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Response of the Effelsberg 100 m radio telescope to signals in the near-field at 24 GHz

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Abstract. Short range radar (SRR) for cars has been proposed to operate over 5 GHz of bandwidth at the 24 GHz ISM band. To estimate the level of interference from these devices on radio telescopes, the near-field antenna pattern has to be known. We report on new measurements with the Effelsberg 100 m radio telescope. These measurements were performed with a transmitter set up at a distance of 1.7 km from the telescope. The strength of the signal picked up by the telescope sidelobes shows that the proposed SRR would interfere with sensitive radio astronomical observations.

1 Introduction

The near-field of parabolic radio antennas is usually defined by a radius R of the Fresnel zone of $R = 2D^2/\lambda$, where D is the diameter of the antenna and λ the wavelength (Balanis 1996). For the 100 m radio telescope and cm-wavelengths R is of order 1000 km. The entire terrestrial horizont is located within the near-field zone. However, all astronomical objects are located in the Fraunhofer zone (far-field). Because of this, the response of the antenna to sources in the near-field is only poorly known. At short cm-wavelengths the 100 m antenna has a very narrow beam of less than 1 arcmin. To measure the response over a larger solid angle centered on the main beam is time consuming and normally not possible.

This lack of information makes it difficult to estimate the influence of terrestrial transmitters on sensitive radio astronomical measurements. Because of the complexity of a radio astronomical antenna with focal cabins and support legs a simple calculation based of Fresnels theory in often misleading. This complexity and the different topological conditions make every radio telescope unique concerning susceptibility to artificial radio signals produced in the neighborhood.

A recent example of proposed terrestrial transmitters is connected to short range radar, SRR, for cars. Devices are proposed to operate over 5 GHz of bandwidth centered at the 24 GHz ISM band. Though the spectral power density per unit bandwidth of the individual SRR emitters considered is very low (about −90 dBm/Hz), compared to other transmitting radio devices, the passive radio services, i.e. radio astronomy and Earth exploration, also detect and analyse naturally occuring broad band noise power over large bandwidths. Many astronomical objects are observed down to the natural horizont of the particular radio telescope. At the Effelsberg 100 m radio telescope the lowest elevation of 8° is reached towards the south, the west, and the north. The location of roads in the neighborhood of the antenna is shown in Fig. 1.

The direction towards west, where the road with highest traffic density passes the telescope at a distance of about 1.7 km was choosen on 8 May 2002 to perform measurements of the antenna response to a test signal. In Sect. 2 the measurement is decribed followed by a determination of interference levels in Sect. 3.

2 The measurements

A test transmitter was set up at the above mentioned road, from where a large part of the telescope aperture is visible when pointing towards the azimuth of the transmitter. The coordinates of the test transmitter location have been determined using GPS and checked with a detailed map. The coodinates were $50^\circ\ 31'\ 13.1''$; $6^\circ\ 51'\ 39.5''$. The distance and the azimuth of the transmitter as seen from the radio telescope, the coordinates of which are very well known, were calculated to be 1696 m and 256.8°, respectively. Towards this azimut cosmic sources can be followed down to an elevation of 8°.

The test transmitter consisted of a sweeper HP8350B with transmitter module 83570A set to CW mode at a fixed frequency of 23.8 GHz. The output was connected to a standard gain horn with a coaxial cable. The transmission loss of the cable and the output power at the horn flange had been

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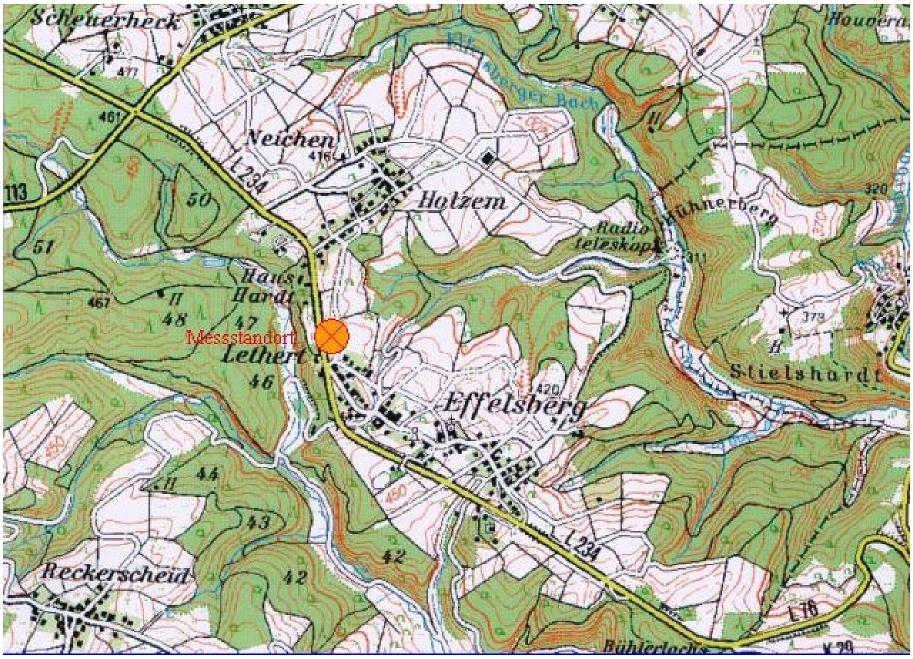

Fig. 1. The location of roads in the neighborhood of the 100-m-RT and the location of the test transmitter (red circle).

Fig. 2. Set-up of the test transmitter.

measured in the laboratory before. The horn was mounted on a tripod at 1 m above ground, E-field vertical, and pointed towards the telescope. The set-up is shown in Fig. 2.

At the radio telescope the primary focus K_a band receiver was set to a receiving frequency of 23.8 GHz and the backend was set to continuum mode. The telescope was pointed at 8.1° elevation, at which it scanned in azimuth over a range of ten degrees, centered at the calculated azimuth of the test transmitter. The received signal strength – and hence the sidelobe gain pattern – shows considerable scatter (see Fig. 3). The origin of the received signal was repeatedly verified by switching the test transmitter off and on. At the position of the maximum field strength, at 256.8° azimuth, a scan in elevation was measured, which also exhibits considerable gain variations. To the surprise of experienced observers even, a sharp peak in sidelobe gain was detected near

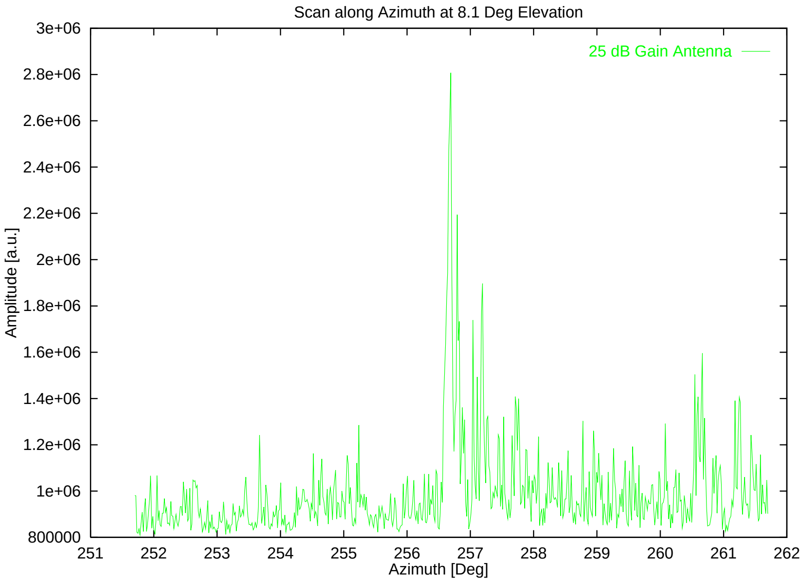

Fig. 3. Azimuth scan at 8.1° elevation.

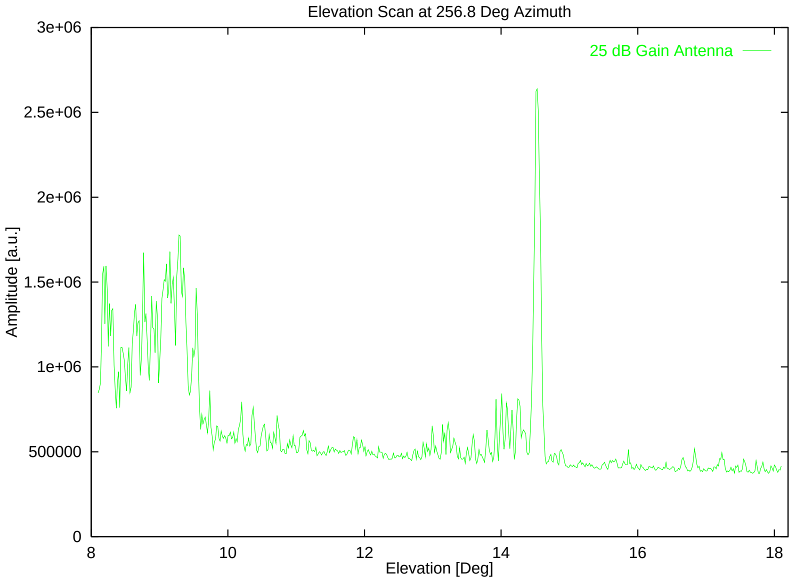

Fig. 4. Elevation scan at 256.8° azimuth.

14° elevations, which could be confirmed by serveral checks (see Fig. 4). There was, however, not sufficient time available to perform more complex side lobe structure measurements.

The autocorrelator spectrometer was then used to measure the spectrum of the test transmitter signal. The spectrum was found to be the same as the sweeper output spectrum measured with a spectrum analyser in the lab before, and is displayed in Fig. 5.

The spectrum was calibrated by comparing the output power in each spectrometer channel with the output power produced by a broadband calibration signal, which is fed into the receiver before the first amplifier stage. This is a standard procedure for calibrating astronomical measurements and hence the signal strength is given in milli Kelvin (mK) of brightness temperature. For independent calibration and for comparing the artifical signal to an astronomical signal the telescope was then pointed towards a well-known strong source of celestial molecular line emission at 24 GHz, the Kleinmann-Low nebula in the Orion Molecular Cloud. The elevation of the cloud during the measurement was 32°. The ammonia line spectrum at 23.694 GHz is shown in Fig. 6. The signal, seen through the main beam of the 100 m antenna, is several orders of magnitude weaker than the artificial signal of the test transmitter seen through a side lobe of the radio telescope.

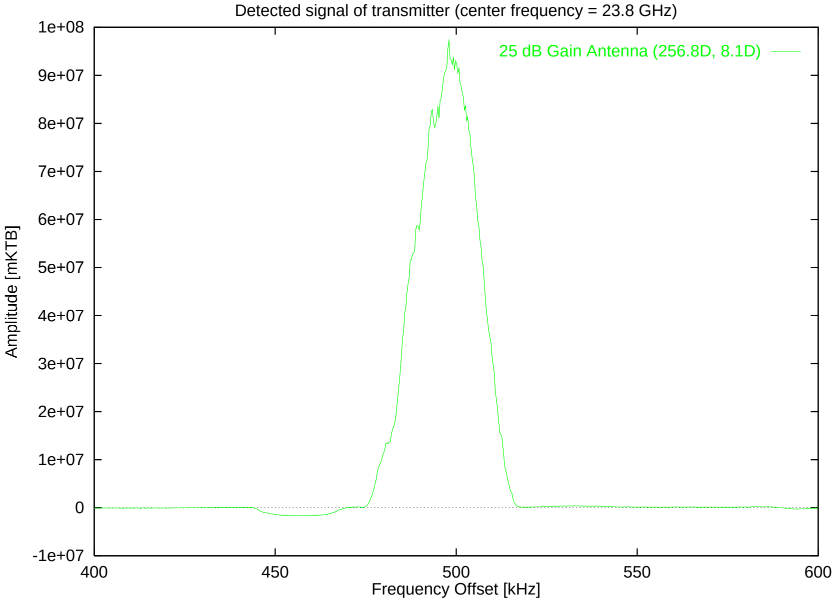

Fig. 5. Spectrum of the test transmitter measured through a sidelobe of the Effelsberg 100 m radio telescope.

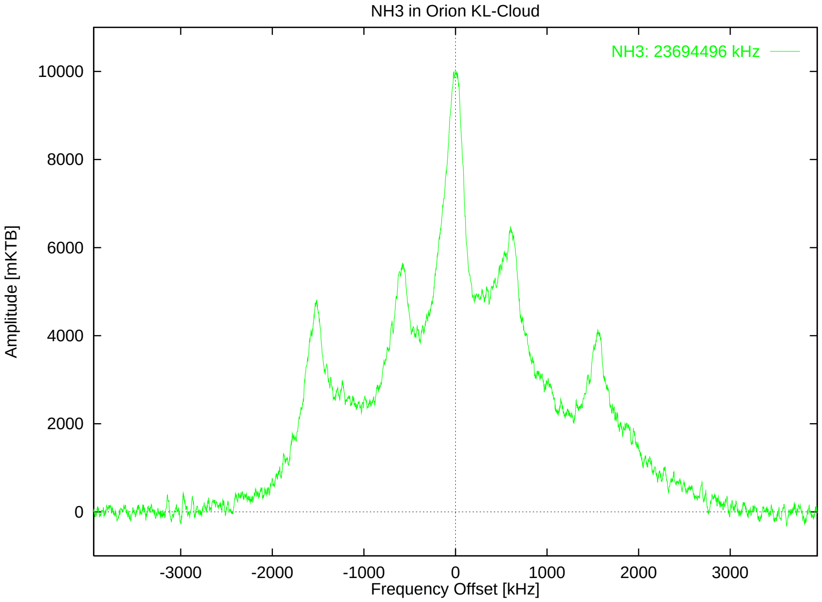

Fig. 6. NH_3 in OMC1.

3 Determination of interference levels

The output power at the transmitter horn flange had been determined in the laboratory to be -13 dBm. The horn gain is given as 25 dB, hence the eirp of the transmitted signal towards the radio telescope was 12 dBm. Taking the measured spectrum of the test transmitter, Fig. 5, the 3 dB bandwidth is $BW_{3dB} = 20\ kHz$ and $T_B = 7.5 \times 10^7\ mK$, respectively. From the NH_3 measurement a system temperature of $T_{sys} = 155\ K$ was determined, corresponding to $\approx 230\ K$ at 8° elevation. Given the air temperature of 19° and a partly cloudy sky at the time of the measurement, this relatively high system temperature appears to be reasonable. Taking $T_{sys} = 230\ K$, the allocated bandwidth of 400 MHz, and an integration time of 2000 s as recommended for sensitive radio astronomy measurements in Recommendation ITU-R RA.769, the minimum detectable change in brightness temperature is $T_B = 0.3\ mK$.

The following calculation leads to the maximum allowable eirp for an artifical signal in order not to exceed the sensitivity limit for observations with the Effelsberg 100 m radio telescope at 24 GHz. It should be noted that the 10% criterion from Recommendation ITU-R RA.769 is not included in the calculation!

Table 1.

Output power:	−13 dBm
Antenna gain:	25 dB
3 dB bandwidth of signal (20 kHz, taken from figure 5	−43.0 dBHz
Eirp:	−31.0 dBm/Hz
Necessary attenuation ($7.5 \times 10^7\ mK/0.3\ mK$)	−84.0 dB
Maximum allowable eirp:	−115 dBm/Hz

4 Conclusion

Test measurements were performed with the 100 m Effelsberg radio telescope at a frequency of 23.8 GHz under mean atmospheric conditions. A signal from a test transmitter located next to a nearby road, at a distance of 1.7 km from the telescope, picked up by a telescope sidelobe, was compared with a signal received through the main beam from a well-known astronomical source. The measurements show that the power of any devices producing artificial radio signals should be well below −115.0 dBm/Hz in order to protect routine radio astronomical measurement at the 100 m telescope.

References

Balanis C. A.: Antenna Theory and Design, John Wiley, 2nd Edition 1996.