Building a 10.7 cm horn for monitoring the Solar Flux Index

Society of Amateur Radio Astronomer (SARA) member John DuBois and DSES member Rodney Howe are building a horn antenna and radio to monitor the Solar Flux Index (SFI). The Solar Flux Index is used to assist NOAA modelers in predicting the upcoming solar cycles. We would like to setup a DSES standard reference observatory for collecting data for the Solar Flux Index.

In 1947, when looking at the sun with World War II Radar, Penticton found his radar unit, at the 10.7 cm line, could measure solar flux densities (in Janskys). Scientists also noticed that these readings varied from year to year, and that these variations matched closely to the sunspot count numbers, and decided that the 10.7-cm radio band should be adopted as the 'solar flux index':

> These solar radio noise indices are published in accordance with a CCIR Recommendation originally from the Xth Plenary Assembly, Geneva, 1963 (maintained at XIth through XIVth Plenaries), which states "that the monthly-mean value of solar radio-noise flux at wave- lengths near 10 cm should be adopted as the index to be used for predicting monthly median values of foE and foF1, for dates certainly up to 6, and perhaps up to 12 months ahead of the date of the last observed values of solar radio-noise flux."
> ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_RADIO/FLUX/Penticton_Absolute/docs/penticton.txt

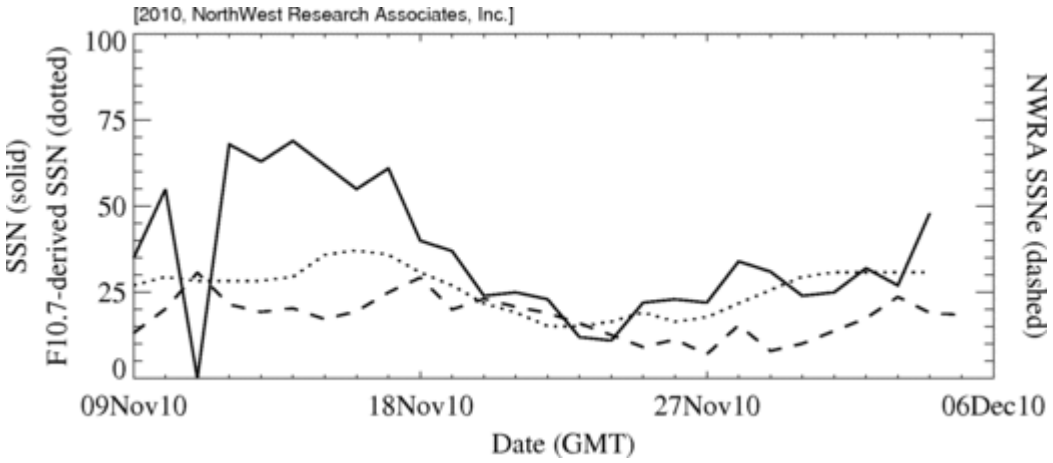

Figure 1 illustrates the differences between the "real" sunspot number (SSN), which is calculated from optical observations of the sun, a sunspot number derived from the 10.7cm solar radio flux (SSNf), and a sunspot number derived from fitting an ionospheric model to ionospheric measurements. All of these indices are used as inputs to models of the ionosphere for use in communications-performance predictions - this plot shows that they don't always

agree as to what the SSN should be in that particular context.
http://www.nwra.com/spawx/comp.html

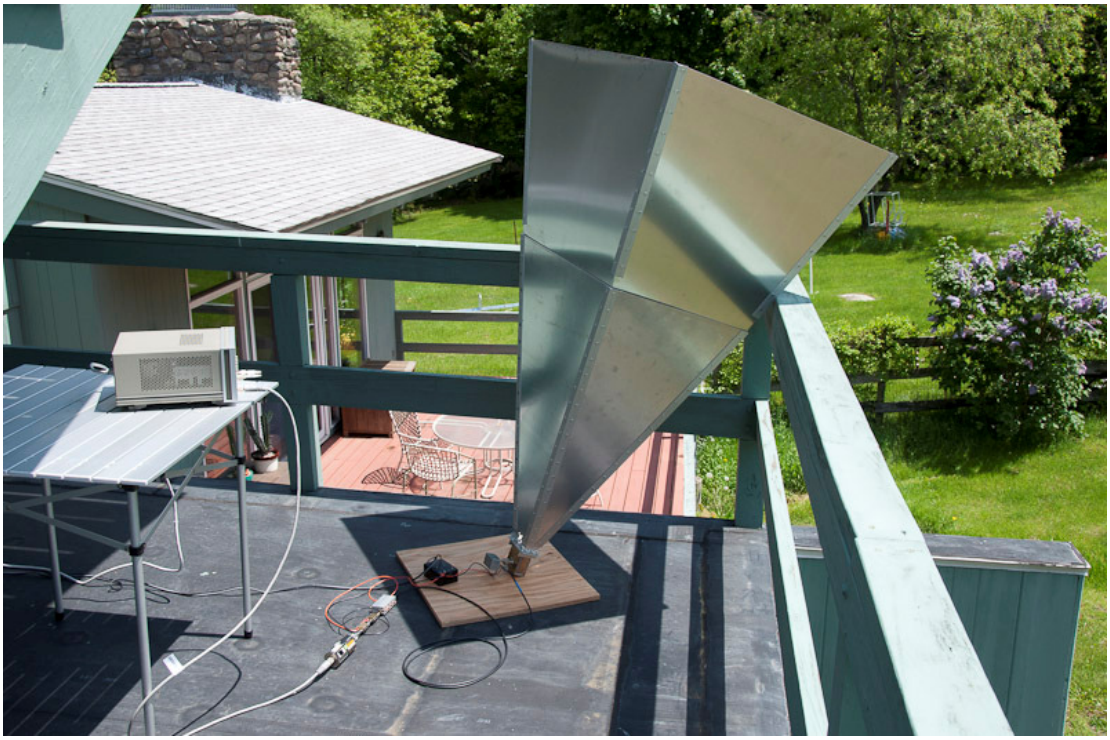

Figure 2 prototype 2.8 GHz (10.7 cm) horn is the right size for setting up on a porch and pointing to the sun.

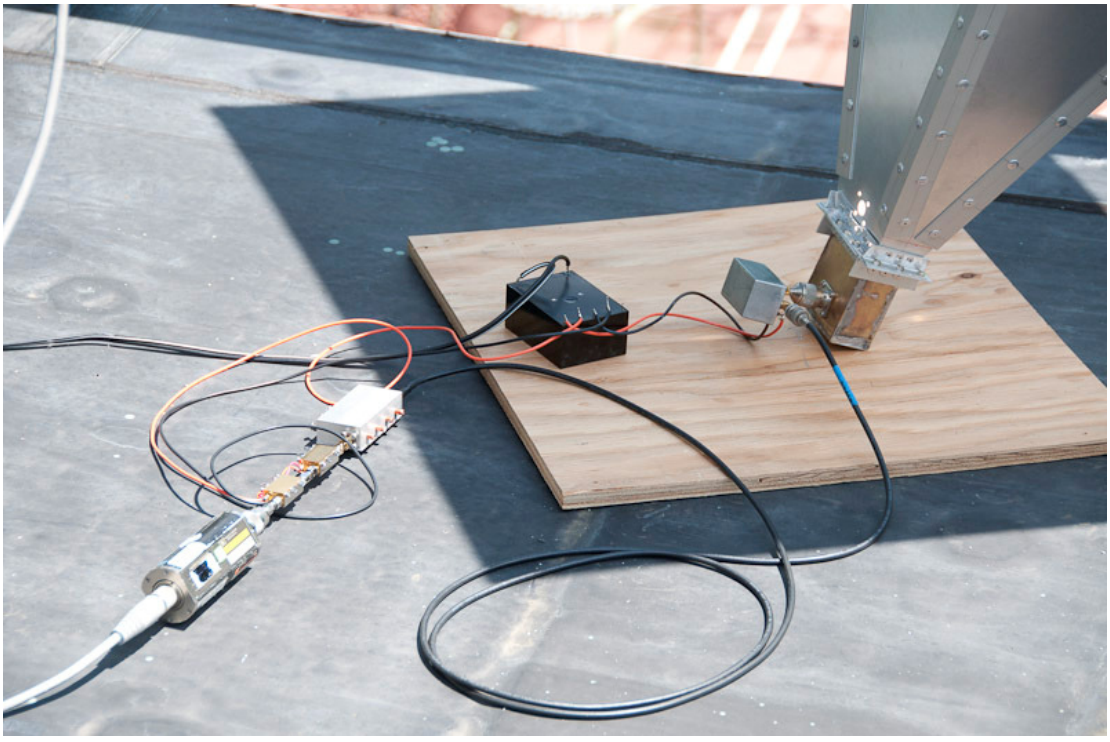

Figure 3, Predicted, and Observed Performance of Solar Radiometer with 36 inch Horn 21. Horn Area: m^2 Cascade Gain dB Equivalent Sun Temp at Horn: K 0.6420 60.5 93. Noise BW: 40 MHz, MHz Sky+Ground, Deg. K 40 -102.89 45; Solar Flux Unit (SFU) 8.00E-021 Calc: (Sun+Sky)/Sky: dB 2.75 Obs: (Sun+Sky)/Sky: dB 2.70 24.0" x 17.75" horn = .2748 m^2 Extended 24" horn (36.0" x 27.1") = .642 m^2 1.657E-010, (May 11, 2011)

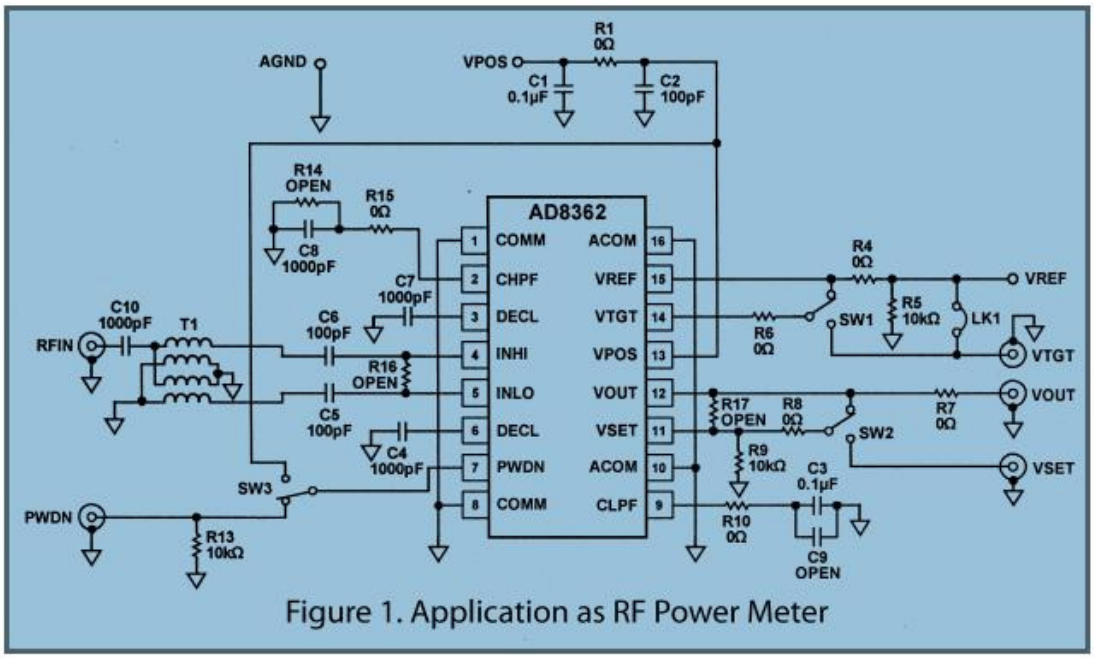

Figure 4, the chip set being used for the backend will be the AD8362 from Mini-Circuits. It will give a read out as a total power meter for the Solar Flux Unit (SFU), which will be displayed as an LED.

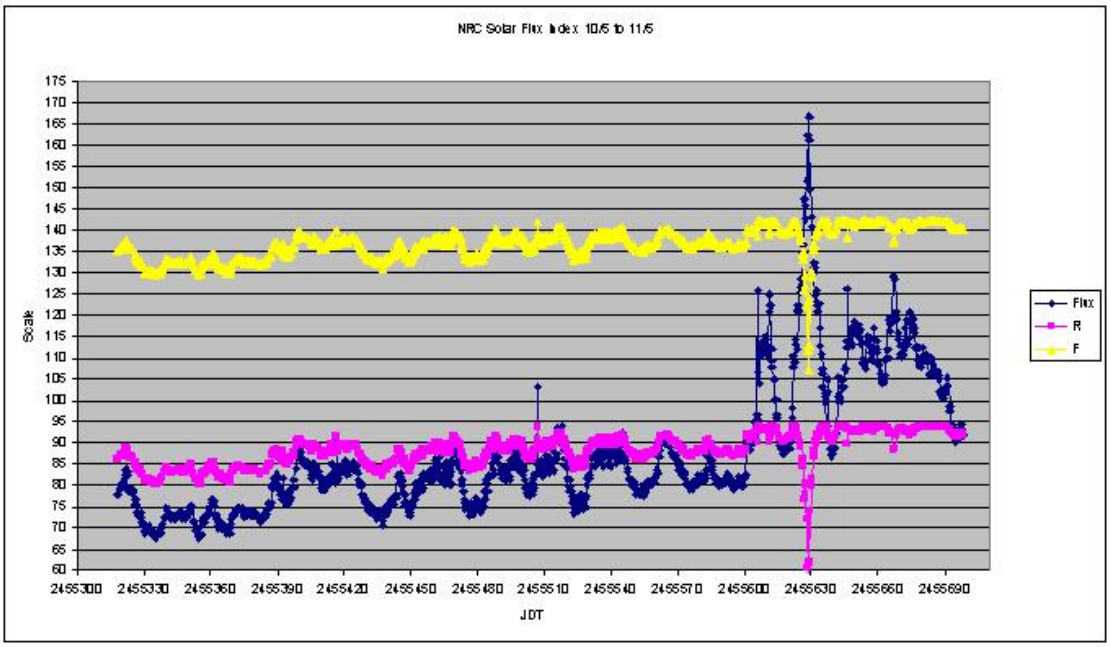

Figure 5, the horn's data will be compared with the optical sunspot count when taking daily readings with an optical scope. These data will be compared to the Space Weather Canada data: http://www.spaceweather.gc.ca/sx-3-eng.php as shown above for the previous year. Notice that only during the last 3 months has there been 'activity' with SFI solar flares.

Figure 6, Rodney using a Baader white filter on a 10" Meade to count the sunspots. The long term goal will be to compare the SFI from the 2.8 GHz horn with the sunspot counts during this upcoming solar cycle 24.

It would be useful I think if DSES as an organization could be considered a reference observatory for collecting data on the Solar Flux Index. These data would then be used for comparing AAVSO's optical sunspot observer program. http://www.aavso.org/solar

DSES would then become another 'observer' of sunspot counts, only these would be Solar Flux Unit counts calculated from the 2.8 GHz radio SFU using the following formula, which creates the Solar Flux Index:

- R = 1.61 FD - (0.0733 FD)** 2 + (0.0240 FD)**3
- where, FD = F - 67.0, and ** means "raised to power of".

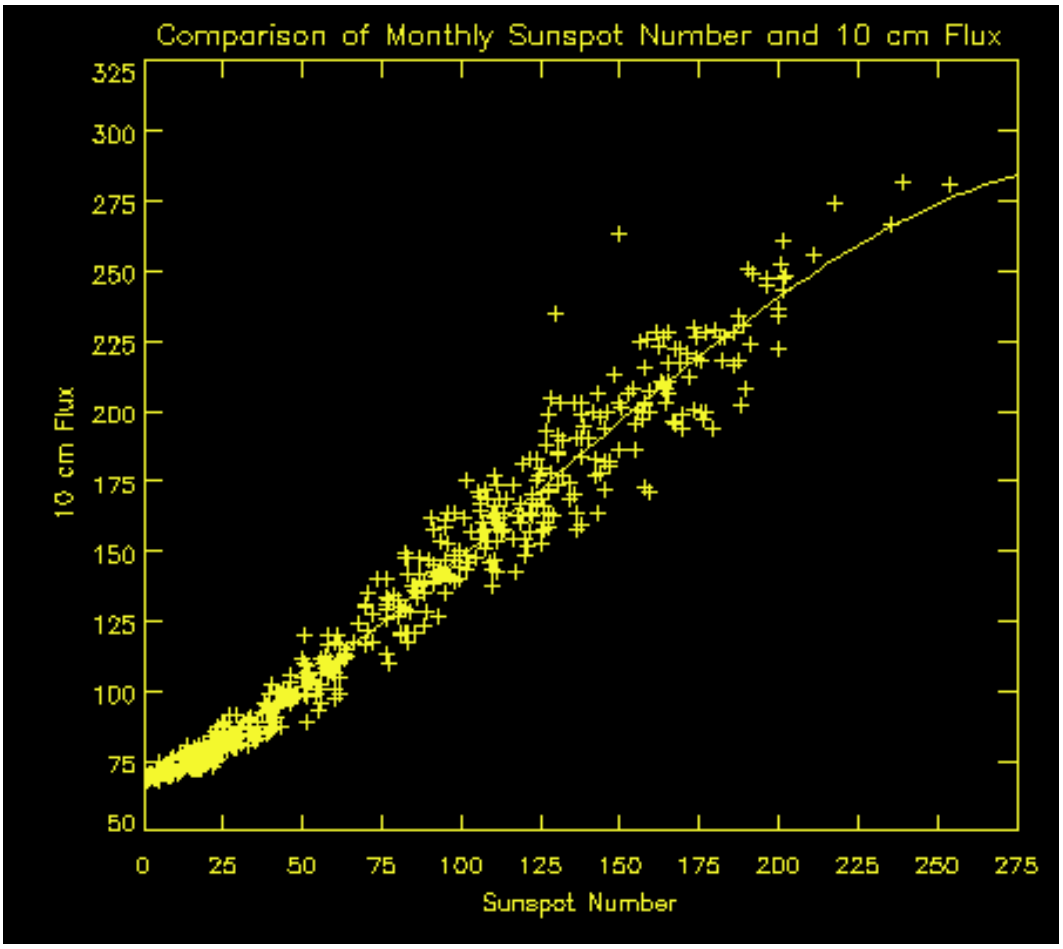

Figure 7, shows how well the SFU from the 10.7cm wavelength correlates with the optical sunspot counts. During the solar cycle's quiet years of this last cycle 23 the optical sunspot count has a tight correlation with the SFI, however as the solar flares increase there is 'dispersion' in the scatter graph. This may be due to the fact that the SFI at 2.8 GHz is measuring activity which would be comparable to the Hydrogen Alpha emissions rather than white light sunspot counts collected from optical observers. This graph was generated by the IPS group in Australia: http://www.ips.gov.au/Educational/2/2/5

Specifications for the NRC radio can be found here:
http://faesr.ucar.edu/view/833

As a member of DSES anyone with a satellite dish and a desire to collect data with a 2.8 GHz radio over the next solar cycle, could participate in making DSES a reference observatory for the Solar Flux Index. For this frequency you do not need a feed horn with dimensions much larger than a soup can!

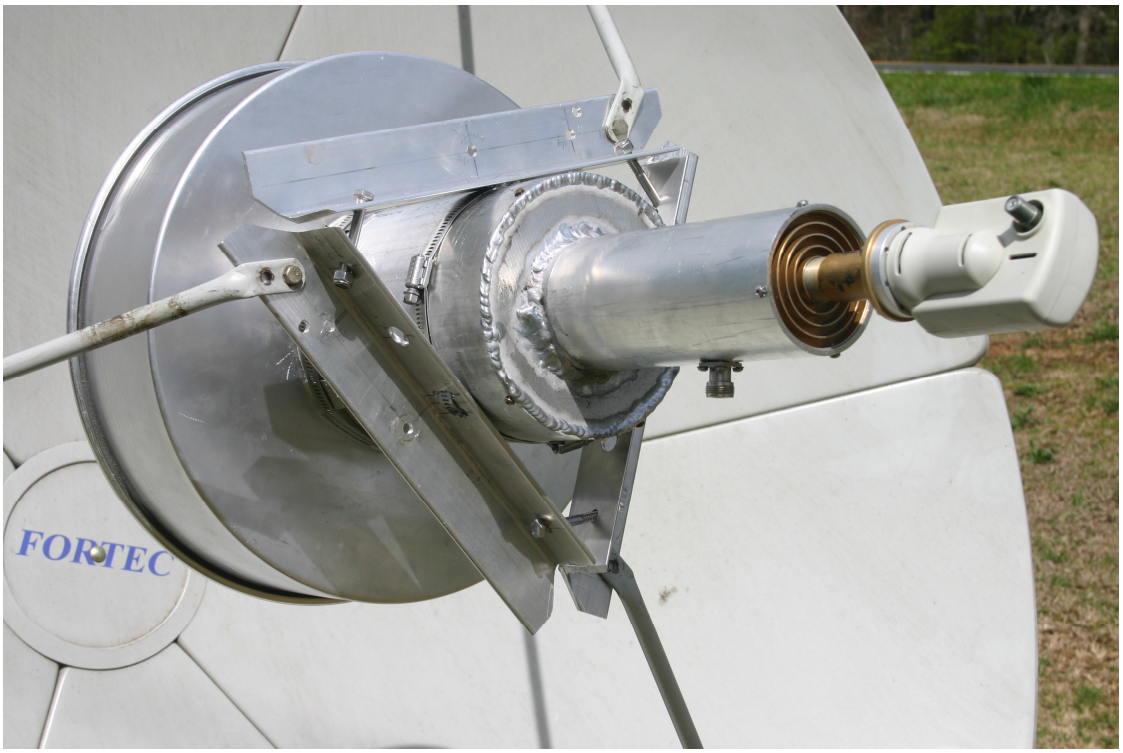

Figure 8, the choke is helpful but not necessary; here you can see another prototype for building a 2.8 GHz radio for a 6 foot satellite dish. This feed horn was built by Paul Oxley, DSES member.

The current software for recording the Solar Flux Unit is designed for drift scan operations. It calculates the RA and Dec, based on the Latitude, Longitude of the observer, and Azimuth, Elevation of the dish or horn.

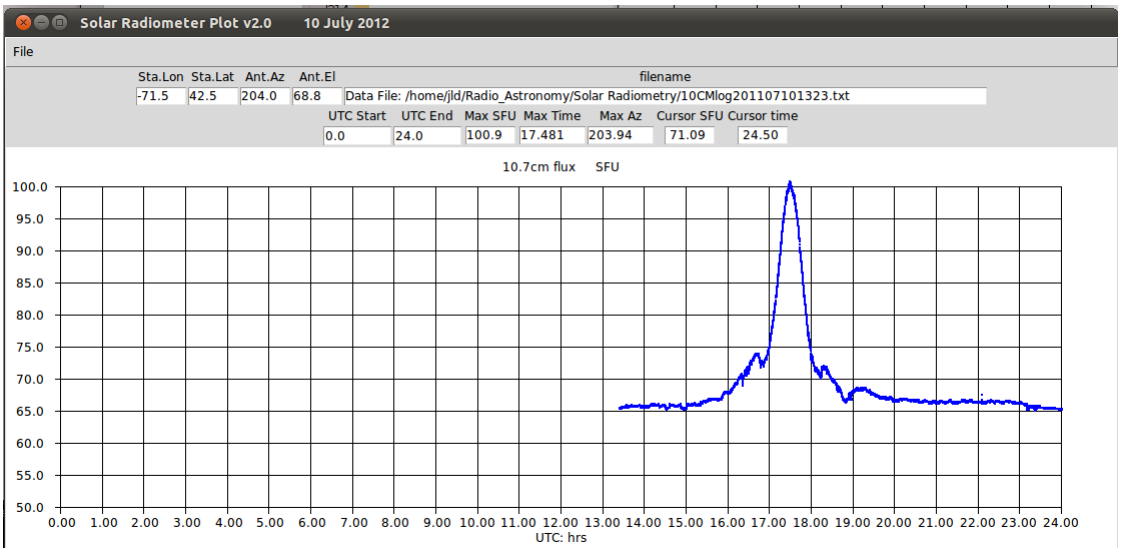

Figure 9, a plot for July 10, 2011 using the horn. This is a linear response to the sun passing in front of the horn, notice the side lobes. We will be recording all responses during the day; however it is the peak which will count as the SFU for that hour/day.

We will be making comparisons with NOAA's daily Solar Radio Data and their SFU counts for at least two other observatories. Here is an example of 18 days of data compared to the Sagamore Hill, Mass. observatory and the Penticton observatory in Canada (NRC). These correlations will become tighter as we gain experience in our observing and recording skills.

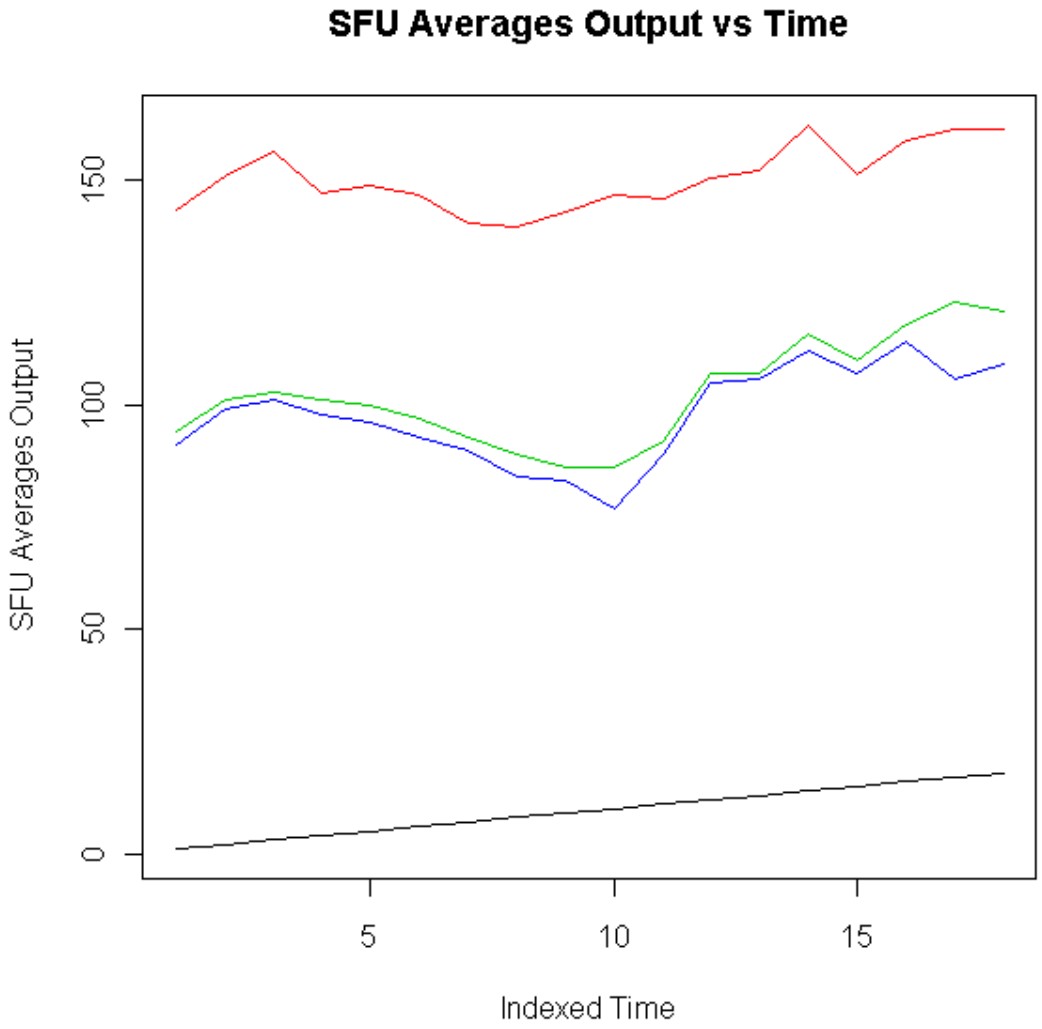

Figure 10, compares the temperature response (Kelvin) of the horn receiver (red) and the daily Solar Flux Units (SFU) from Penticton (green) and Sagamore Hill (blue) observatories. Indexed Time is in days. NOAA Data:
http://www.swpc.noaa.gov/ftpdir/lists/radio/45day_rad.txt

References:

Hathaway, 2011: http://solarphysics.livingreviews.org/Articles/lrsp-2010-1/

IPS, 2011: http://www.ips.gov.au/Educational/2/2/5

NRC data: http://faesr.ucar.edu/view/833

AAVSO monthly sunspot counts:
http://www.ngdc.noaa.gov/nndc/struts/results?t=102827&s=5&d=8,420,9

Royal Greenwich Observatory data (RGO Schema.txt):
http://solarscience.msfc.nasa.gov/greenwch.shtml

SIDC uses this author's methods :
http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V3S-4N61FY1-2&_user=10&_coverDate=12%2F31%2F2007&_rdoc=1&_fmt=high&_orig=gateway&_origin=gateway&_sort=d&_docanchor=&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=f7c2eb704d99b23b0737ab81dacfe6e7&sear

Wolf number (history):
http://astro.ocis.temple.edu/~alan/WolfMathIntel.pdf

K values: http://www.aavso.org/accuracy-and-consistency-production-american-sunspot-number-ra

The folks in Zurich use their own number:
http://www.aavso.org/dances-wolfs-short-history-sunspot-indices

NGDC has the AAVSO monthly data, which were sent them over the years:
http://www.ngdc.noaa.gov/nndc/struts/results?t=102827&s=5&d=8,420,9

Schaefer's 1993 on K factors:
http://adsabs.harvard.edu/full/1993ApJ...411..909S

Zurich value is figured in this equation:
http://www.leif.org/research/Sunspot-Calibration.pdf

NOAA's perspective:
ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SGD_PDFversion/1973/sgd7302x.pdf

(Waldmeier, 1960s) and the rational for using the 10.7cm line:
http://adsabs.harvard.edu/full/1974JAVSO...3...30T

Nice history, but no k factors.
http://arxiv.org/ftp/astro-ph/papers/0702/0702068.pdf

Radio emissions at other frequencies than 10.7 cm:
http://adsabs.harvard.edu/full/1978SoPh...56..405R

NOAA's web site for Solar Radio Data:
http://www.swpc.noaa.gov/ftpdir/lists/radio/45day_rad.txt