33 Years of Continuous Solar Radio Flux Observations

Christian Monstein, Switzerland

In 1982, after development and testing of several analog receiver concepts, I started continuous solar radio flux observations at 230 MHz. My instruments for the observations were based on cheap commercial components out of consumer TV electronics. The main components included a TV-tuner (at that time analog), intermediate frequency (IF) amplifier and video-detector taken from used TV sets. The 5.5 MHz wide video signal was fed into an integrating circuit, in fact a low pass filter, followed by dc-offset circuit and dc-amplifier built with four ua741 and CA3140 operational amplifier integrated circuits. At that time the signal was recorded with a Heathkit strip-chart recorder and ink pen; an example is shown in figure 1.

The radiometric sensitivity was quite good due to the wideband signal and high integration time in the order of a few seconds. Soon after a Commodore PET computer was upgraded with an 8-bit analog-digital converter (ADC) to sample and convert the analog signals to a digital format and BASIC programs were written to address the digitized solar radio flux using low level poke() and peek() commands. Data was stored on a tape recorder and later on 5 1⁄4" floppy disks. Sometimes the data from the observed solar activity was printed on an old teletype machine, see figure 2. All these hardware units were extremely expensive, taking away many monthly salaries.

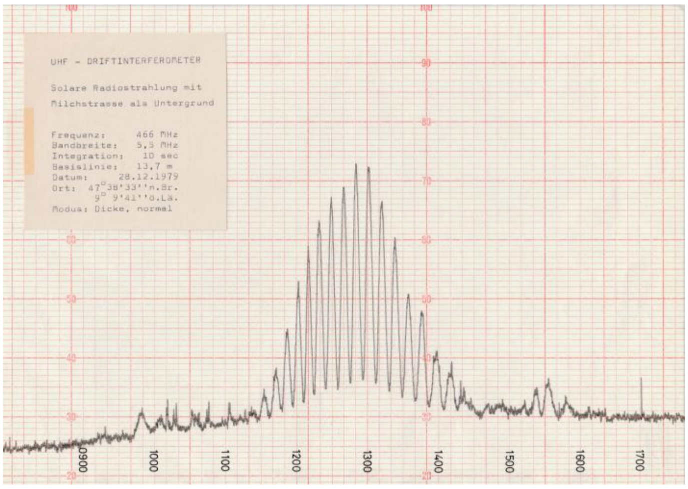

Fig. 1 ~ Scan of a historic paper strip chart recording from 1979 showing interferometric observation of the Sun. The flag on top left describes the observation parameters in German. Beside the main beam fringes we can also recognize both side-lobes at ~10:00 and ~15:30 local time.

The equipment, observations and calibration process was described in detail and published in the 'Handbuch für Sonnenbeobachter' (Handbook for Sun Observers) in Germany in 1982 [1].

During the 1980s of the last century more and more TV channels were commissioned and the number of personal electronic gadgets increased exponentially, producing too much radio frequency interference (RFI). So, in 1984, I decided to go to a higher frequency at 470 MHz which at that time was still free from RFI. In 1997 the 230 MHz observations had to be switched off completely. It wasn't possible to perform any acceptable observation of a solar transit. Similarly the observations at 470 MHz were suffering more and more from new TV channels in the UHF-band.

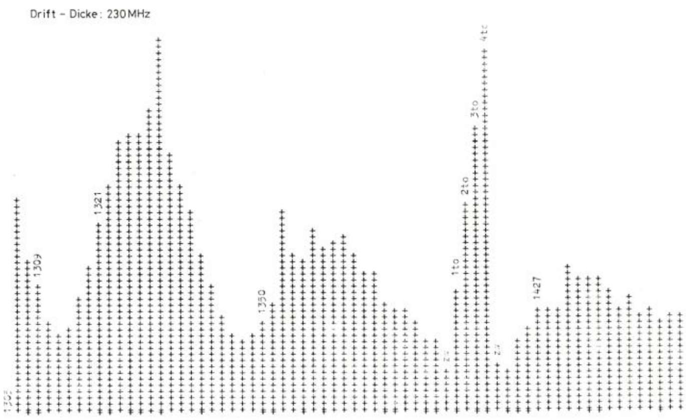

Fig. 2 ~ Scan of a historic teletype printout from 1980 of an interferometric observation of the Sun. The teletype replaced the strip chart recorder. Observation was at 230 MHz with calibration steps around 14:00 local time with T0, 2T0, 3T0 and 4T0, where T0 is 300 kelvin.

As a result of the television interference, I again had to redesign the equipment, namely antenna and receiver, for a higher frequency band at the protected frequency around 610 MHz (analog channel 37 in Europe). In the year 2000 the 470 MHz band could not be observed anymore and also was finally switched off. Up to today the observed and calibrated flux values were published once per month in SONNE, a German journal dealing with solar observations. From 2000 onwards transit-plots and numerical flux values are archived and published on the web here: http://www.e-callisto.org/HB9SCT/solarflux/solarradio.htm

Calibration

The current calibration model is based on antenna-gain, excess noise temperature of a semiconductor noise source and the actual distance between Earth and Sun. The noise source as well as a 50 ohm reference are switched-in once a minute, controlled by a standard PC.

$$Tant := \frac{Thot - Tcold}{Ihot - Icold} \cdot (Iant - Icold) + Tcold$$

$$S := \frac{Tant \cdot 8 \cdot \pi \cdot k}{G \cdot \lambda^2} \cdot \left(\frac{r}{R}\right)^2$$

Tant = antenna temperature [kelvin]
Tcold = reference temperature = 273.15 kelvin + measured ambient temperature [°C]
Thot = noise source temperature = 701 kelvin
Ihot = measured digits when the noise source is applied
Icold = measured digits when the termination resistor having ambient temperature is applied
Iant = measured digits when the antenna is switched on while pointing to the sky or to the Sun
S = solar flux expressed in sfu where 1 sfu = 1E-22 W/m^2/Hz = 10'000 FU = 10'000 Jansky
Tant = antenna temperature in kelvin
pi = 3.1416, k = Boltzmann constant = 1.38E-23 J/K
G = antenna gain in the order of 14 dB +/- 0.6 dB
lambda = wavelength = 49.18 cm at 610MHz
r/R = correction factor of Sun distance to the Earth (one calculated number per month)

The calibrated flux quite nicely fits with values published by others, for example, see NOAA here: ftp://ftp.sec.noaa.gov/pub/lists/radio/7day_rad.txt
Although during the winter season the deviations are rather large because of thermal radiation from the terrestrial horizon at about 300 kelvin and also from the Milky Way galaxy which add up to the antenna temperature of the Sun and, therefore, end up in a flux value which is too high. Models to compensate for this effect are not easy to implement – one would need either the full 3-dimensional beam pattern for modeling or an antenna with a higher gain (smaller beam) to avoid looking into unwanted sources.

Fig. 3 ~ 610 MHz Yagi on the balcony, pointing to the meridian position of the Sun.

Observations mode

The instrument is of transit meridian type in vertical polarization at the author's location in Freienbach, Switzerland (JN47je = location code expressed in radio amateur coordinate system). The changing declination of the Sun is compensated once or twice a month, which is sufficient given the large antenna beam width of more than 24°. The antenna is a massive aluminum Yagi-antenna originally sold for TV reception on channel 37 (UHF). The antenna was produced for many years by WIPIC Company, which no longer exists. Nowadays it is almost impossible to get such good antennas for individual TV channels.

Receiver

I currently use a commercial AR-3000A communications receiver from AOR, see figure 4. The IF-output is fed into a home brewed quadratic detector (multiplier based on the old SIEMENS circuit SO42P). The output voltage of the detector is sampled via a universal USB interface comprising 10 bit ADC, digital-analog converter (DAC) and general purpose digital output and inputs. The interface appears on the Windows device manager as a serial device which is easy to handle in any modern computer languages. I still use BORLAND BUILDER 6 C++ for communication, data analysis and plotting. The program runs 24h/365d, only interrupted by Windows updates which require a restart of the PC. Real-time information of the current antenna temperature is automatically transferred to my website every 5 minutes.

Fig. 4 ~ Communication receiver AR-3000A, controlled via RS-232 from a standard PC.

Output

Every month data from each day are read into the data analysis tool which calculates antenna temperature and solar flux as described above. Daily transits are then compiled in a monthly plot as shown in figure 5. In addition, an average flux per day and per month is produced and transferred to the website already mentioned above.

In the plot we can find some wavy structure, almost identical every day. This is due to reflection of the solar radio radiation from the ground and parts of the building. My antenna is mounted on the balcony and therefore influenced by all the conducting/reflecting stuff around it. A place far away from any infrastructure would be a big advantage.

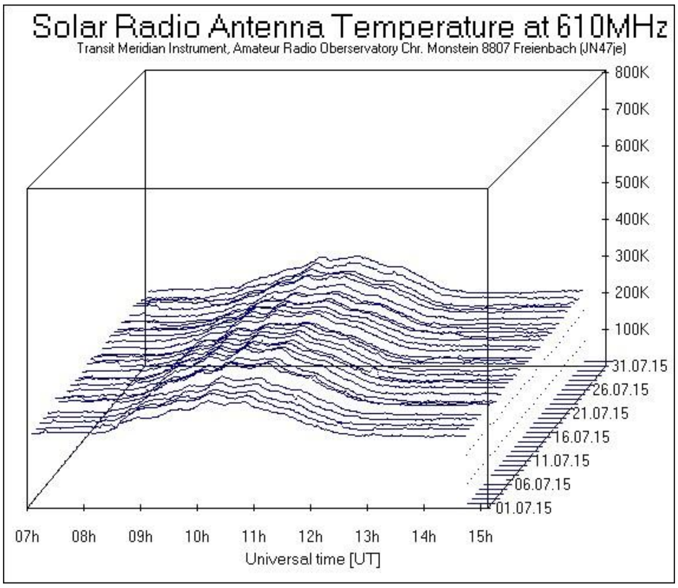

Fig. 5 ~ Monthly plot of solar antenna temperature produced with home-brewed C++ software on a Windows 7 PC.

Plots of long-term data obtained over the years described above at the different frequencies are given in figures 6, 7 and 8.

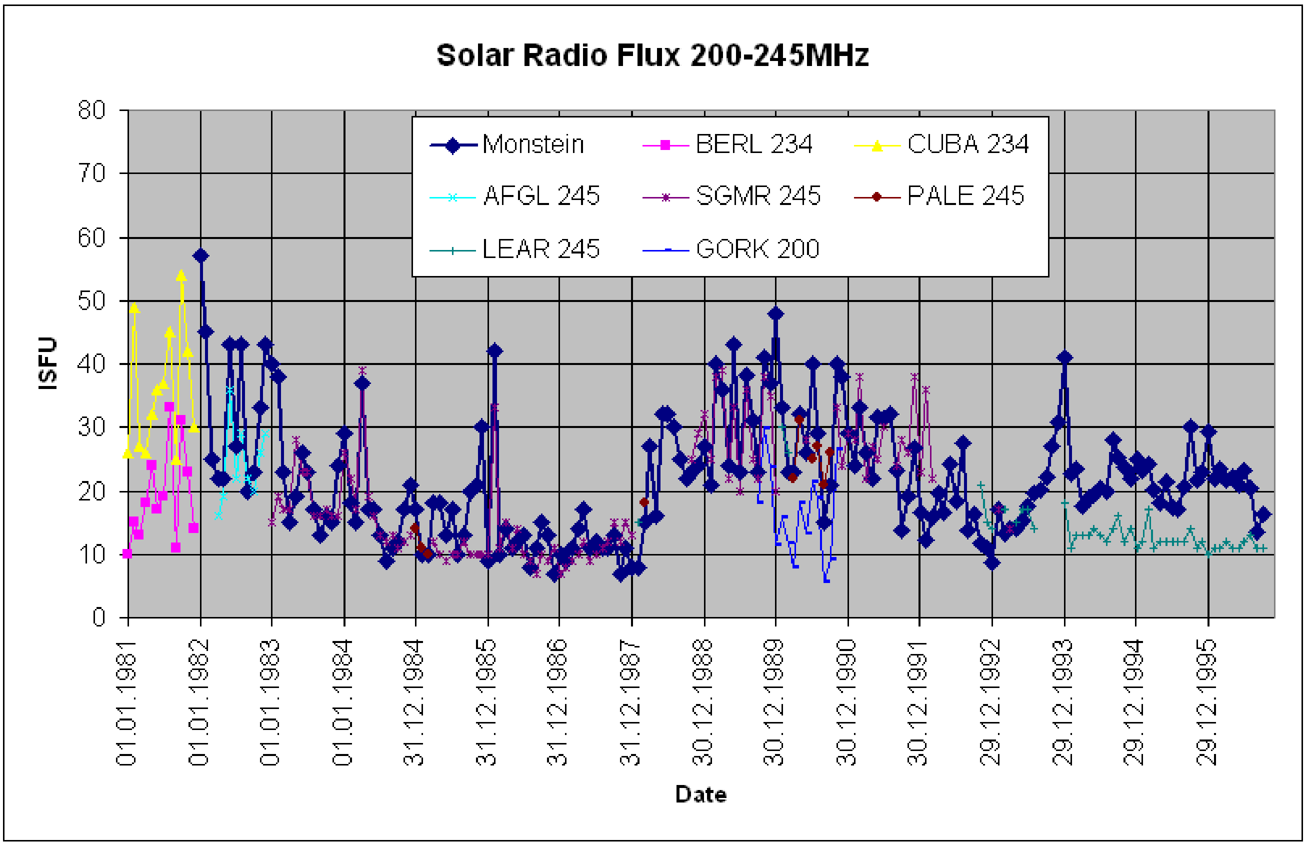

Fig. 6 ~ 15 years observation at 230 MHz. Many of the reference stations (BERLin, CUBA, AFGL and GORKi) have been shut down in the mean-time. AFGL = Air Force Geophysics Laboratory, currently Phillips Lab.

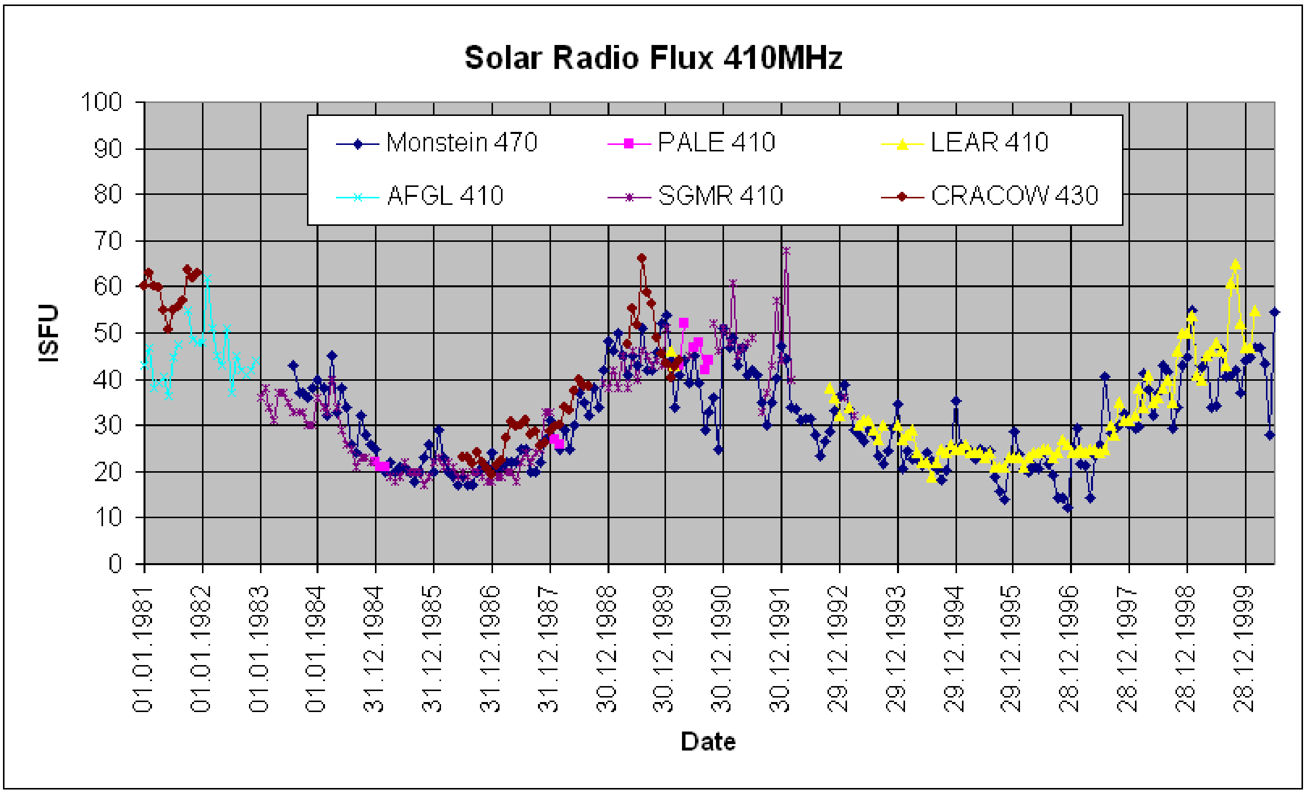

Fig. 7 ~18 years of solar observations at 410 MHz. Stations AFGL and CRACOW have already been shut down.

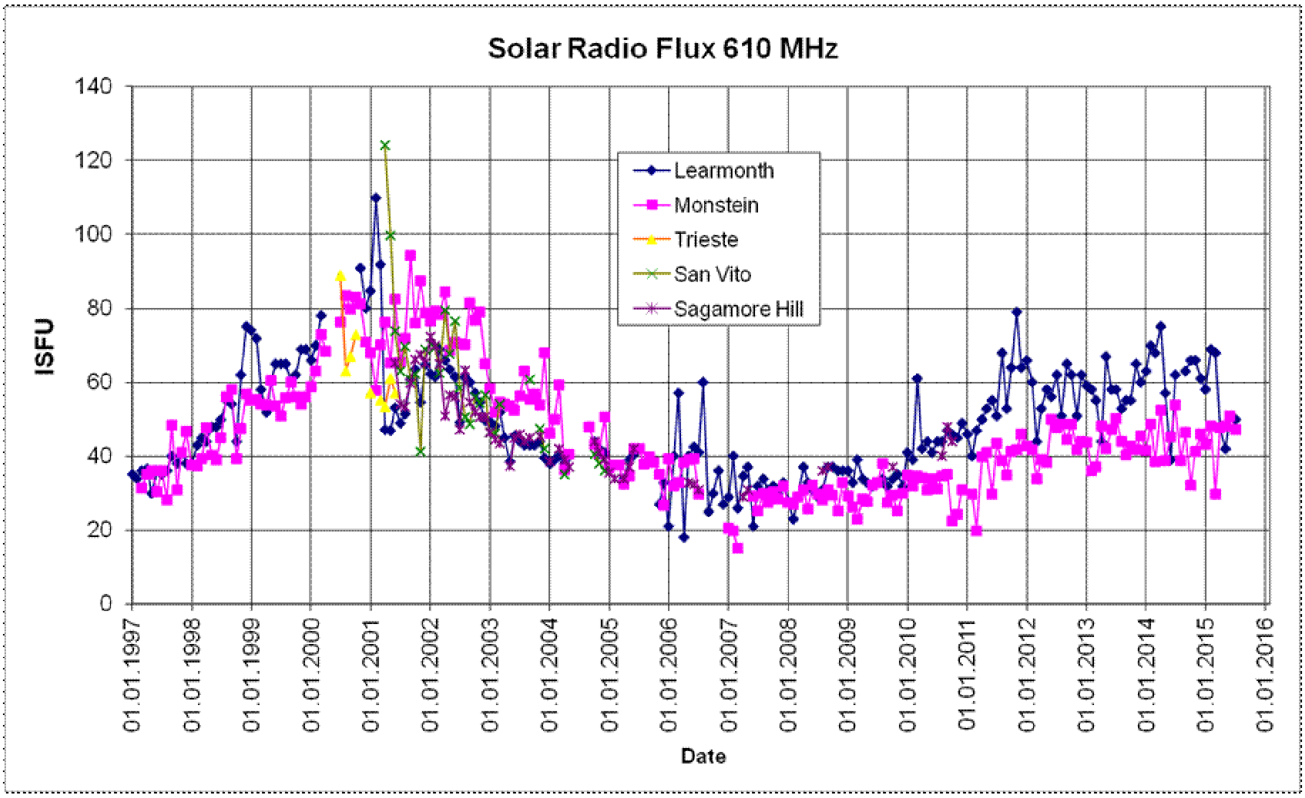

Fig. 8 ~ 19 years of observation at 610 MHz. The last solar maximum (cycle 24) was of very low level, much lower than the one from ~2001 (cycle 23).

Conclusions

If flexible enough in the selection of receiving frequency one can still perform solar radio flux measurements with acceptable precision, based on cheap commercial radio components. Also, one is able to demonstrate the variability of solar radio flux. Taking into account the shut-down of many professional solar radio observatories it might make sense that this activity is taken over by amateurs to guarantee long term data on solar activity, similar to those who observe the sun-spot number on a voluntarily basis and provide their data to the community.

References

[1] Rainer Beck, Heinz Hilbrecht, Klaus Reinsch and Peter Völker, Handbuch für Sonnenbeobachter, VDS Berlin 1982. ISBN 3-923787-00-6 (For radio part, see pages 114-131)