Observation of Virgo A with a 10m parabola antenna

Christian Monstein

HB9SCT, Wiesenstrasse 13, CH-8807 Freienbach, Switzerland, cmonstein@swissonline.ch

Abstract. Virgo A has been observed with a fully computer steerable parabola antenna at $435MHz$ with amateur instrumentation. All measurements where done during August 10th 1996 at constant elevation in azimuthal scanning mode.

Key words. Radio telescope, receiver, bandwidth, integration time, observation Virgo A.

1. Introduction

On 10th of August 1996 we observed the rather weak radio source Virga A (M87) respective NGC4486 (Kraus, 1986) at right ascension $\alpha = 12 : 30 : 49.4s$ and declination $\delta = +12^{\diamond}\ 23'\ 28''$ with the radio telescope of Léon Kälin HB9CKL near Ermenswil Switzerland, see Fig. (1). All observations have been made with the same setup according to Table (1).

1.1. Explanation/apology by the author

Due to high disorder in my office the floppy disc with the stored data unfortunately got lost sometimes in 1996. After a long period of rainy weather the office was cleaned up and eventually (what a wonder) 6 years later the floppy disc reappeared. As a consequence the data have to be evaluated and presented in the following paper.

1.2. Block diagram

The instrument is composed mainly of two parts. The heavy part is the steerable antenna on top of a cannibalized crane. The azimuthal deflection is powered by a three phase alternating current electro motor which is controlled be a power frequency converter. This converter is directly controlled by the personal computer in the shack. The vertical deflection in elevation is controlled by a hydraulic cylinder where the oil flux can be switched on and off by electronic modulating valves. These valves are also controlled by the same personal computer. The actual angles are measured by optical encoders which are feed back via digital interfaces to the personal computer. The second part is the receiving system composed of the receiving feed, a cannibalized TV-antenna for band IV/V with an ordinary balun that converts 240Ω wave resistance into

Fig. 1. View from South-East to the semi professional radio telescope with a 10m full metal parabola antenna near Ermenswil Switzerland. The shack with the radio frequency electronics is shielded by an additional metal cabinet against electro magnetic disturbances.

60Ω cable resistance. This signal is then feed to a low noise GaAs-FET preamplifier LNA435 from SSB electronics, see Fig. (2). The amplified signal leads then down to the shack via a directional coupler and an additional rf amplifier to the receiver AR3000. The $40MHz$ IF is taped by a thin coaxial cable and is then feed to the square law detector via an adjustable IF attenuator. The square law detector S042P is followed by a passive low pass filter of $200msec$ time constant which then is directly feed to the analog-to-digital converter PCL-812 within the personal computer.

1.3. Cumulation process

Every data file (Fig. (3) until Fig. (12)) has to be treated in the following way since we have different azimuthal deflections, different number of elements, different dc-offsets
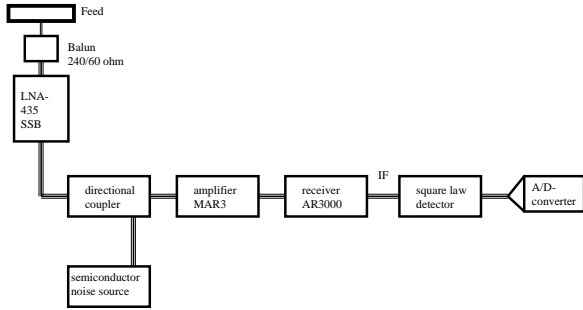
parameter	unit
Antenna	$Parabola\,10m$
Feed	$B-IV\,antenna$
Preamplifier (GaAs-FET)	$LNA432(SSB)$
Receiver	$AR3000$
Square law detector	$S042P$
Receiving frequency	$435MHz$
Intermediate frequency	$40MHz$
Measuring bandwidth	$220KHz$
Integration time	$200msec$
Sampling rate	$5Hz$
IF attenuation	$1.5dB$

Table 1. Measuring parameters used for Virgo A.

Fig. 2. High frequency block scheme of the radio astronomy receiving system as part of the 10m parabola antenna. Minor details such as IF attenuator and low pass filter are not shown here. The A/D-converter is part of the personal computer and is connected to it by an ordinary ISA bus connector.

etc., which makes analysis very time consuming. In further observations one has to take care about consistency in the data structures that means all observations have to be done with identical parameters. As a first step one has to sort all measurements with descending azimuthal deflections in such a way, that all files will end up in ascending order (from East to West). The second step transforms all different telescope azimuth into a symmetric version by subtracting azimuth (telescope) minus azimuth (source) in such a way that the output becomes in the order of $\pm 15\ degree$ respective $\pm 20\ degree$. In a third step all disturbances that can be recognized visually have to be killed. This can easily be done with a Microsoft EXCEL sheet since one can immediately see successfully 'cleaned' data. There are several reasons for such disturbances such as calibration pulses from the noise source and/or electromagnetic pulses from man made interference. In a forth step the dc offset of every files has to be evaluated and subtracted form each data point. These are very important requirements otherwise it is not possible to fit different observations together. This operation can also easily be done in a single EXCEL statement. In the next (fifth) step all prepared files have to be appended together to one single ASCII file. After the appending process the data base has to be sorted in terms of ascending azimuth again. Finally in the sixth step the now quite long ASCII file has to be integrated over a period of 10 pixels due to the fact that 10 observation files are involved. After that process the intensity has to be normalized by dividing every bin by 10. The output of this lengthy but straight forward process is shown in Fig. (13). It is obvious that the standard deviation σ of the cumulated data file is lower than the individual σ in every single file. That is the main reason of all that work mentioned above to reduce the standard deviation by integration as much observations as possible. The standard deviation according to the radio-meter
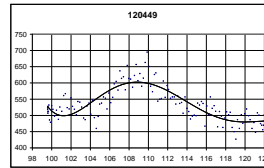
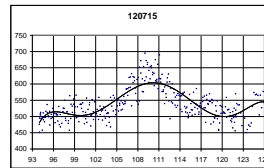**Fig. 3.** First observation of Virgo A at $12:04:49$, where $\sigma = 114FU\ and\ N = 132$

Fig. 4. Second observation of Virgo A at $12:07:15$, where $\sigma = 100FU\ and\ N = 343$
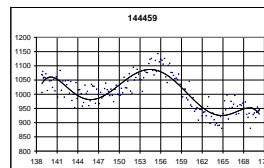
Fig. 5. Third observation of Virgo A at $14:44:59$, where $\sigma = 108FU\ and\ N = 175$

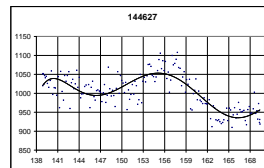equation can be reduced by the square root of the number of samples involved.

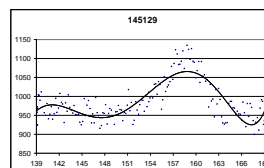**Fig. 6.** Forth observation of Virgo A at $14:46:27$, where $\sigma = 103FU\ and\ N = 172$

Fig. 7. Fifth observation of Virgo A at $14:51:29$, where $\sigma = 110FU\ and\ N = 171$
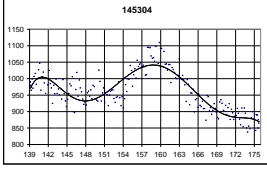
Fig. 8. Sixth observation of Virgo A at $14 : 53 : 04$, where $\sigma = 110FU$ and $N = 204$
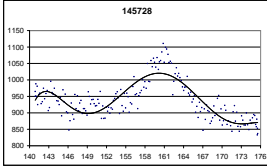

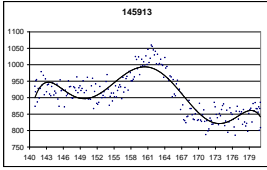**Fig. 9.** Seventh observation of Virgo A at $14 : 57 : 28$, where $\sigma = 101FU$ and $N = 192$

Fig. 10. Eighth observation of Virgo A at $14 : 59 : 13$, where $\sigma = 119FU$ and $N = 222$
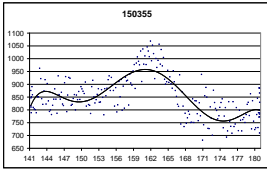

Fig. 11. Ninth observation of Virgo A at $15 : 03 : 55$, where $\sigma = 161FU$ and $N = 229$
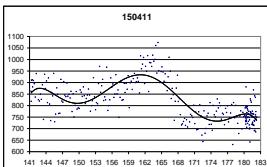

Fig. 12. Tenth observation of Virgo A at $15 : 04 : 11$, where $\sigma = 198FU$ and $N = 278$
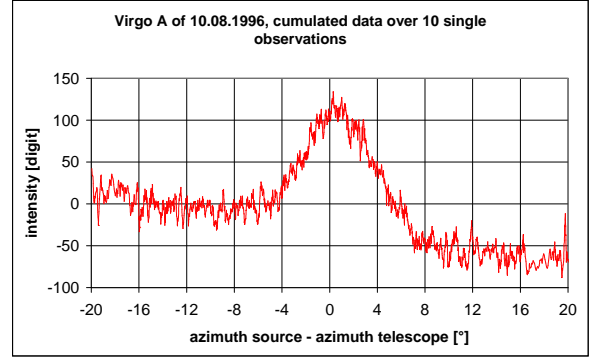

Fig. 13. Final chart of the cumulation respective integration of 10 different observations into one single observation to improve the signal to noise ratio. Here the final signal to noise ratio $S/N = 14.8$, which is about $11.7dB$. The resultant standard deviation $\sigma = 40FU = 40Jansky$.

and eventually

$$\sigma(Ta) = \frac{\sigma(S) \ A_{eff}}{2 \ k} = 0.6 Kelvin \tag{3}$$

where the efficiency $\eta = 0.53$ was measured with other strongers sources such as the Sun, Cygnus A respective Cassiopeia A. The effective aperture in our case is $A_{eff} = \eta \ \pi \ R^2$ where with $R = 5m$ we get $A_{geo} = 78.5m^2$.

2. Result

After applying all tasks to the individual files which takes about two days of work we get an output with a higher signal to noise ratio, see Fig. (13). The expected radio flux was not measured but calculated using an equation of (Baars et al, 1977) describing spectral flux distribution of Virgo A, where

$$\log(S) = a + b \ \log(\nu) \tag{1}$$

where $a = 5.023 \pm 0.034$ and $b = -0.856 \pm 0.010$ for frequencies $400MHz < \nu \le 25GHz$. In our case we then get $S = 581Jansky$. By knowing the physical parameters of the antenna hardware we may evaluate the antenna temperature involved, where

$$Ta = \frac{S \ A_{eff}}{2 \ k} = \frac{S \ A_{geo} \ 0.53}{2 \ k} = 8.8 Kelvin \tag{2}$$

3. Conclusion

With the method just described it is more or less easy to observe weak radio sources such as Virgo A and even weaker sources with flux intensities in the order of a few Jansky. If we combine cumulation of data files with higher integration time and larger observation bandwidth it might be possible to observe sources actually below 1 Jansky. Despite this possibility it takes a lot of effort and time to do such observations to be sure to get proper data under controlled measurement conditions.

References

John. D. Kraus, *Radio Astronomy 2nd edition*, Cygnus-Quasar Books 1986.

J. W. M. Baars, R. Genzel, I. I. K. Pauliny-Toth and A. Witzel, *The Absolute Spectrum of Cas A; An Accurate Flux Density Scale and a Set of Secondary Calibrators*, Astronomy And Astrophysics 1977, p. 102 (Table 3).