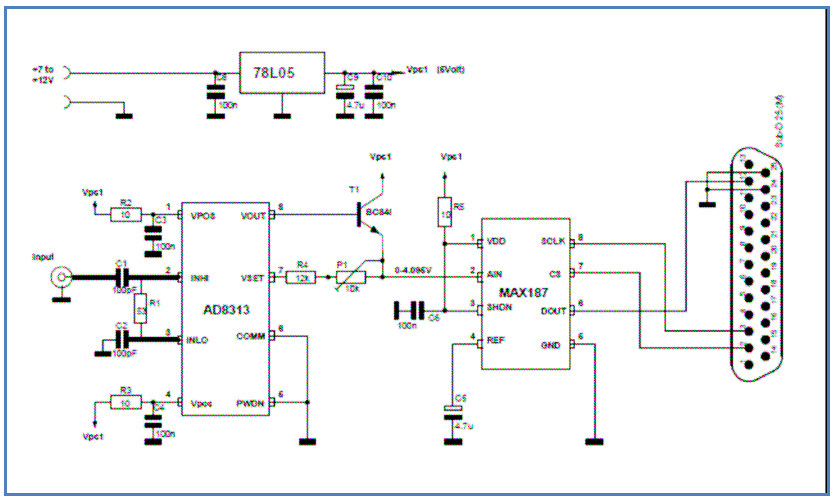
Total Power Experiment **J.A.Kappert PA0PLY**

Since I was involved in the restoration of the Radio Telescope in Dwingeloo, I got more and more interested in Radio Astronomy, more over to be able to receive those sky objects myself.

I choose to set up a system to measure Total RF Power from a sky object, known as Total Power Radiometer.
To receive as much power as possible, a wide band configuration shall be developed. From experience on EME, the 70cm band is maybe not the best choice due to increased environmental sources which will give an unwanted contribution to the Total Power Radiometer.
For this reason, the next best choice in my case is the use of my 3m dish and select the 23/21cm frequency band.
Since the beam width of this antenna on 23cm is relatively small, it will minimize the chance of picking up unwanted RF sources from the environment.

3m Prime focus antenna – PA0PLY

The system layout consists of a pre-amplifier, G4DDK design, mounted directly on the feed, possible followed by a 2nd RF amplifier. Then the RF signal will be fed to a RF detector IC (AD8313). The resulting DC signal is converted to a digital signal using a MAX187. This digital signal is connected to the printer port of a computer.



Schematic Total Power Detector - v01

The reason to select the AD8313 RF detector from Analog Devices is following:
Specifications:

- Frequency range: 0.1 -2.5GHz min.
- Dynamic range: 70dB
- Accuracy: +/- 1.0dB over 65dB

Based on these specifications the RF signal from the antenna can be fed directly to the RF detector without the need for converters. Selecting 1420 MHz as the center frequency of the RF chain, it will be possible to measure the RF signals from the Hydrogen band, the Milky-way, as well.

A second advantage of this RF detector is that it can be connected to the IF output of an LNB Block.

In this way it will be possible to perform Radio Astronomy on 10 GHz, or?

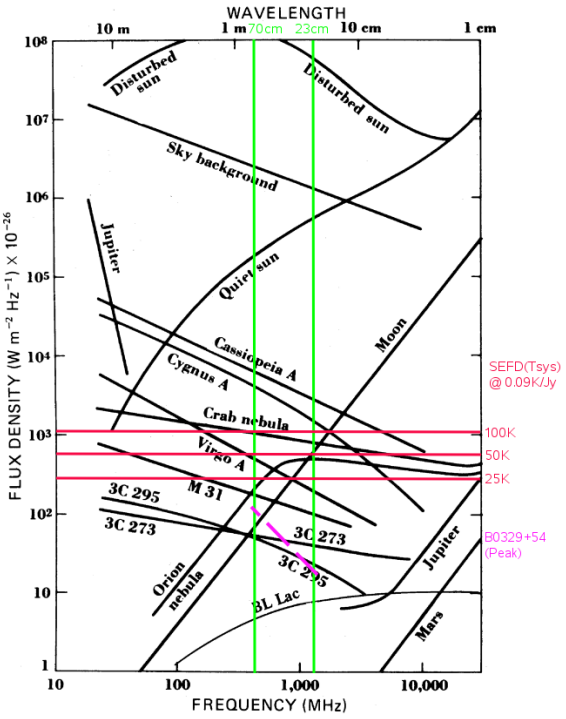
Based on below graph the possibilities can be investigated.

[The horizontal red lines are related to the sensitivity of the Radio Telescope of Dwingeloo, better known as the PI9CAM EME station.]

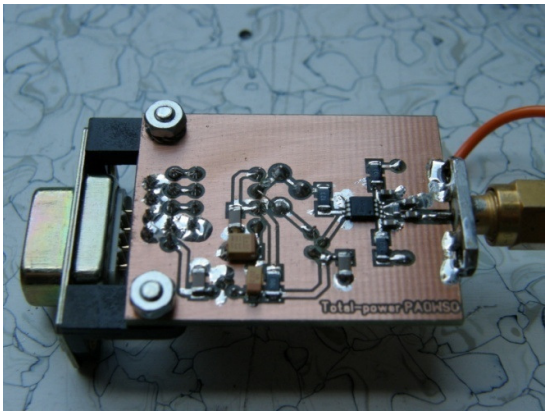
I'm not a really expert on using the sensitivities in Radio Astronomy, like K/Jy. Therefore I still stick with the dB's to have at least some meaningful idea of sensitivity.

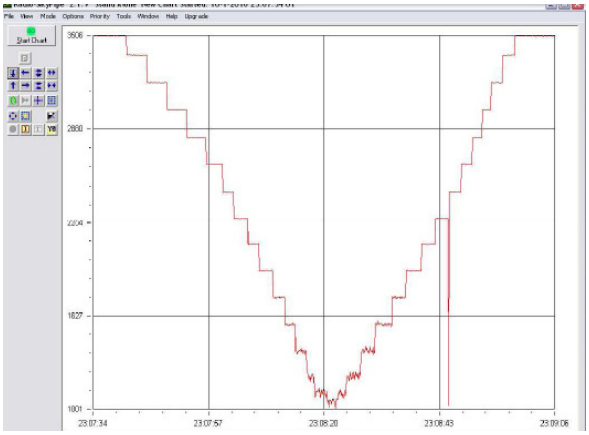
For 10Ghz, a Moon noise level of 0.5 – 1.0dB shall be reachable with a 3m dish.
Checking this in the graph it can be concluded that there will be no chance to receive any further sky signals as those are much much weaker then the moon noise.

On 1296-1420MHz however, the Moon might not be detectable, but most likely Cas-A and maybe even Cyg-A are realistic options to detect.

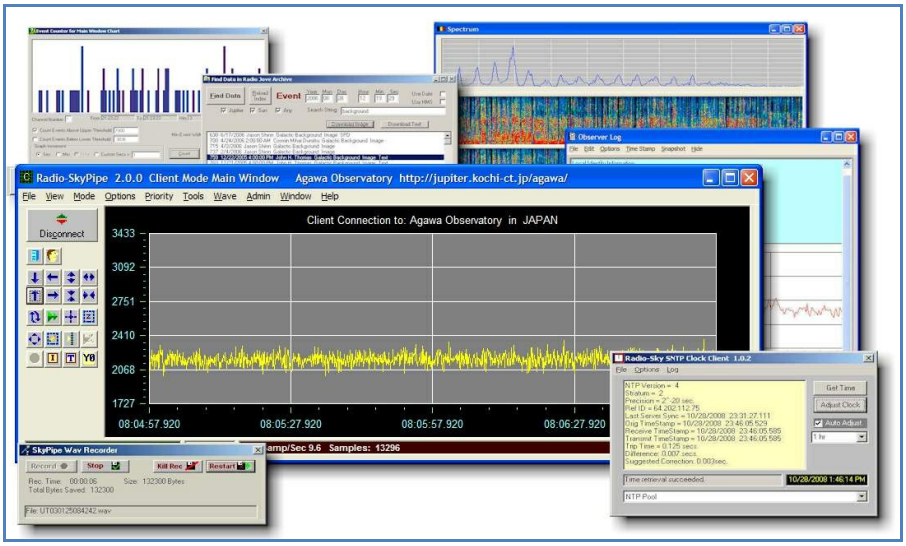


After the construction of the PCB, the circuit is calibrated in order to get a meaningful figure during measurements. A signal generator on 1400MHz was used, while the RF output was stepped in 5dB steps starting from 0dBm to -70dBm and back to 0 dBm. The result is shown in below graph. The RF detector was set to 40mV/dB.



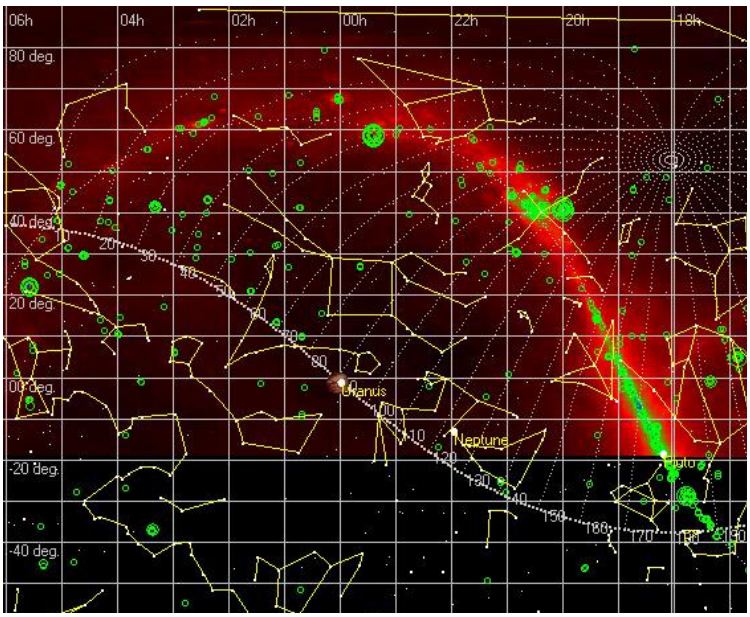


After converting the analog DC signal into a digital signal, using the MAX187 produced by MAXIM, the signal is connected to the printer port of a computer.
Freeware software RADIO-SKYPE is then used to further process the signals received. This software package is a modern version of a strip chart recorder with many possibilities for set-up.



Radio-SKYPIPE freeware software

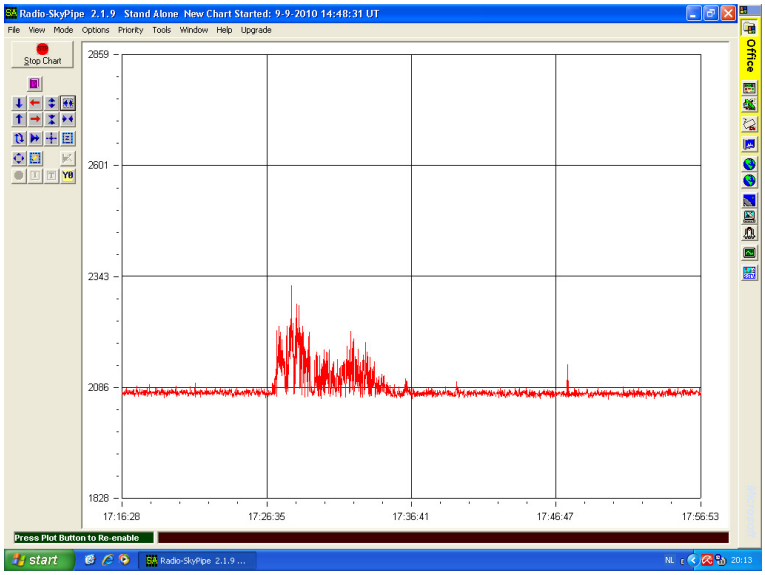
After all this theoretical investigations it is time to hook up the Electronics to the antenna and perform actual measurements. The next question immediately arises; where to point the dish? Software packages such as Radio-Eyes or Stellarium [free-ware] will help to define the pointing direction. Below pictures is an example originating from Radio-Eyes. The red colored line is the Milky-way.



Example of Radio-Eyes display

Pointing the antenna to AZ: 90grd and ELE: 54grd will be a good position to start with. Better would be to use Zenith, however in my current set-up I'm limited to a maximum elevation of 63 degrees.

Using a set-up with the RF LNB block, reception was prepared in the 10 GHz frequency band. With this antenna pointed, several days were logged while the graphs were compared. The Sky-Pipe graphs show signals as indicated below.

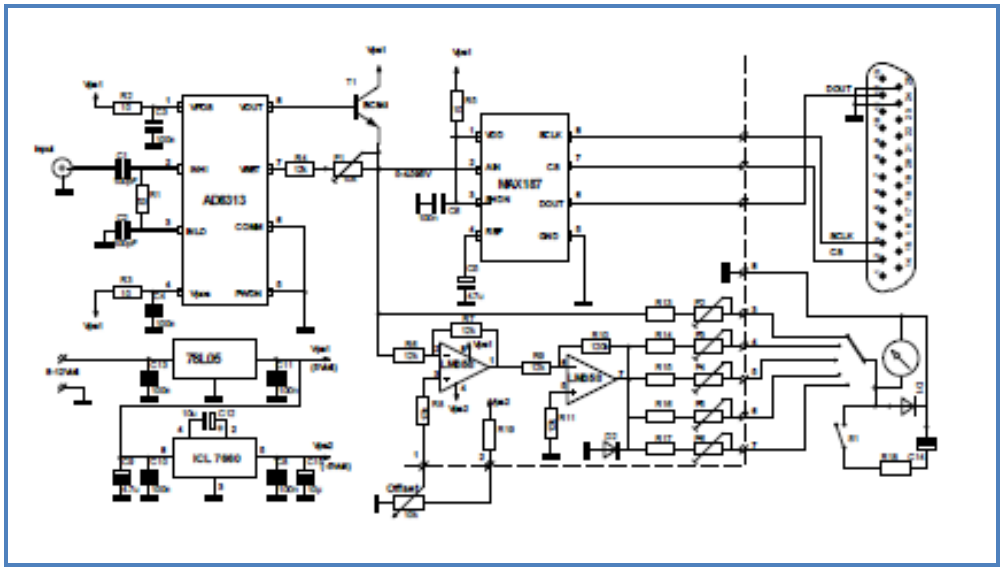


As pointed out in the pre-investigation already, it will be unlikely to receive anything from sky. However the actual result was different and showed some signals. How to analyze where it originated from is the question of course. Does it originate from the sky or from some local source?
This is also the main question for Radio astronomers and it takes quite a lot of time to conclude.
In my case the final conclusion could be drawn fast as there was no 4 minutes deviation between following day records as it should be once this signal originates from some sky object.
In the meanwhile the RF set-up is changed into reception for 1420MHz. The Milky Way spectrum is approximately 2 – 2.5MHz wide around 1420MHz. To avoid environmental signals to disturb this signal, a band pass filter shall be included in the RF chain. Also here experiences will have to be gained in making correct conclusions on the origin of the received signals.
Some further pre-investigation has been done bases on below table. Larger EME stations have done some measurements on sky objects as shown below.

EME stations 1,296GHz						2450 Jy	875 Jy	1495 Jy	1060 Jy
						3C461	3C144	3C405	M17,W38
Call	D (m)	f/D	Sun (SF)	CS/G	Moon [dB]	Cas A[dB]	TauA[dB]	CygA[dB]	Omega17
CT1DMK	5.6		15 (68)		0.1		0.1		
G3LTF	6	0.37	21.2 (175)		0.3		0.5	1	
K5SO	8.6	0.43	20.1 (73)		0.7	1.2	0.6	1.3	1.1
OK1CA	10	0.26	20.2 (80)		0.7	1.8	0.8	1.7	1.3
OK1KIR	4.6	0.42	14.5 (70)	6.2	0.15	0.45		0.5	1
VK3UM	8.6	0.43	19.6(62)	7.6	0.65	below hor	0.7	1.25	
W2UHI	5.5	0.45	19,6(235)	4.5	0.2	0.7	0.2	0.5	
IZ1BPN	8	0.4	18(80)	6.0	0.36	0.84	0.4	0.68	
PI9CAM	25	0.48	27.7(53)		2.13	5,15	2,86	4,1	

Although the table is not up to date, it provides some useful information. Looking at the results of station OK1KIR; a radio clubstation from Prague, Cas-A is received with a level of 0.45dB, while the Moon noise is detected at 0.15dB. The antenna is a dish-antenna with 4.6m diameter.
Based on this result it will be a challenge to receive anything using a 3m dish set-up!

Having some experiences with V01 of the Total Power Radiometer design, a second version is prepared by Wim, PA0WSO. This version is an extension of V01 and provides a connection for an analogue meter with adjustable full scale as well as off-set.
Using a differential amplifier for the DC line, one will be able to zero the environmental noise and thus apply more gain in the DC chain to the analogue meter-circuit. Using the LNB block converter, the detection of the moon noise will be much easier once a full-scale value of 1dB can be used.



Schema Total Power Detector - v02

Another useful application of this version will be a “normal” power meter function with a frequency range up to 2.5GHz.
Overlooking the various applications of this circuit, it is a useful circuit and hopefully gives people a push forward to start experimenting.

Kind regards,
Jan Kappert, PA0PLY

Note:
Both Analog Devices and MAXIM provide the described components as free samples.

Thanks to:
Frans de Jong PE1RXJ
Wim Schaap PA0WSO
Paul Boven PE1NUT

References:
www.analog.com
www.radiosky.com
www.stellarium.org