Amateuroberservation of the Solar Radio Noise

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One of the most seldom hobbies on the world is probably radio astronomy. It offers the possibility to produce as much data as you want fully automated and independent from weather by day and by night. The data may be analysed and interpreted on line or off line manually or computerised with high superior tools. But the availability of data does not mean that they must be analysed too. The way to get the data is interesting enough and allows us to fill up all the spare time year by year.

The receiving equipment here at my location in Freienbach is composed of four independent and nearly identical receiving stations. The first one is operational since 1982 on the frequency of 230MHz (Megahertz means million cycles per second) , the second one since 1983 on 470MHz, the third one since 1985 on 108MHz and the last one since 1994 on 10GHz. The yagiantennas for the VHF- and UHF bands (very high frequency respectively ultra high frequency) as well as the 10GHz parabolic antenna are mounted on a massive support made of aluminium on the balcony of our house at longitude of 8° 45' east and latitude 47° 12' north at an altitude of about 414m above sea level. The basis of the boom is east-west oriented, what means that the antennas lie in the meridian plane of the mean transit of the sun. The elevation of the antennas corresponds to the mean declination of the sun. This elevation must be adjusted manually twice a month. Most of the antennas are polarised vertically first to save place, second to eliminate most of the jam produced by local radio- and tv-stations that are often polarised horizontally. The acceptance angle depends on the receiving frequency and on the geometry of the antenna. In my case the acceptance angle is about 30 degrees to 40 degrees at 470MHz. This is a very bad value in comparison to a small optical instrument and does not allow to recognise any details on the radio sky. It is impossible to recognise any details on the solar disc too. If we want to see any details we must change the receiver to a very high frequency (some GHz) or the receiving area of the antenna must be increased drastically. In my case I have neither high frequency equipment nor large antennas, so I can measure the sun only as a whole. With my transit meridian instrument I have to wait until the sun crosses the antennapattern. In an ideal case we should follow the sun with a fully steerable antenna, but this is not the case in my configuration. This has two simple reasons, first a fully steerable antenna is very expensive and the second reason is also very important. In my area I have found, that the man made noise depends strongly on the azimuth of the antenna. In such a case it is useful to leave the antenna in a fixed position and to compensate electronically the man made noise as good as possible. If you turn the antenna you would simulate a radiosignal that does not come from the sky but from the computers and other electronic equipment in the neighbourhood. Therefore I have decided to let the antennas in a fixed position pointing to the suns transitpoint. So every day the instrument produces a signal like a cosine, where the time of the peak of the cosine corresponds to the transit time of the sun at high noon. The peak itself corresponds to the mean equivalent radiotemperature of suns disc. The signal level left and right of the cosine shows the cold sky, where at some times we can see the slightly higher temperature of our milky way. On low frequencies the radiotemperature of the sun is much smaller than that of the milky way. On frequencies above about 300MHz the radio temperature of the sun is mostly higher than that of the milky way. The extremely weak radio signals, which will be received through the antennas, in the order of 10 to the power -15 watt to 10 to the power -17 watt are conveyed to the frontend beside the antennas over a shortest possible coaxial cable with a wave resistance of 50 Ohm and as less loss as possible. In this frontend the radio signal arrives first on the main entrance of a coaxial directional coupler. There can be inserted a calibration signal by a semiconductor noise source which has a defined behaviour on frequency, impedance and power. This calibratable signal arrives now on a DICKE - switch /1/. This DICKE - switch changes about 500 times per second between the antenna with - or without calibration signal and a termination resistance that is stored at ambient temperature. The termination resistance has 50 ohms too and serves as a temperature reference with 300 Kelvin. This switched radio signal becomes conveyed to a high sensitive, low noise GaAs-FET - amplifier (gallium-arsenic-field-effect-transistor). This low noise GaAs-FET - amplifier is built for hams (radio amateurs) and is freely obtainable on the market. It has been persuaded however for my purposes from 435MHz on to 470MHz. After processing in the frontend the signal arrives now over a special low loss coaxial cable of the type RG213 in the shack (room where the receivers and computers are stored). The inevitable losses as well as the deterioration of the signal through the final physical temperature of the cables and plugs as well as other components become corrected as far as possible mathematically. This is absolutely necessary for the following calculations of the solar radio flux. In the shack the signal is conveyed directly to the receiver assembled from old tv - scrap. The receiver is composed of a original tv-tuner with small changes. The gain control, the receiving band (VHF, UHV) as well as the receiving frequency are fixed through high precise dc voltages. The intermediate frequency IF of about 33,4MHz (audiocarrier) and 38,9MHz (videocarrier) is conveyed to the unchanged IF (intermediate frequency) amplifier. It has a standard bandwidth of 5,5MHz. Here the IF gain control is regulated backwards over the reference signal by the synchronous demodulator. The amplified IF signal arrives on the video demodulator which has taken one by one from the salvaged tv-set. This videosignal is strengthened with an OP (operational amplifier) of type CA3140 and the signal bandwidth is reduced something. That from the antenna originating, very weak radio signal is strengthened so altogether around about 100 dB (10 to the power 10). The signal is conveyed to a synchronous detector and splitted into two separate signals. We have now greatly simplified the both signals T1 and T2 at the disposal. In the first clock we get T1=T (antenna) +T(disturbances, internal noise, drifts). In the second clock we receive T2=T(reference) +T(disturbances, internal noise, drifts). Both signals are integrated separately during about five seconds and the difference is formed by using an operational amplifier. It arises on the average the differential signal T(antenna) - T(reference) = Ta-Tr. The internal noises and disturbances are eliminated through the subtraction by the above mentioned method. Additional the summed signal T(reference) +T(disturbances) becomes smoothed over about 30 seconds. It is then used for the automatic and delayed gaincontrol of the IF amplifier. This leads to an extremely slight drift of the equipment for many years. The looked for signal Ta-Tr is conveyed directly over an analogue to digital converter with 12 bits resolution to the personal computer. In this PC the relative minimum of the differential signal will be searched for within two minutes. This function is useful to search for the smallest desired signal and to eliminate unwanted signals like radio, tv, lawnmowers, computer noise, coffee machines and so forth. Indeed just as short solar radio events are suppressed too. Because I do not document the short-term impulsive events, but the slowly changeable solar radio flux, this would play no role. That thus stabilised, from most extensive disturbances freed signal Ta-Tr is now stored. The data thereby become completed with the current time and date of the year. Thereby the time of day itself is derived by DCF77. DCF77 is an atomic clock located in Germany and distributed with VLF on 77,5 kHz. The above mentioned analog to digital conversion happens with a purchasable PC - LabCard of the type PCL-711 from Advantech. The computer program is developed personally in the common used language BORLAND-PASCAL. It records daily from 07:00 MEZ (middle European time) all two minutes one single measurement (minimum) until 15:30 MEZ and stores them in the RAM of the PC. The measurements are indicated continuously numerically and graphically on the screen. At the end of every day all data are stored firmly on the harddisc. The program itself runs during 24 hours without interruption year by year. At the end of each month the data (1 file per frequency and per day) will be transferred to a small diskette. The data are then analysed and interpreted on an other PC of the type 486 / 25MHz. Lately the data can be transferred alternatively over a network onto the laptop without using diskettes. Monthly an evaluation is accomplished per frequency how subsequently described. The evaluation contains a numerical list as well as a bargraph of the daily solar radio flux to the time of the culmination and a monthly linegraph. In these linegraph the recordtime is labelled in MEZ. Each day of the month is shifted slightly on to the right. The ordinate (y-axis) is labelled with the equivalent solar radio noise temperature in Kelvin. Only the temperature recorded to the time of culmination is converted into flux units and transferred in the previously described lists and graphs. At the inquiry of the effective culmination radio temperature the smallest measured background temperature is subtracted every day. In the months December, January and February this is indeed problematic. To these times the galaxy is found behind the sun and feigns by virtue a too high noise temperature because of the large acceptance angle. In the yearly presentation the solar flux is clearly too highly calculated at the change of the years. This undesirable error can only become prevented either by an antenna with an acceptance angle of 0,5 degrees or by compensating the galaxy statistically and mathematically. To it a FFT/IFFT (fast Fourier transform and inverse fast Fourier transform) could be used with good success, because the cosine function of the galaxy is clearly broader than that of the sun. In suppressing the low frequencies after the FFT there could be the pure sunsignal after transforming back the spectral lines into the time range. To it I have to meet personally still at few attempts accomplished around clear statements. Further analyses and comparisons with professional publications of the solar flux are to be refined necessary around the methods. The temperature resolution of my receiving equipment at 470MHz is about 0,7 Kelvin which well suffices the measuring of the solar radio flux in the amateur range. In the range of radio frequencies we may procure the Raleigh-Jeans approximation for calculating the radio flux. For it counts h*f << k*T, whereby h=6,62 * 10 to the power -34 Js (Planck's constant) and k=1,38 * 10 to the power -23 J/K (Boltzmann's constant). Hereby f means frequency of receiving equipment in hertz and T means measured equivalent radio temperature in Kelvin. For my relationships, i.e. at measurement of only one polarisation emerges for the radio flux:

$$FU = \frac{2 \cdot f^2 \cdot k \cdot T}{c^2} = \frac{2 \cdot k \cdot Ta}{\lambda^2} \quad (1)$$

This formula is simplified too greatly, it must be completed through the specific antenna parameters. The antenna temperature will be measured too low if the acceptance angle Ω (Greek omega) of the antenna is greater than that of the source. On the other side the antenna temperature is measured the smaller, the larger the losses γ (Greek gamma) are between antenna and preamplifier. My Yagi antenna has an acceptance angle Ω (Greek omega) of about 35 degree in the square that equals 0,4 sterad spaceangle. The cable loss factor γ (Greek gamma) is about 0,6. The generally used Yagi antennas own unfortunately not only a mainlobe. They have widely still several undesirable sidelobes, which falsify the measurements. These falsifications can be described and corrected with the help of the stray factor β (Greek beta) quite well. Since β (Greek beta) can not be determined directly, until today I use steadily 0,25 like it is also to be met frequently in the literature. Through comparison my calculated solar radio flux with the international data (see fig. 4) I hope to be able to determine β (Greek beta) more exactly in the course of time. With it then my flux values could be calculated more reliable. Since the originally presented flux values are very small numbers, these become standardised with the factor of 10 to the power 22. So handy numbers emerge for the practical use. Thereby counts: 1 Jansky = 1Jy = 10 to the power -26 Watt/m²/Hz = 1 IFU and on the other side 1 ISFU = 1 international solar flux unit = 10 to the power 4 FU = 10 to the power -22 watt/m²/Hz. Summed up at my relationships we have for the calculation the observed solar radio flux:

$$ISFU = \frac{2 \cdot k \cdot Ta}{\lambda^2} \cdot \frac{\Omega}{\gamma \cdot (1 - \beta)} \cdot 10^{22} \quad (2)$$

This observed flux contains fluctuations as large as about +-7% due to the changing sun earth distance. The flux presented in fig. 4 is adjusted to 1 AU (astronomical unit).

/1/ DICKE-switch mentioned in the literature such as:

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