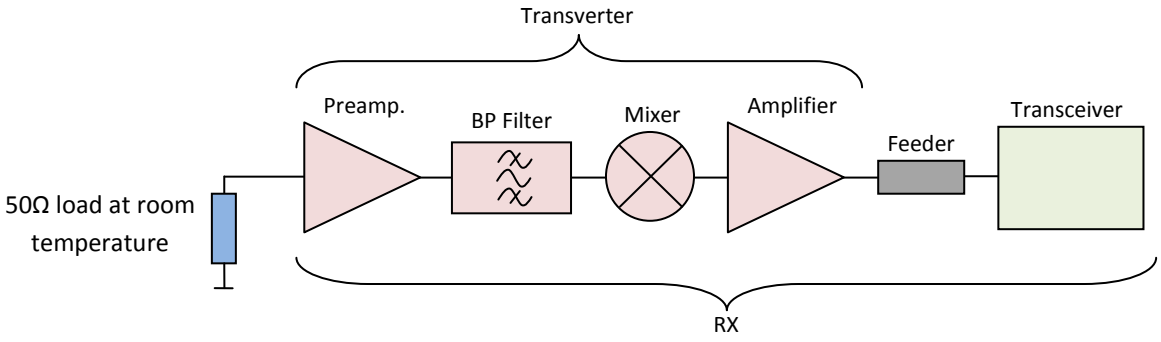
Equipment settings and conditions for a reliable measurement are as follows :

- Transceiver or receiver AGC (Automatic Gain Control) set to OFF.
- Transceiver or receiver set in SSB mode (200-2200Hz bandwidth required).
- Whole receiving chain (RX and soundcard) assumed to be linear.
- Transceiver or receiver Noise Blanker (NB) set to ON. The white noise to be measured is normally not altered by the NB, while the pulse noises (disturbing the measurement) will be suppressed.
- A clear frequency, not subject to disturbances (QRM).
- **The whole station and computer powered ON at least 12 hours before performing the measurement**, so that the whole setup is stable and at temperature during the measurement.
- Good weather with no wind or rain to avoid static noise.

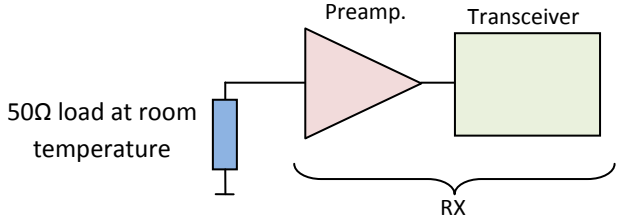
3.3. Step 3 : reference noise ($N_{reference}$)

When the sun is below -10° elevation for a sun rise measurement or above +35° elevation for a sun set measurement :

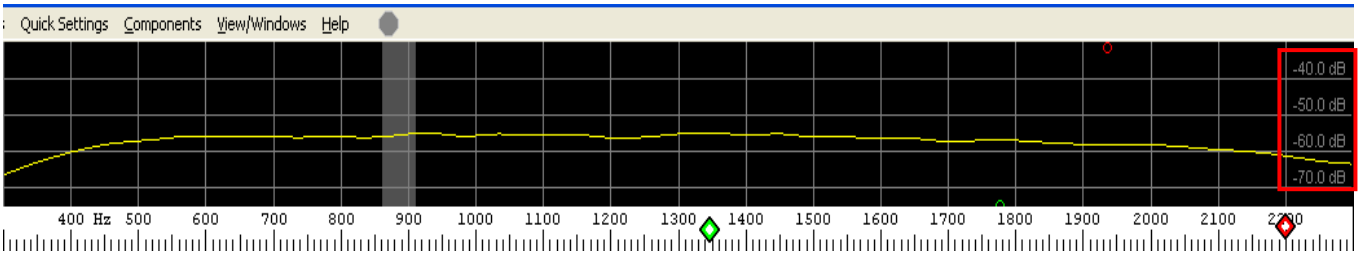
- Connect a 50Ω load at the input of the RX chain, as depicted below :



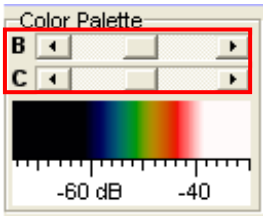
If you are not using a transverter, consider placing a preamp. in front of the transceiver or receiver, particularly if this last is a commercial model, to overcome the possible poor sensitivity and to allow the small (sun) noise variations (few dB's) to be noticed. In this case, the RX chain will look like :



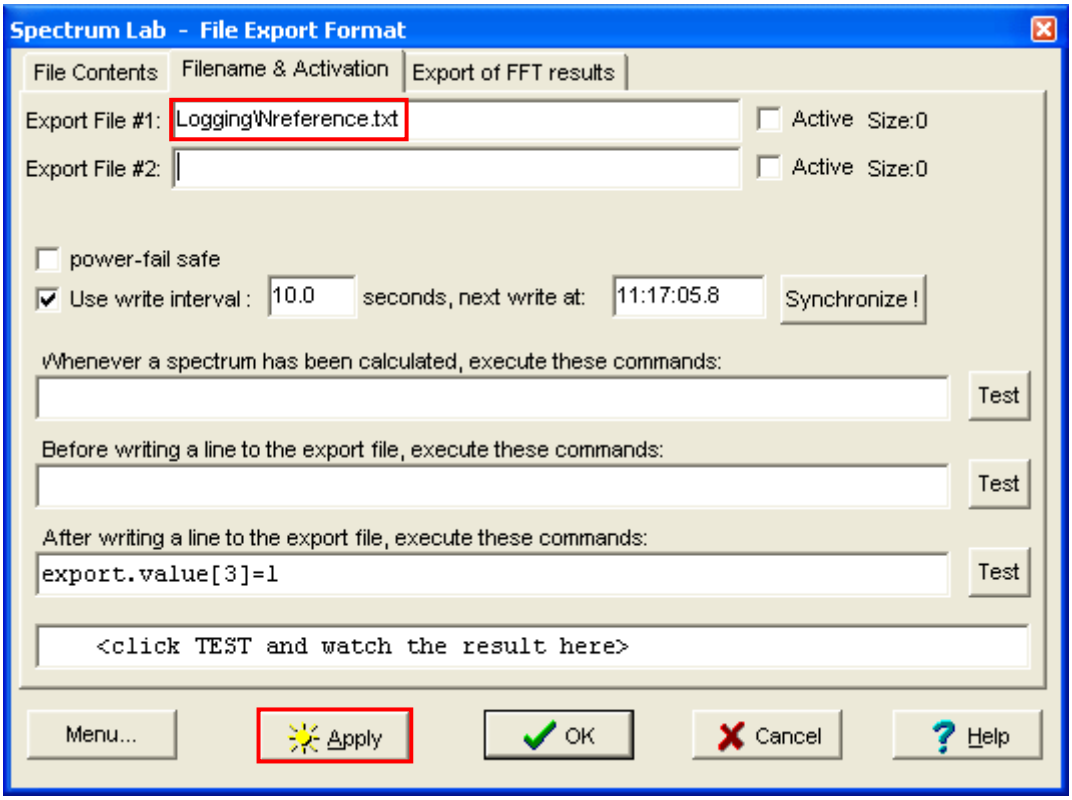
- Start Spectrum Lab.
- Adjust the audio level out of the transceiver or receiver to get the yellow curve on the spectrum window around -50/-60 dB (this is not critical). Once adjusted, don't touch it anymore during the course of the subsequent steps of the measurement.



- Adjust the colour palette sliders as you wish. Don't touch it anymore afterwards.



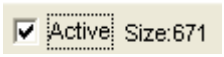
- In the menu toolbar, select **File > Text file export > Export of calculated data** :
  - In the tab **Filename & Activation**, type in the file name as shown on the screenshot below (*Nreference.txt*).
  - Click on **Apply**.



It is very important to click on **Apply**, otherwise the measurement will further proceed on the previously named file.

To effectively start the measurement :

- Check in the checkbox **Active**. The **Size** will start to grow.
- Leave the measurement running up to when the **Size** has reached around 500 to 1000 (not critical).



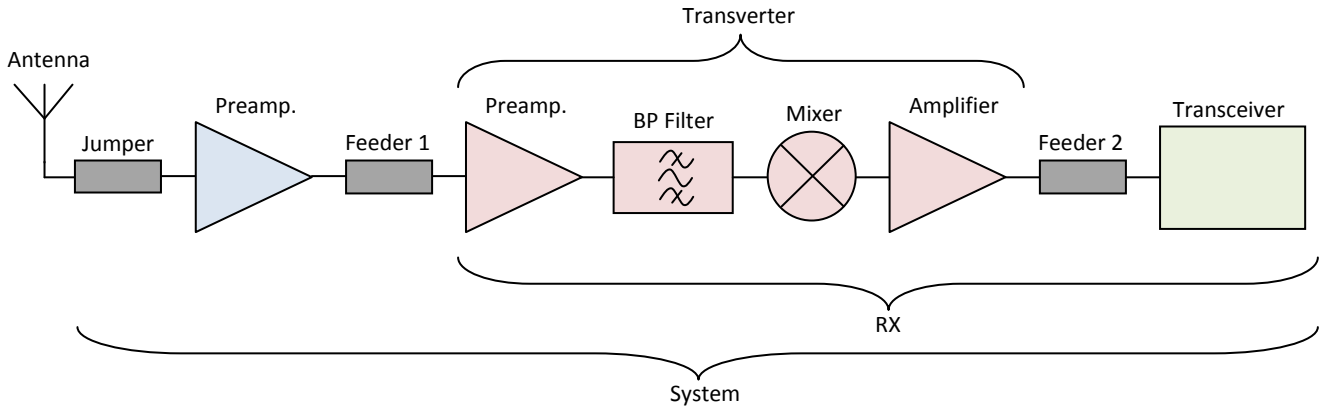
- Uncheck the checkbox **Active** to stop the measurement.

You can click on **OK** to close the window, but it is not required at this stage to close this window ; leave it open.

3.4. Step 4 : background noise before sun noise measurement (N_{bgd} PRE)

Once Step 3 is completed :

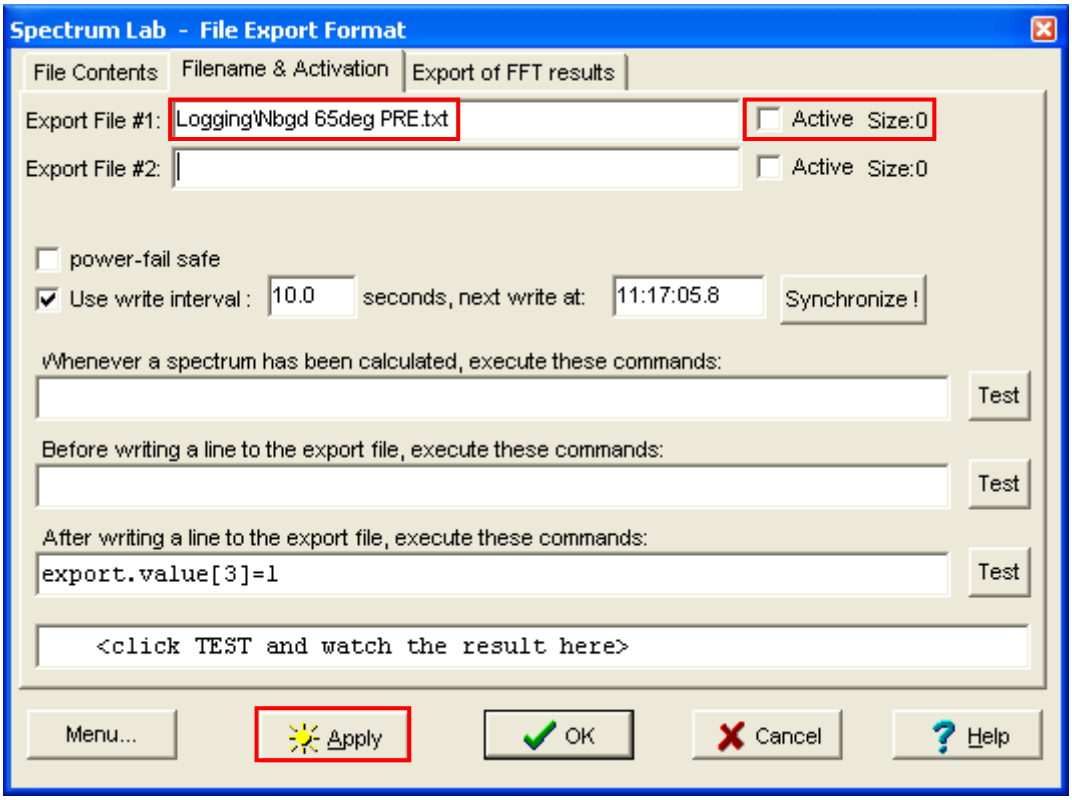
- Disconnect the 50Ω load and connect the antenna line. Don't forget to set the external (masthead) preamp. in by-pass mode.



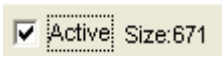
- Rotate the antenna towards the first azimuth onto which N_{bgd} has to be measured.

For the example given here, the azimuth span ranges from 65° to 140°. Let's start with 65°.

- Direct your antenna to 65° azimuth.
- In Spectrum Lab name the data to record as on the screenshot below (*Nbgd 65deg PRE.txt*).



- Click on **Apply**
- Check the **Active** checkbox to start the measurement. The **Size** starts to grow every 10 seconds.
- Leave the measurement running until the **Size** has reached around 500 to 1000 (not critical).



- Uncheck the checkbox to stop the measurement.
- Then rotate the antenna towards 70° :
  - Update the file name (now *Nbgd 70deg PRE.txt* instead of *Nbgd 65deg PRE.txt* as above).
  - Click on **Apply**.
  - Check the **Active** checkbox and uncheck it once the size has reached 500 to 1000.

And so on up to 140° azimuth, per 5° azimuth steps.

The overall sequence is as shown hereunder.

In the menu toolbar, select **File > Text file export > Export of calculated data :**

Azimuth x+5°

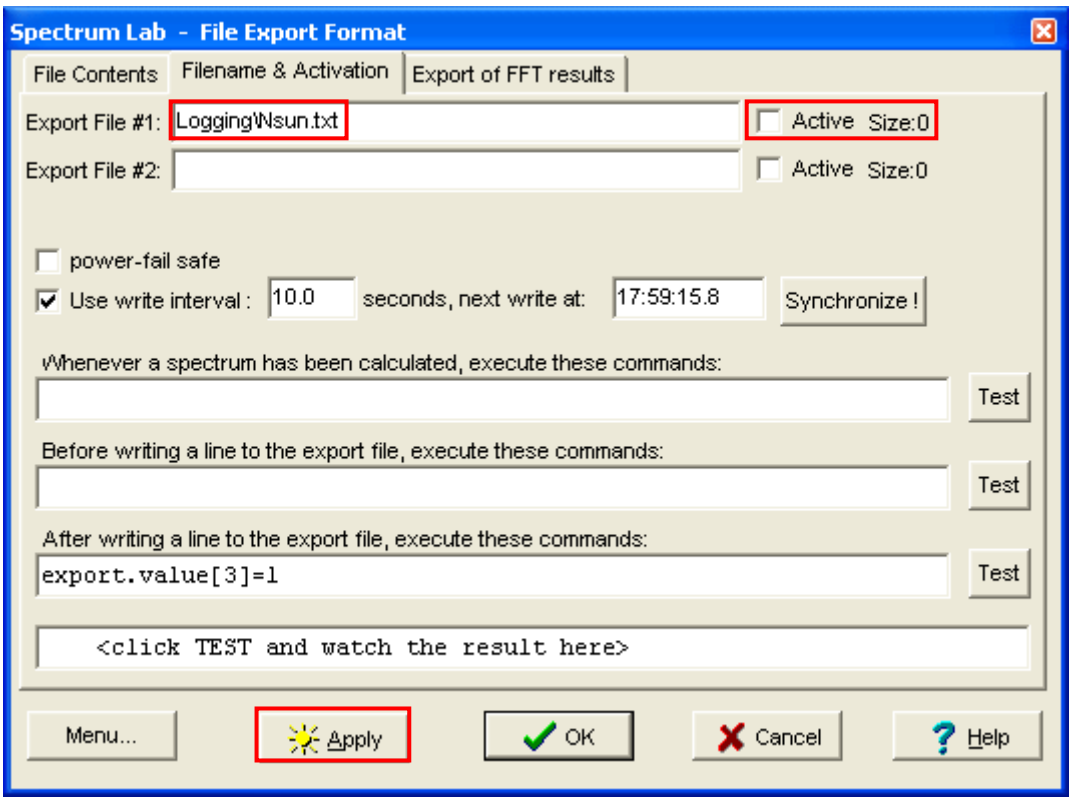
- Name the data file to record (mandatorily as *Nbgd xdeg PRE.txt* ; x = 0 to 360).
- Click **Apply**.
- Check in checkbox **Active** to start.
- Once size has reached 500 to 1000, uncheck to stop.

3.5. Step 5 : sun noise (N_{sun})

Right after Step 4 has been performed, the sun should be around -5° elevation for a sun rise measurement or around 30° elevation for a sun set one. Measure the sun noise in tracking mode up to around 30° (sun rise) or down to around -5° elevation (sun set). "Tracking mode" suggests an automatic way for the antenna to follow the motion of the sun in azimuth ; otherwise, you need to manually adjust the antenna position from time to time.

Once the antenna is set to the proper azimuth and ready to follow the motion of the sun, go to the menu toolbar of Spectrum Lab, select **File > Text file export > Export of calculated data** :

- Name the data file to record, mandatorily as *Nsun.txt.*
- Click on **Apply**.

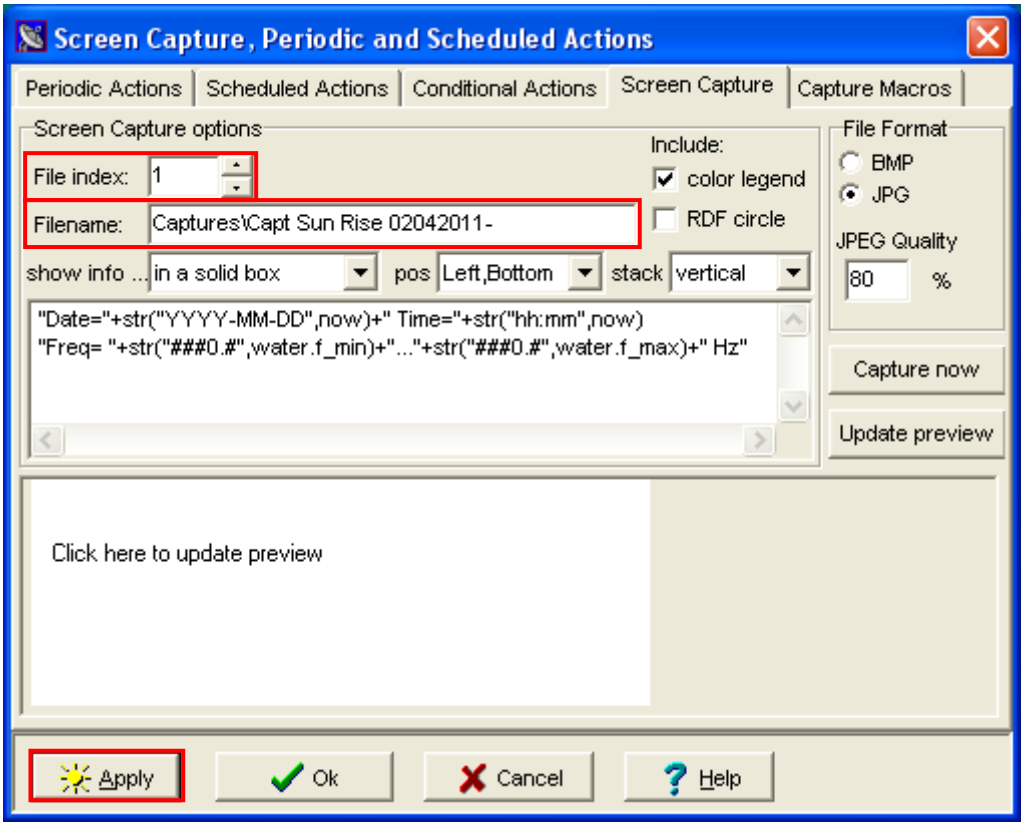


- Check in checkbox **Active** to start (*).
- Let the measurement running and once the sun is out of range, i.e. above 30° elevation (sun rise) or below -5° elevation (sun set), uncheck **Active** to stop.

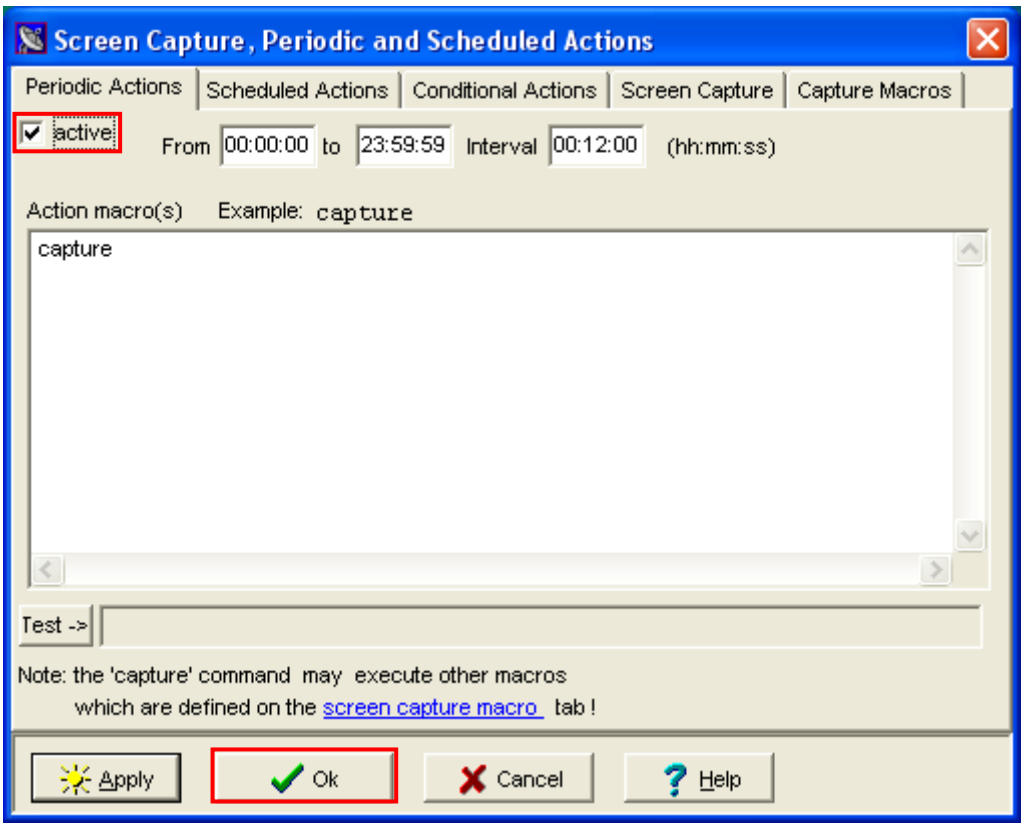
This measurement can take several hours, according to your latitude and period of the year.

To allow identifying *a posteriori* if some disturbance occurred during the measurement, it is wise to activate screenshot captures prior to start the measurement (*). To accomplish this, follow the steps below.

- In the menu toolbar, select **File > Screen Capture > Screen Capture options..** :
  - In the tab **Screen Capture**, Set **File Index** to **1** and **Filename** to any name you want (no specific naming convention required here).
  - Click on **Apply**.



- In the tab **Periodic Actions**, check in the checkbox **active** and then **OK**.

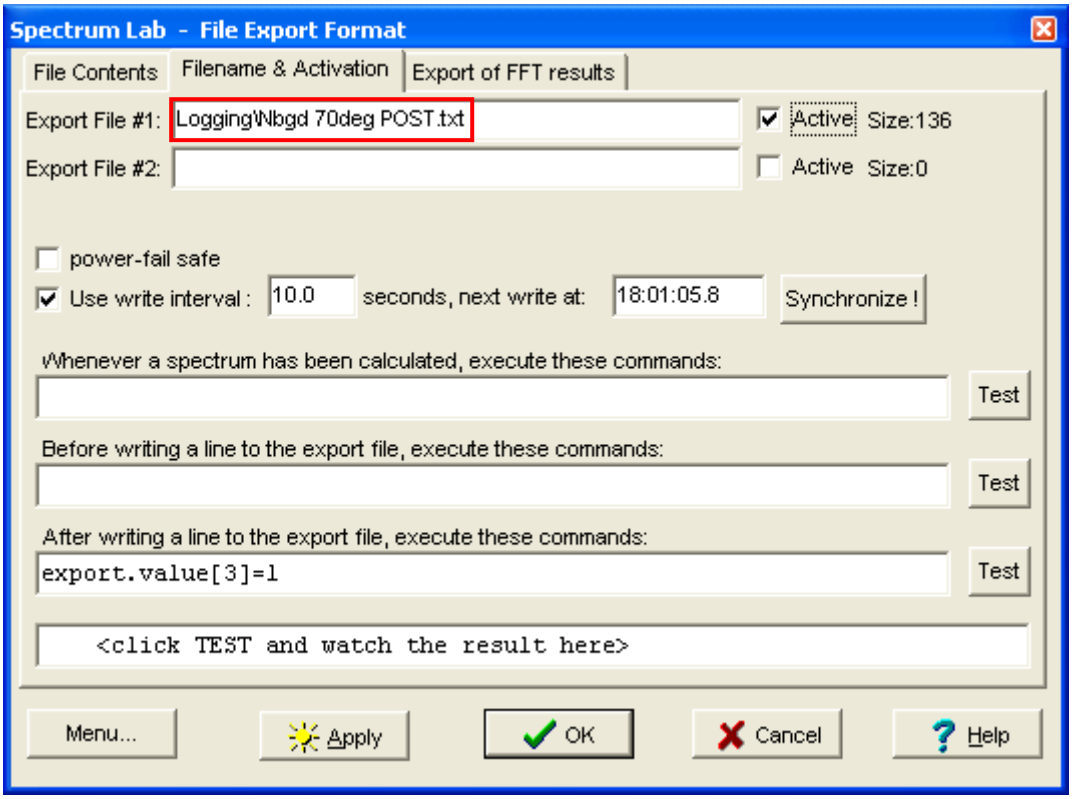


This will generate a screenshot capture named **Capt Sun Rise 02042011-1**. After 12 minutes, the next capture will be **Capt Sun Rise 02042011-2** and so on every 12 minutes throughout the whole measurement.

3.6. Step 6 : background noise after sun noise measurement (N_{bgd} POST)

When the sun is out of influence (above +35° for a sun rise or below -10° elevation for a sun set), repeat exactly (over the same azimuth span) the measurement performed at step 4 but in the data file names, use here **POST** instead of **PRE**.

For example, *Nbgd 70deg PRE.txt* at step 4 will be now *Nbgd 70deg POST.txt.*



4. Post processing

4.1. Process the data files

Since the measurement data collection is now finished, we can move to the next step which is the process of the data.

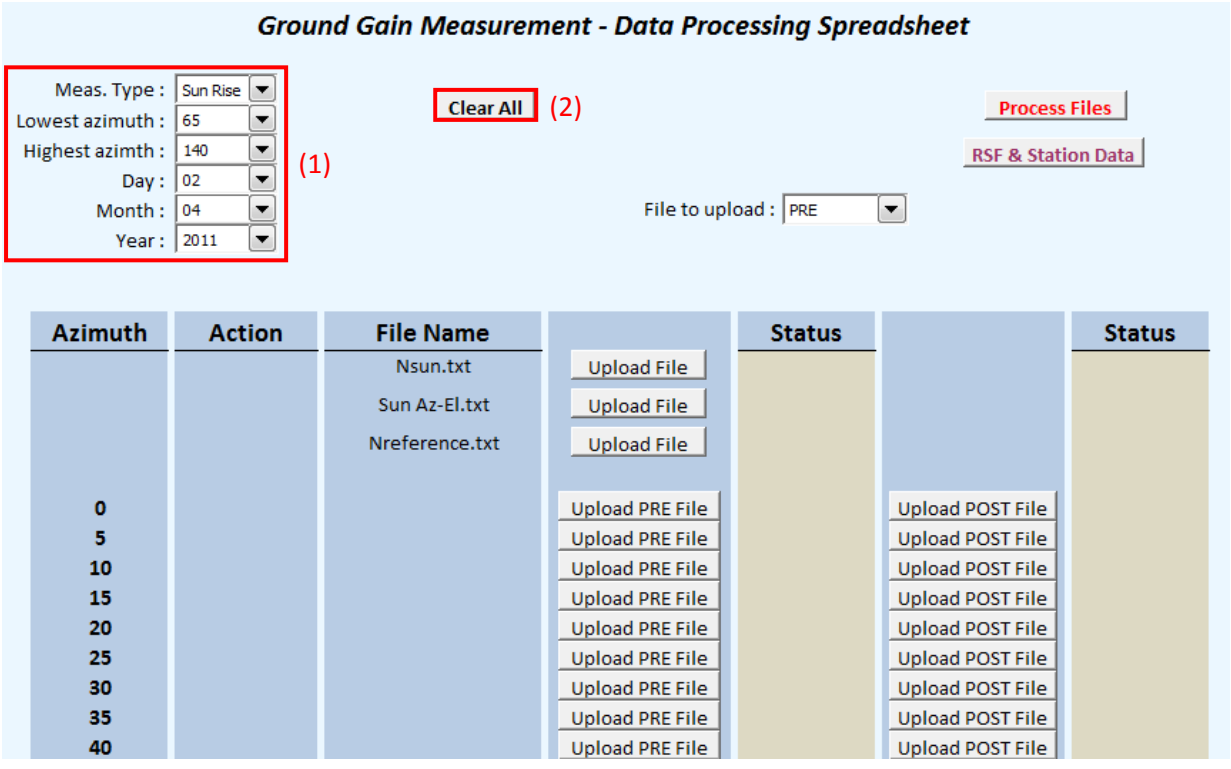
- Copy the files included in the sub-directory ***Logging*** of Spectrum Lab to C:\Sun Noise Measurement.
- Delete these files from the same sub-directory ***Logging*** of Spectrum Lab, otherwise any future measurement will further proceed on the preceding files if these are not deleted.

In the directory C:\Sun Noise Measurement, you have now the following types of files :

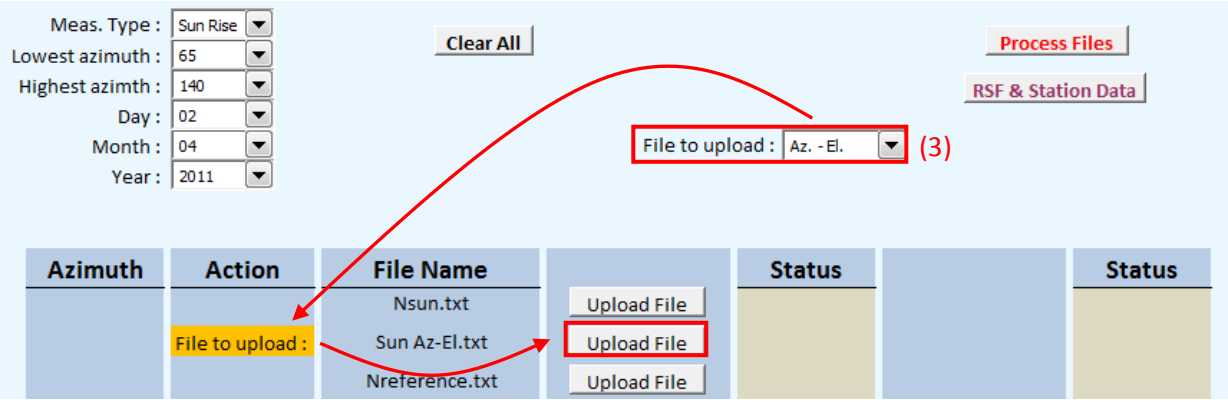
Sun Az-El.txt	Azimuth & elevation of the sun
Nreference.txt	Reference noise level when RX chain connected to a 50Ω load (calibration)
Nbgd xdeg PRE.txt	Background noise when RX chain connected to the antenna, before the sun noise measurement, per 5° azimuth steps
Nsun.txt	Sun noise in manual or automatic tracking mode from -5° (sun rise) or 30° (sun set) elevation to 30° (sun rise) or -5° (sun set) elevation
Nbgd xdeg POST.txt	Background noise when RX chain connected to the antenna, after the sun noise measurement, per 5° azimuth steps

- In the sub-directory ***Tools*** provided with the package, open the file *Ground Gain Sun Noise Measurement Processing File.xlsm*.

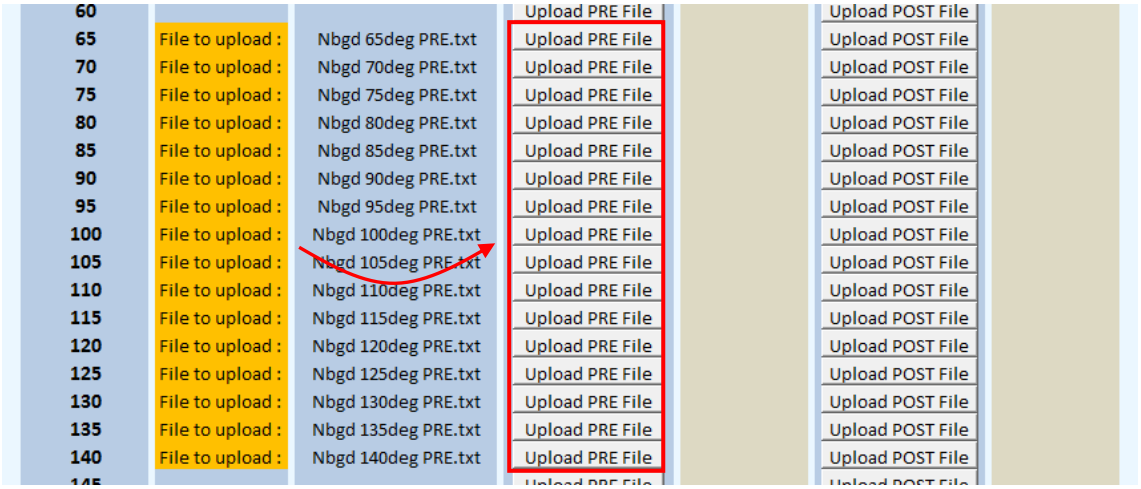
- (1) : In the drop down lists on the left, select the measurement type, azimuth range and date.
- (2) : Click on **Clear All** prior to launch any new file upload.



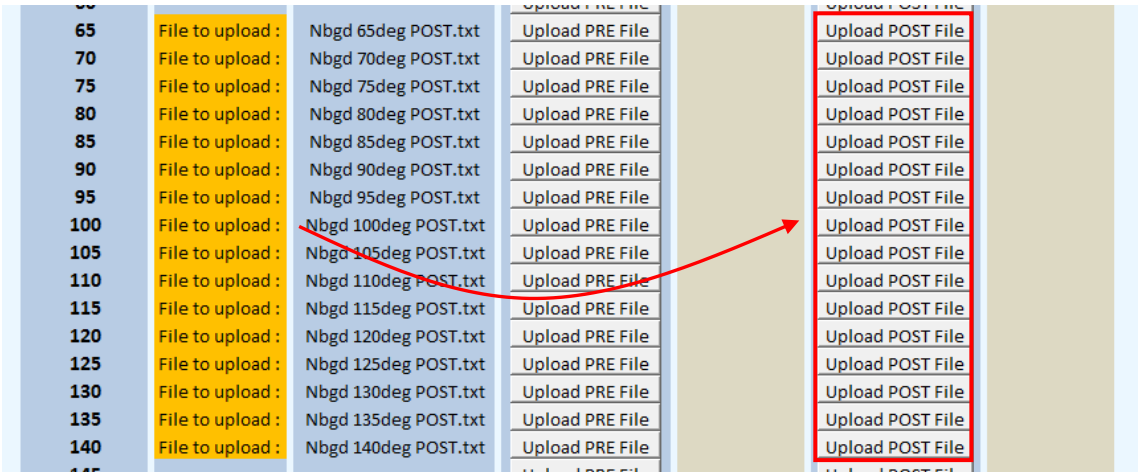
- (3) : In the field **File to upload**, select alternatively :
    - **Az. – El.**, then click on **Upload File** in front of the corresponding file name (*Sun Az-El*), preceded by **File to upload** highlighted in orange in the column **Action.**



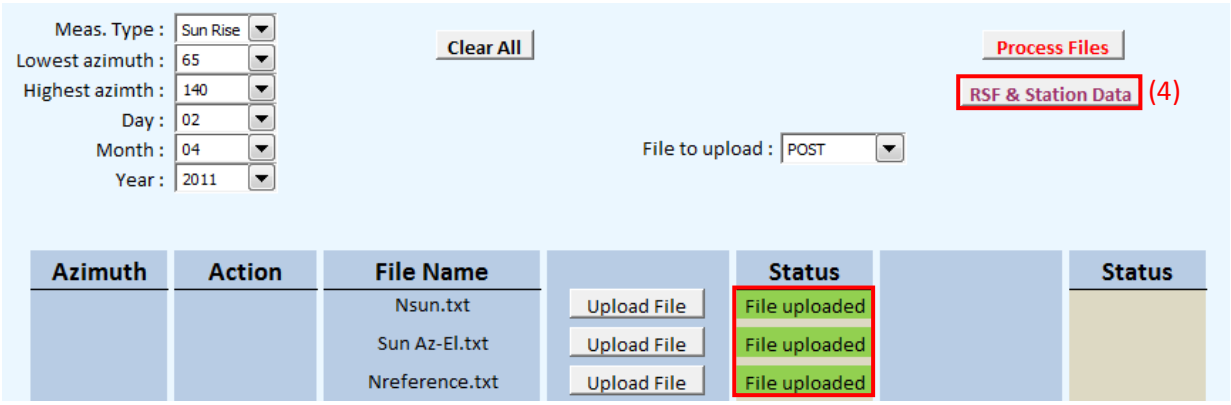
    - **REFERENCE**, then click on **Upload File** in front of the corresponding file name (*Nreference*), preceded by **File to upload** highlighted in orange in the column **Action.**
    - **PRE**, then click on **Upload File** in front of the corresponding file name (*Nbgd xdeg PRE*), preceded by **File to upload** highlighted in orange in the column **Action.**



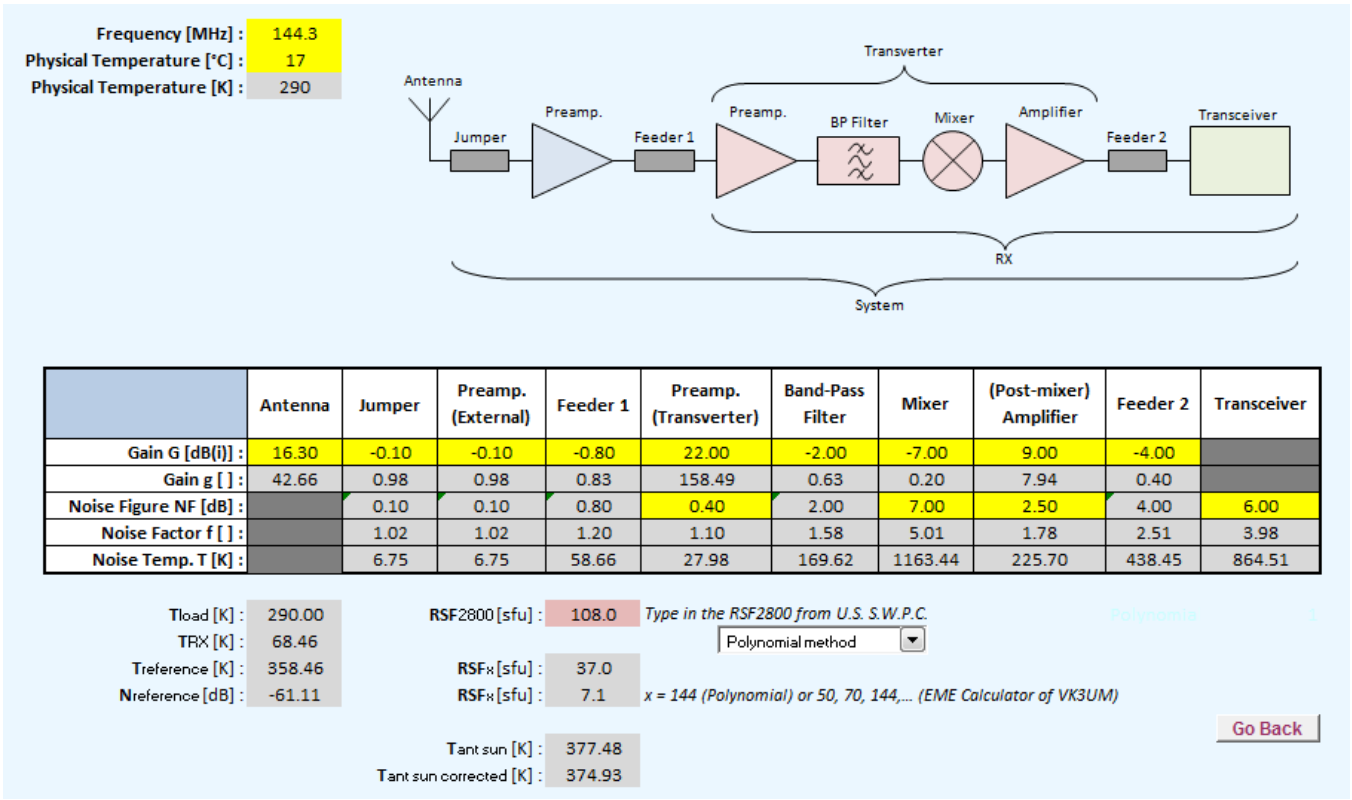
    - **SUN**, then click on **Upload File** in front of the corresponding file name (*Nsun*), preceded by **File to upload** highlighted in orange in the column **Action.**
    - **POST**, then click on **Upload File** in front of the corresponding file name (*Nbgd xdeg POST*), preceded by **File to upload** highlighted in orange in the column **Action.**



When the files are uploaded, the status becomes **File uploaded**, highlighted in green.



- (4) : Click on **RSF & Station Data**, you get the following window :

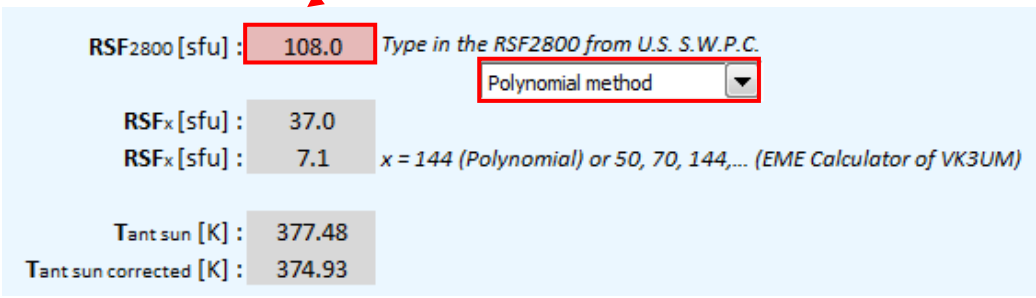


- According to your specific RX station data, fill in only the cells highlighted in yellow (all the others in grey show calculated figures). If you are not using a transverter, refer to the Annexes (section 6.1.).
- Select the RSF_x (x is the frequency band) calculation method and fill in the associated RSF figure, prompted by a dynamic cell highlighted in dark red. Two methods are possible :

    - Method 1 : a polynomial law that extrapolates the RSF_{2800} (2800 MHz) down to 144 MHz, thanks to the data got from the U.S. Space Weather Prediction Centre website : http://www.swpc.noaa.gov/ftpdir/lists/radio/rad.txt

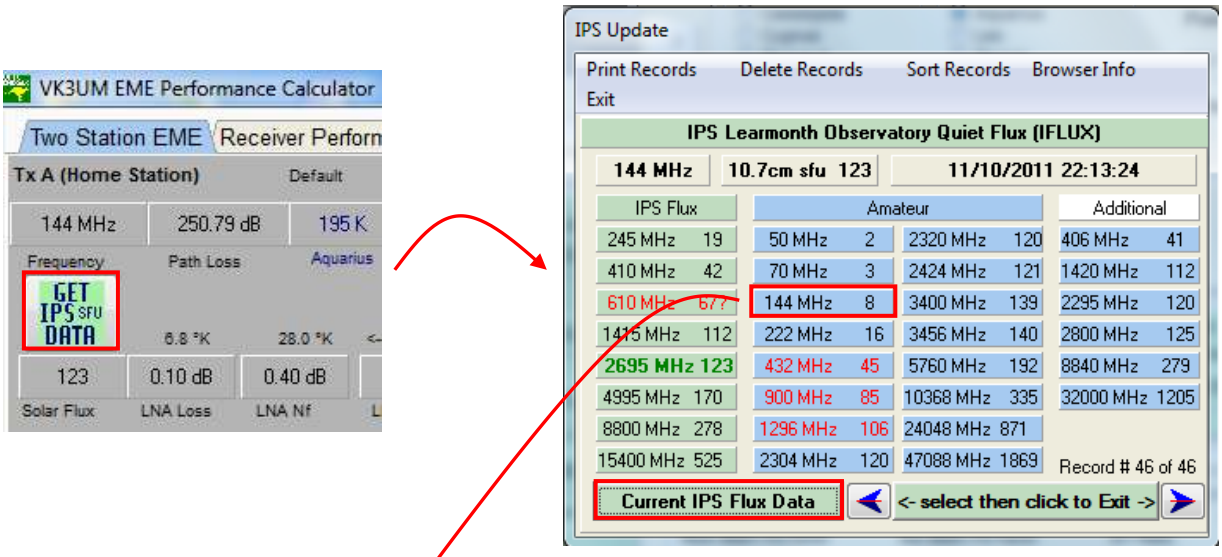
Example of a U.S. Space Weather Prediction Centre data :

```
2011 Apr 2
   245        37        27        26        -1        -1        20        -1
   410        54        41        44        -1        -1        40        -1
   610        63        -1        58        -1        -1        59        -1
  1415       107       100       104        -1        -1       112        -1
  2695       108       103       103        -1        -1       111        -1
  2800        -1        -1        -1       108       108        -1       109
  4995       151       147       143        -1        -1       150        -1
  8800       253       267       271        -1        -1       233        -1
 15400       531       561       574        -1        -1       501        -1
```



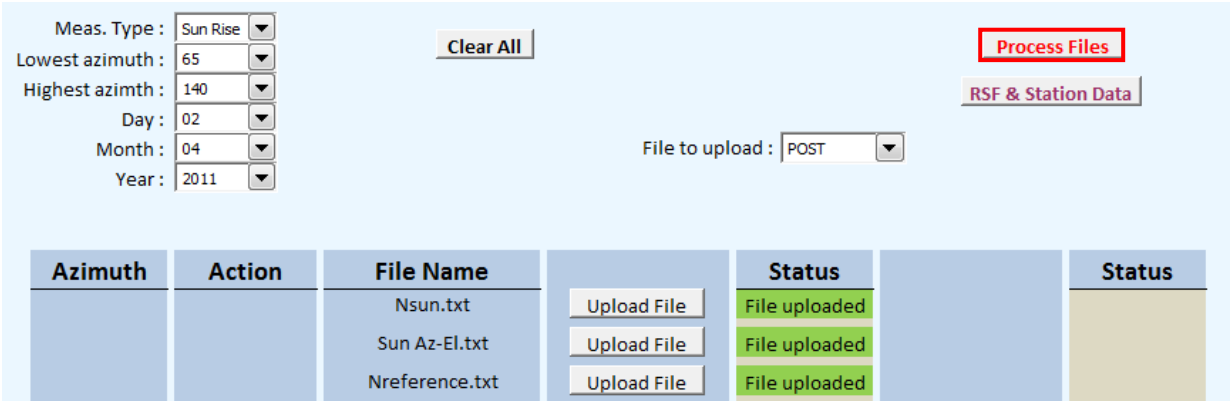
- Method 2 : data out of the EME Calculator of Doug, VK3UM. In this case, data for other bands than only 144 MHz are also available.
  The software can be downloaded here : http://vk3um.com
  If it is about using this software only to derive de RSF figures, there is no need to configure it, just install it anywhere on you computer.

  In VK3UM EME Calculator, click on **GET IPV SFV DATA** at the top left of the window.
  A new window (**IPS Update**) appears. Click on **Current IPS Flux Data**.



The data got from the EME Calculator of VK3UM have proven to be more reliable in case of high or stormy solar activity.

- Click on **Go Back** at the bottom right of the window to come back to the previous window.
- In this previous window, click on **Process Files**.



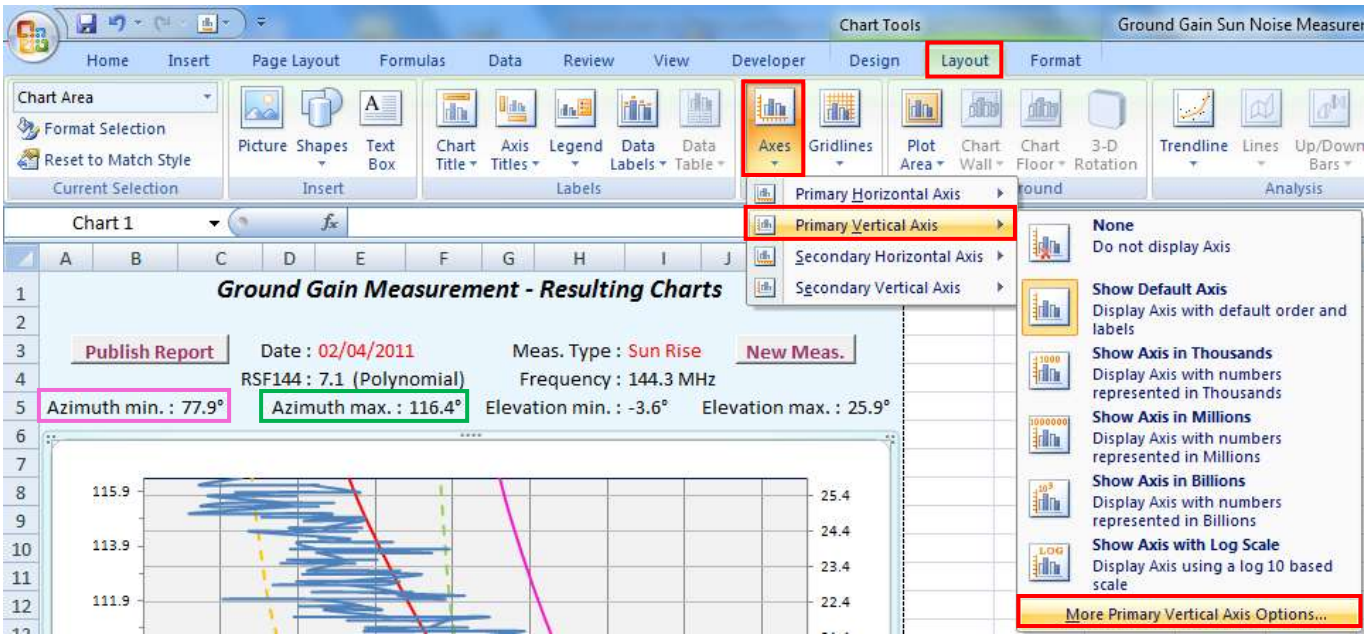
4.2. Publish the Report

Once the files are processed, you get two resulting charts. Here a manual operation is required on both charts before completion.

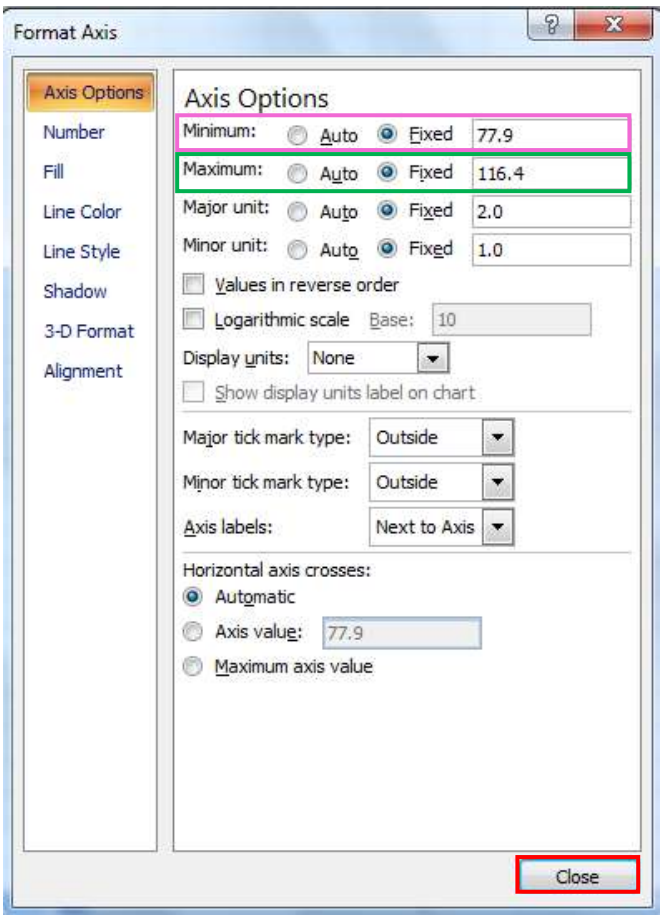
4.2.1. Sun rise measurement

In MS Excel (2007) :

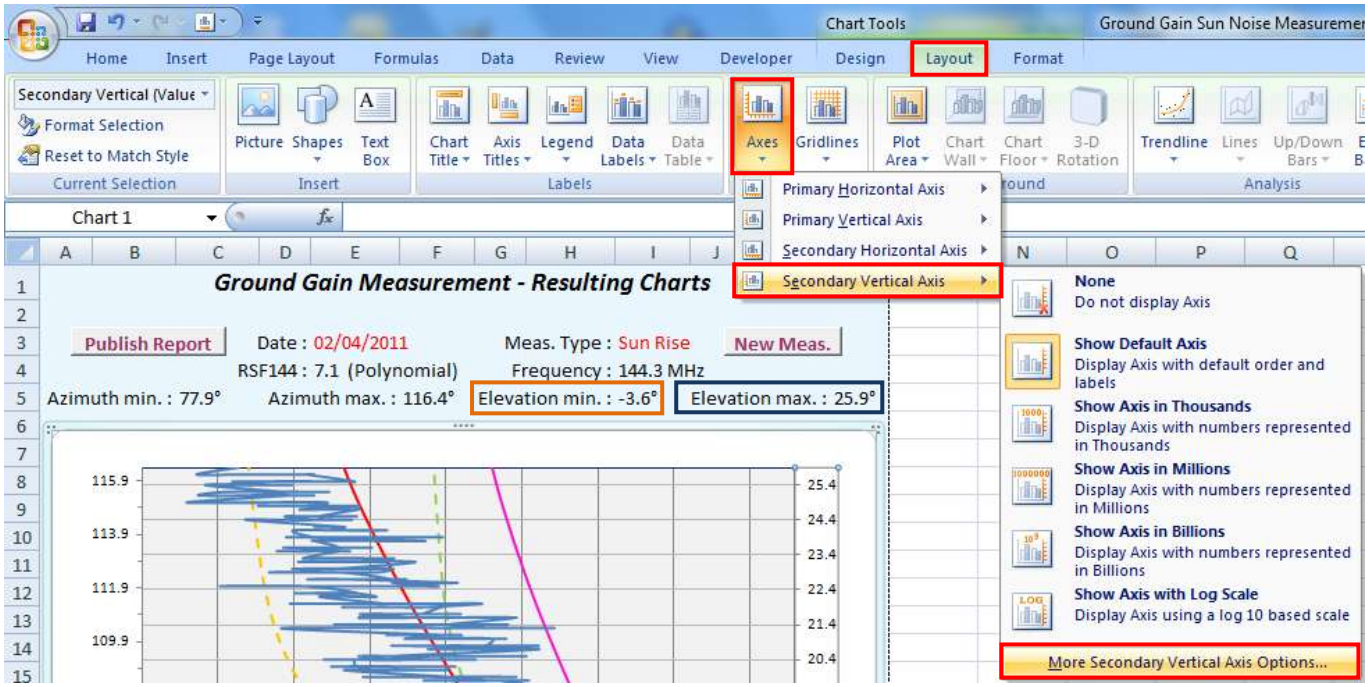
- In the menu toolbar, select **Layout > Axes > Primary Vertical Axis > More Primary Vertical Axis Options...**



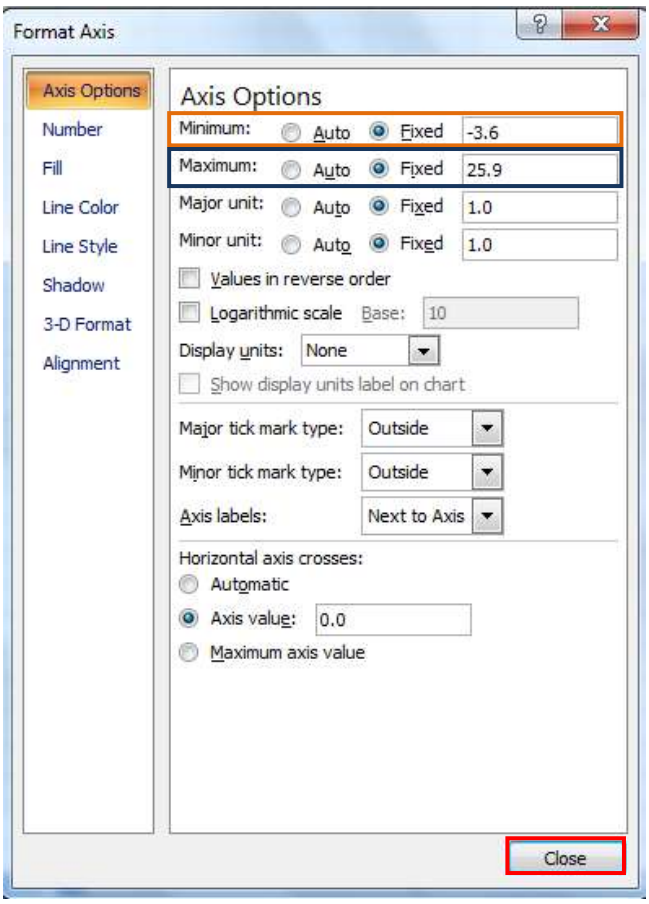
- The window on right (Format Axis) pops up.
- Copy the **Azimuth min.** figure on the chart to the field **Minimum** in the Axis Options (here 77.9).
- Copy the **Azimuth max.** figure on the chart to the field **Maximum** in the Axis Options (here 116.4).
- Click on **Close**.



- In the menu toolbar, select **Layout > Axes > Secondary Vertical Axis > More Secondary Vertical Axis Options...**

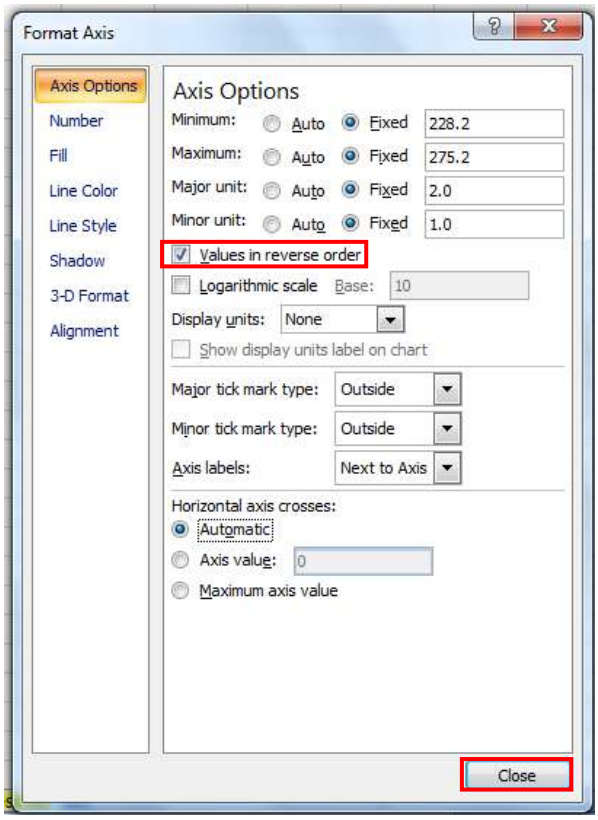


- The window on right (Format Axis) pops up.
- Copy the **Elevation min.** figure on the chart to the field **Minimum** in the Axis Options (here -3.6).
- Copy the **Elevation max.** figure on the chart to the field **Maximum** in the Axis Options (here 25.9).
- Click on **Close**.



4.2.2. Sun set measurement

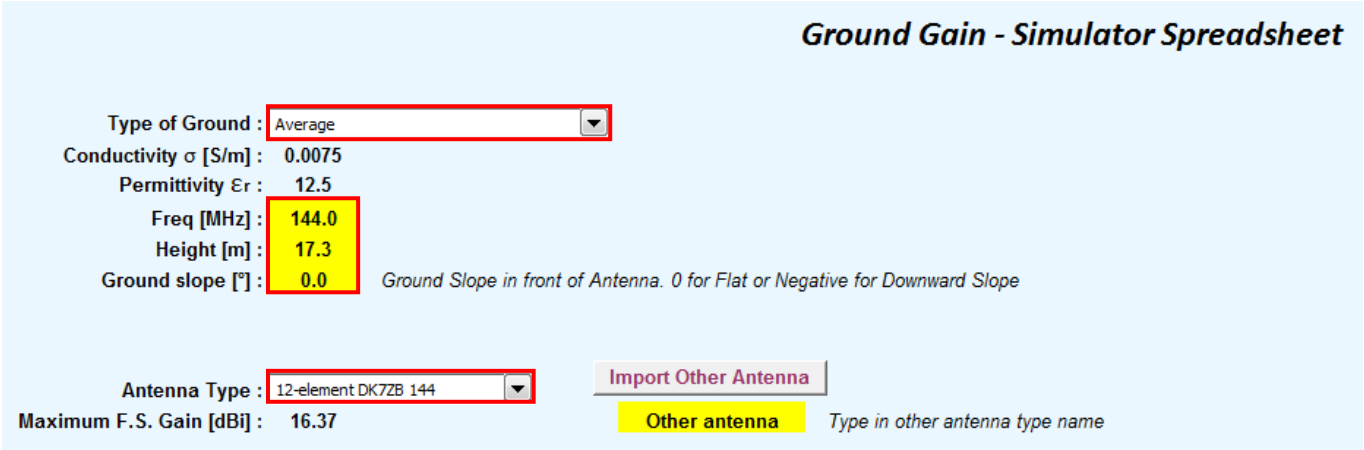
Proceed exactly as described in section 4.2.1. ; the only difference is that in the window **Format Axis** which appears when you select **Layout > Axes > Primary Vertical Axis > More Primary Vertical Axis Options...** in MS Excel, you have to check in the checkbox **Values in reverse order**. Then **Close**.



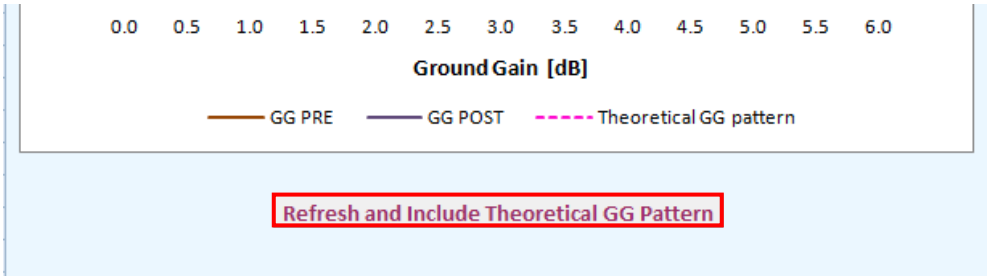
4.2.3. Completion

On the **Ground Gain** graph (the second resulting chart), the **Theoretical GG pattern** (purple dashed curve) shows by default the elevation pattern of a 12-element DK7ZB at 17.3m agl over a perfect and flat ground. You can change this and select another antenna type, type of ground, antenna height and a flat or downwards tilted ground.
To achieve this, you have to :

- **Open** the file *Ground Gain Geometry and Magnitude Calculator File.xlsm* provided in the package (directory C:\Sun Noise Measurement\Tools).

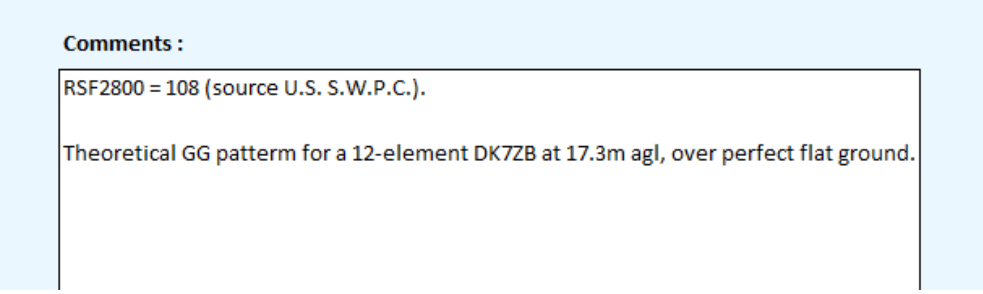


- Select the **Type of Ground** and **Antenna Type** and fill in the **Frequency**, **Height** and **Ground slope**. You have the choice between a few antenna types, ranging from a dipole to a stack of 2x12-element antennas (144 MHz).
- **Save** this file (don't change its name) in C:\Sun Noise Measurement\Tools (nowhere else) and **close** it.
- Come back to the currently open file (*Ground Gain Sun Noise Measurement Processing File.xlsm*) and click on **Refresh and Include Theoretical GG Pattern**.

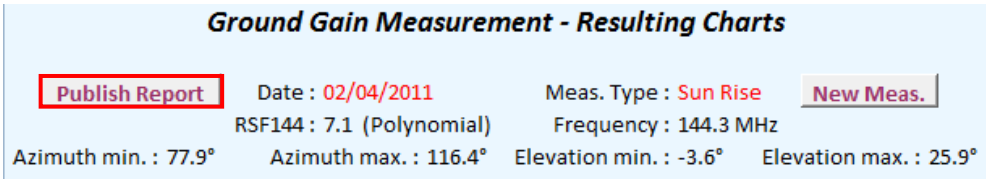


It is also possible to import your own antenna pattern ; refer to the Annexes (section 6.2.).

- You can also include some comments in the report (at the bottom of the **Ground Gain** graph).



- Click on **Publish Report** at the top of the page.



You have now a file named *Ground Gain Sun Noise Measurement Processing File.pdf* in the directory C:\Sun Noise Measurement.

- Rename this file in a more explicit way, e.g. *Ground Gain Sun Rise ddmmyyyy.pdf*
- Move this file *Ground Gain Sun Rise ddmmyyyy.pdf*, together with the Sun Az-El.txt, Nreference.txt, Nbgd xdeg PRE.txt, Nsun.txt and Nbgd xdeg POST.txt files somewhere else on your computer (wherever you wish, no specific convention required here).
- Delete these files from C:\Sun Noise Measurement ; this is mandatory to avoid disturbing the future measurements.

5. Additional information

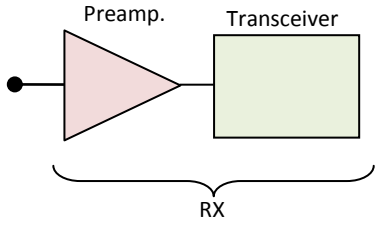
The **Ground Gain** graph indicates the geometry and magnitude of the Ground Gain lobes (or antenna elevation pattern) but only the magnitude of the first lobe (the less elevated one) is reliable, since the calculated sun noise rise (NR_{sun}) is not weighted according to the free space antenna radiation pattern in the elevation plane. This will perhaps be updated in a future release of the tools.

To train how the file processing works, you can temporarily copy the measurement files provided as examples and available in the sub-directories (sorted by dates) part of the directory ***Measurement Campaigns***.

6. Annexes

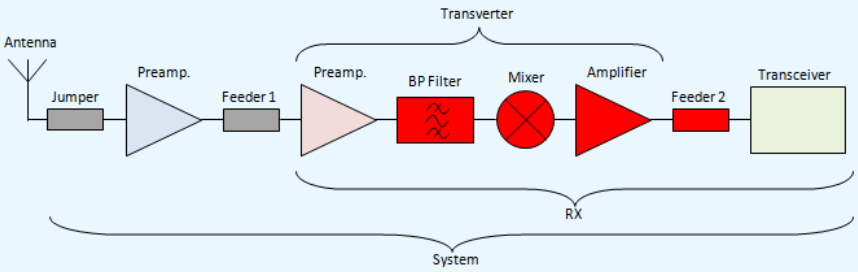
6.1. If not using a transverter

As written previously in this document, it is recommended to place a preamplifier in front of the transceiver (or receiver), all the more any external (masthead) preamplifier has to be set in by-pass mode to meet the calculation spreadsheets constraints.



Given the stages in red on the schematic below are not applicable here, the corresponding cells also highlighted in red in the table have to be filled in with **0** when encoding the RX station data (see section 4.1.)

Frequency [MHz] :	144.3
Physical Temperature [°C] :	17
Physical Temperature [K] :	290

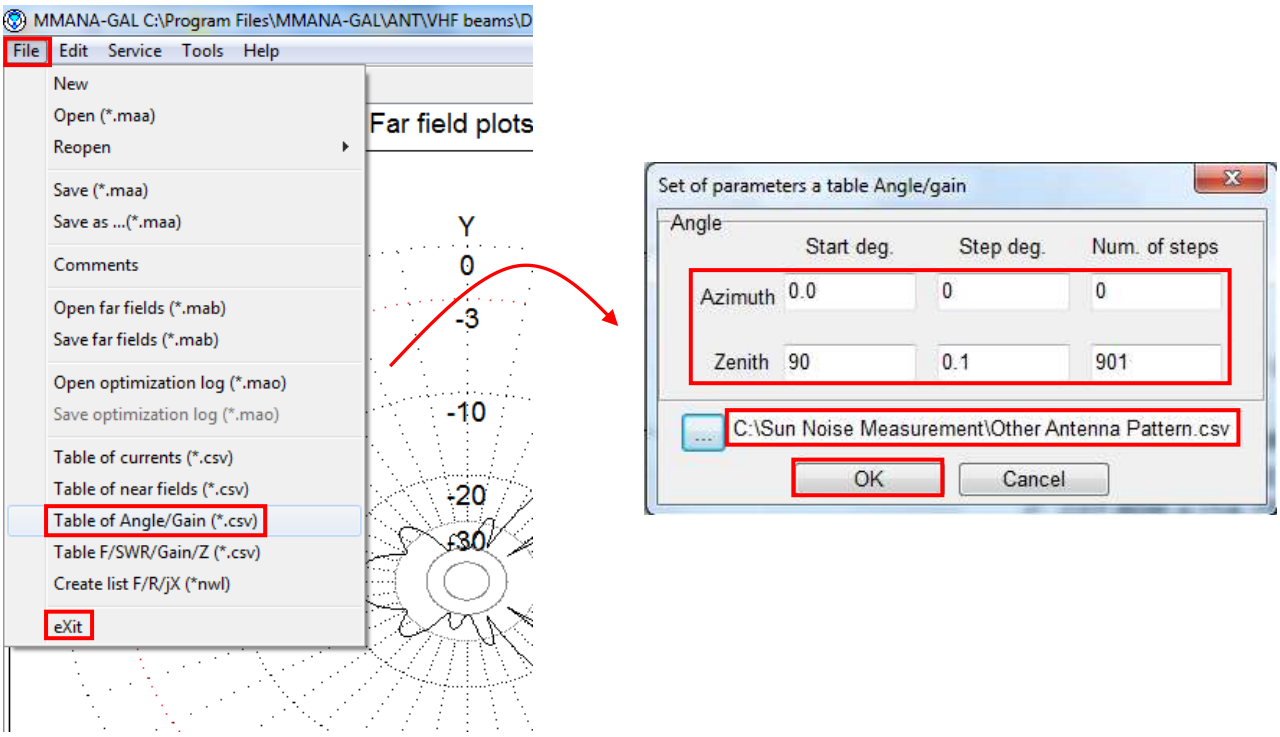


	Antenna	Jumper	Preamp. (External)	Feeder 1	Preamp. (Transverter)	Band-Pass Filter	Mixer	(Post-mixer) Amplifier	Feeder 2	Transceiver
Gain G [dB(i)] :	16.30	-0.10	-0.10	-0.80	22.00	0.00	0.00	0.00	0.00	
Gain g [ ] :	42.66	0.98	0.98	0.83	158.49	1.00	1.00	1.00	1.00	
Noise Figure NF [dB] :		0.10	0.10	0.80	0.40	0.00	0.00	0.00	0.00	6.00
Noise Factor f [ ] :		1.02	1.02	1.20	1.10	1.00	1.00	1.00	1.00	3.98
Noise Temp. T [K] :		6.75	6.75	58.66	27.98	0.00	0.00	0.00	0.00	864.51

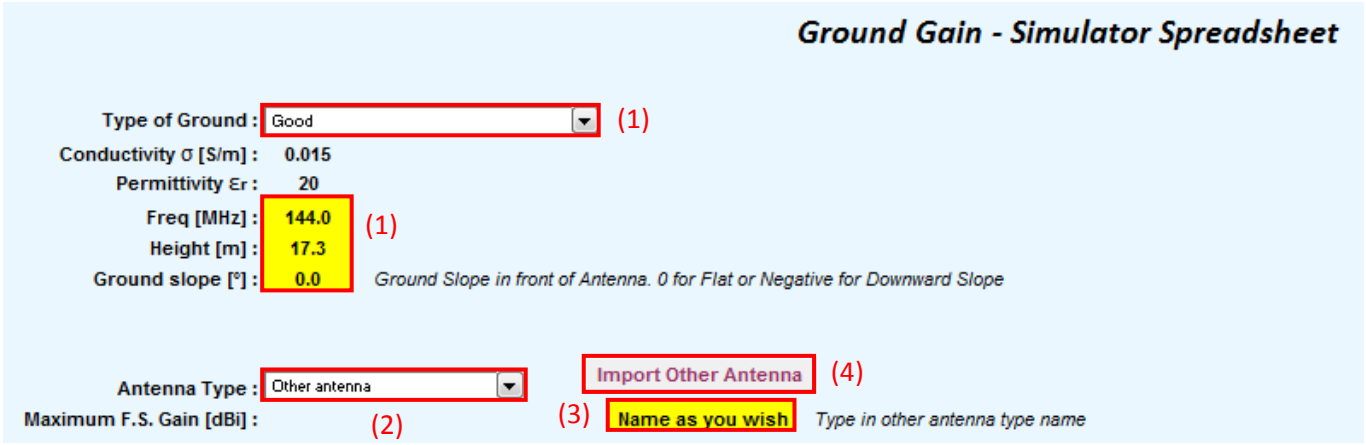
6.2. Import your own antenna pattern

Explaining how to model antennas is beyond the scope of the present document. However, it is shown here how to export a free space elevation radiation pattern out of the modelling software MMANA-GAL (http://hamsoft.ca/pages/mmana-gal.php). Once your antenna has been modelled and its pattern calculated :

- In the menu toolbar of MMANA-GAL, select **File > Table of Angle/Gain (*.csv)**.
- In the new window which has pop up, enter the figures for the Azimuth and Zenith fields exactly as shown below.
- Enter the name **Other Antenna Pattern.csv** (and no other name, otherwise the processing macro won't work), to be saved under C:\Sun Noise Measurement (and nowhere else).
- Click on **OK**.
- **Exit** (Close) MMANA-GAL.



- (1) : In the file *Ground Gain Geometry and Magnitude Calculator File.xlsm* (see section 4.2.3.), select the **Type of Ground**, fill in the **Frequency**, **Height** and **Ground slope**.
- (2) : Select **Antenna Type** as "**Other antenna"**.
- (3) : Replace "**Name as you wish"** in the cell highlighted in yellow by the name of the antenna to import (any name is allowed here, no specific convention required).
- (4) : Click on **Import Other Antenna**.
- **Save** this file (don't change its name) in C:\Sun Noise Measurement\Tools (nowhere else) and **close** it.



Further proceed on the completion of the processing according to the explanation given in section 4.2.3.