Interference Problems at the Effelsberg 100-m Telescope

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Abstract:

We summarise the effect of interference on sensitive radio continuum and polarisation mapping observations with the Effelsberg 100-m telescope. The location of the telescope inside a valley reduces the influence of terrestrial interference substantially. Most problems are noted at UHF frequencies and in the L-band. Spiky interference interference can be largely mitigated. However, steady interference seen by far-sidelobes are a problem. Far-sidelobes also pick up solar emission and thus make daytime mapping observations up to 2.7 GHz nearly impossible. An unsolved problem is the transmission of ASTRA 1D near the protected 10.7 GHz radioastronomy band, which forces a shift of the observing frequency to 10.45 GHz and a reducing of the usable bandwidth.

The site of the Effelsberg telescope

The Effelsberg 100-m telescope is located in a narrow valley of the Eifel mountains. The elevation limit for shadowing of the surface by surrounding hills is lowest towards the south allowing observations of the Galactic Center region for a few hours a day. Shadowing varies with azimuth in the elevation range between 7° and about 25°. The location of the telescope reduces quite certainly terrestrial interference. However, the origin and direction of scattered interference is quite difficult to identify.

Continuum and polarisation observations

At the Effelsberg 100-m telescope a number of highly stable receivers for continuum and polarisation mapping is available. Table 1 lists some relevant parameters.

Table 1: Receivers for continuum and polarisation observations at the 100-m telescope

Frequency [GHz]	Bandwidth [MHz]	Feeds	HPBW [′]	Tb/S [K/Jy]	RX	rms* I [mJy]	rms* U,Q [mJy]
0.86	10	1	14.5	1.9	2	100	-
1.40	20	1	9.3	2.1	2	10	4
2.68	40	1	4.3	2.5	2	7.4	3.2
4.85	500	2	2.4	2.5	4	1.3	0.3
10.5	300	4	1.15	2.2	8	2.3	0.7
32.0	2000	6	0.45	1.8	12	4	2.4

* 1 sec integration time

The achievable sensitivity is limited by the confusion limit from unresolved extragalactic sources within the telescope beam. The confusion limit is reached after a few seconds of integration time at low frequencies. The confusion limit for the Effelsberg telescope is approximately given by:

$S\ [\mathrm{mJy/beam}] \approx 18\ \nu\ [\mathrm{GHz}]^{-2.7}$

At high frequencies a net integration time of several minutes per pixel of a map is needed to approach the confusion limit. The sum of all steady interference contributions must be lower than the confusion limit to reach the maximum possible sensitivity at each frequency and many experiments critically depend on that. For linear polarisation measurements the confusion limit has not been measured so far. However, from the known polarisation characteristics of extragalactic sources it is easily estimated that confusion from unresolved linearly polarised sources must be at least one order of magnitude below that measured for total intensity.

Losses due to interference

The fraction of lost time due to interference as reported by observers is relatively low. In a report to CRAF the loss of 91 hours of observing time in 1994 was listed. About 90% was lost when observing in or near the protected 21-cm-band, although it must be noted that UHF observations were not possible at that time. Apparently the situation has not much changed during the last years. However, the relatively small amount of observing time lost is largely related to the flexible use of the telescope at different frequencies. As mentioned above the sources of interference are difficult to locate. However, systematic spectrum checks when pointing the telescope in the station buildings direction revealed some electronic devices being responsible for some of the low frequency interference. These checks are at present regularly made and any new electronic device being used at the station is carefully checked to eliminate this source of interference.

Spiky or impulsive interference lasting from milliseconds up to a second are occasionally observed at many frequencies. This kind of interference can be eliminated in most cases by editing or filtering the data in a suitable way, although sensitivity is reduced locally and full sampling is not provided anymore.

UHF observations

A broad band receiver for observations of red shifted HI-lines between 800 MHz and 1200 MHz is also used for continuum observations. This frequency range is not protected, but a spectrum investigation for frequencies with a low level of interference was promising (Lochner and Fürst, 1998). However, it turns out that sensitive measurements were not possible for up to 90% of allocated time since interference exceeds several times the system noise level. Obviously the broad band HEMT receiver was affected by strong interference outside of the observing band and therefore narrow IF-filter did not improve the quality of the measurements. Figure 1 shows an example of a RHC and LHC raw map observed that way. The high noise level and the various distorting features due to interference make it impossible to use these data for astronomical purpose. However, when placing narrow HF-filters in front of the HEMT amplifiers the situation changes in such a way that about 90% of observing time could be used for observations. The usable bandwidth is up to 10 MHz. Figure 2 shows the result obtained by 4 coverages observed in orthogonal directions in 4 hours of observing time of the field of Fig. 1 revealing a faint large diameter shell-type source, possibly a weak supernova remnant, near a number of known strong radio sources (Reich et al., 2001). The rms-noise of about 25 mJy/beam measured from that map is at the level of the confusion limit at that frequency.

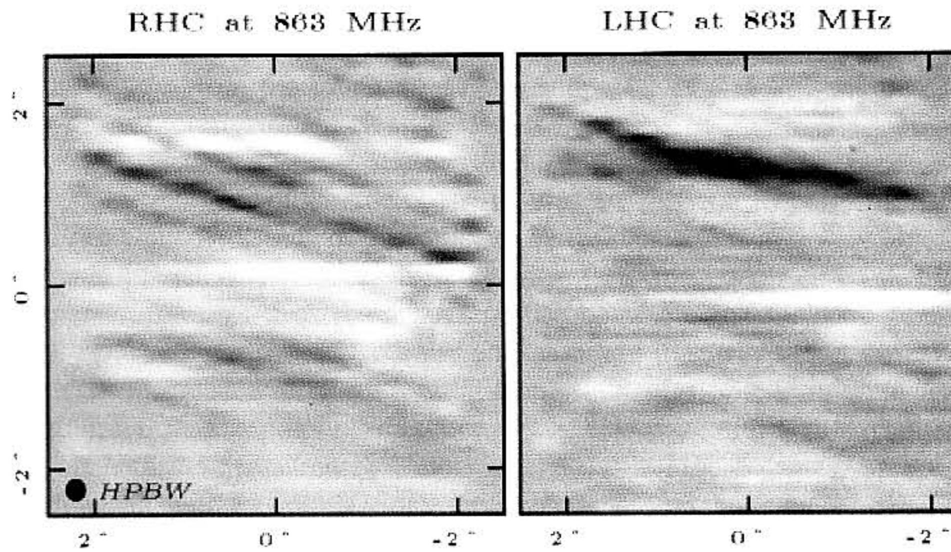

Fig. 1: 863 MHz observations without HF-filter in front of the first amplifiers.

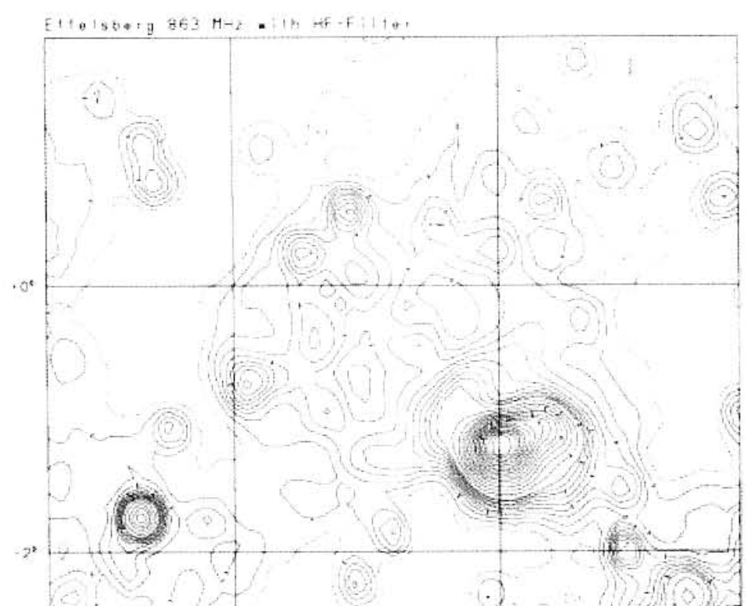

Fig. 2: The same field as shown in Fig. 1 with HF-filter. The peak intensity in the map is 4.0 Jy/beam area. The angular resolution (HBPW) is 14.5′ as indicated in the lower left corner.

Sidelobe structure of the telescope

Interference is picked up by the sidelobes of the telescope. The near-sidelobe structure is well known from measurements of strong radio sources or beacons placed on geostationary satellites. In Fig. 3 the antenna pattern at 11.7 GHz for a 1.4° wide field is shown. It has been observed from the prime focus of the telescope using the beacon signal on-board EUTELSAT at 11.7 GHz in the course of a holography run (Reich and Fürst, 1999). Most feeds used at the Effelsberg telescope are scaled and therefore the antenna characteristic is similar at other frequencies. The features from the four subreflector support legs and also the outer diffraction ring from the 6.5-m subreflector are clearly visible.

Observations of even fainter outer sidelobe structures are difficult to perform. Kalberla et al. (1980) have made a detailed study of the far sidelobe characteristics and were able to model it. The proof of this model is the successful cleaning of HI-spectra observed at high Galactic latitudes from contributions picked up by far-sidelobes from the Galactic plane. The far-sidelobes pick up interference but also solar emission and that way affect observations. The most prominent sidelobe structures are located along four rings of 66° in diameter centred in about 33° distance from the pointing direction of the telescope and result from scattering at the feed support legs. As measured by Kalberla et al. (1980) these „rings" split up in patchy structures with peaks at about –60dB. Solar radiation picked up that way is up to 1 K T_b at 1.4 GHz and exceeds the confusion limit of about 15 mK T_b by a large factor.

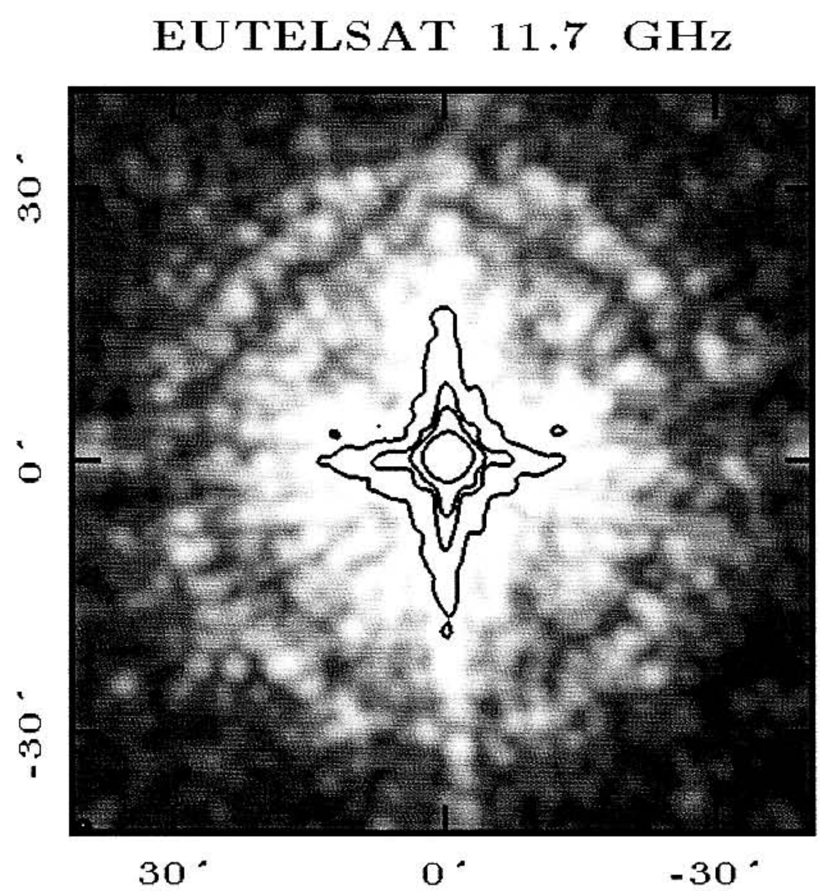

Fig. 3: Antenna pattern at 11.7 GHz slightly convolved to 2' in order to enhance the contrast of the weak outer sidelobe structures. The dynamic range is about 60 dB.

L-band observations

L-band observations are done for a large fraction of time since they are almost unaffected by bad weather conditions. Continuum observations are most times made close to 1.40 GHz just below the Galactic HI-line emission centred at 1.42 GHz. Above that frequency terrestrial DAB transmission is allocated and below 1.40 GHz strong radar signals are seen. The interference situation between 1.6 GHz and 1.7 GHz is affected by the known strong satellite signals. However, a solution by placing HF-filter in front of the first stage of amplifiers is not possible, since sensitive deep integrations for extragalactic HI require the highest possible sensitivity. So far about 20 MHz bandwidth are used as a compromise between loss of time due to interference and useable observations.

Figure 4 shows raw measurements separately for the RHC and the LHC and in addition the difference between these channels. These 10° wide map was observed in the Galactic coordinates system within about 1.5 hour, while moving the telescope forward and backward along the longitude direction relative to the field center. During that time the positions of the map change largely in the horizontal system. The inclined stripes showing up in the difference map are definitely due to steady terrestrial interference having a fixed AZ/EL-position and were picked up by far-sidelobe structures changing in position according to the telescope pointing. Clearly the LHC map is severely affected by interference largely exceeding the noise. It can not be used for measuring extended Galactic structure. The question is: is the RHC map reliable for faint emission and useful in case the $\sqrt{2}$-loss in sensitivity without the LHC map is acceptable ? Without a reference the measurement must be repeated.

Another example of distorted 1.4 GHz measurements is shown in Fig. 5. The measurements run along Galactic longitude starting from the top of the map. The map was started shortly before sun-set. The LHC channel shows a strong feature (about 1 K) running from top across the map and disappears abruptly after sun-set. Other weaker structures show up more pronounced in the difference map and are due to terrestrial interference entering the LHC-channel, while the solar emission feature is not much different in the RHC- and the LHC-channel. Also linear polarisation is distorted as seen from the U- and Q-channel with differences between solar emission and terrestrial interference. Clearly these data are not usable and must be repeated.

Recently a second polarimeter backend has been installed, that by now two channel observations are possible. The polarimeter can be centred at different frequencies within the L-band and have 14 MHz bandwidth each. Interference is much better recognised by the two channel system due to the - in general - small bandwidth of the interfering signal and the frequency dependence of the far sidelobe positions. The reduction of harmful emission is clearly improved, although this might become a time consuming data reduction effort. A new 8-channel polarimeter for the L-band receiver with narrow IF-filter is under construction, which will offer more possibilities for interference rejection.

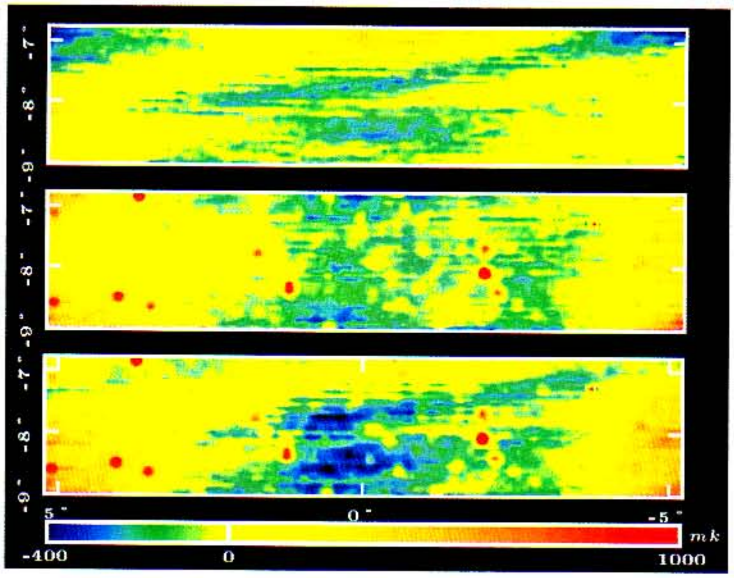

Fig.4 : Colour coded 1.4 GHz observations in the Galactic coordinate system. From bottom to top: LHC channel, RHC channel and the difference between both channels.

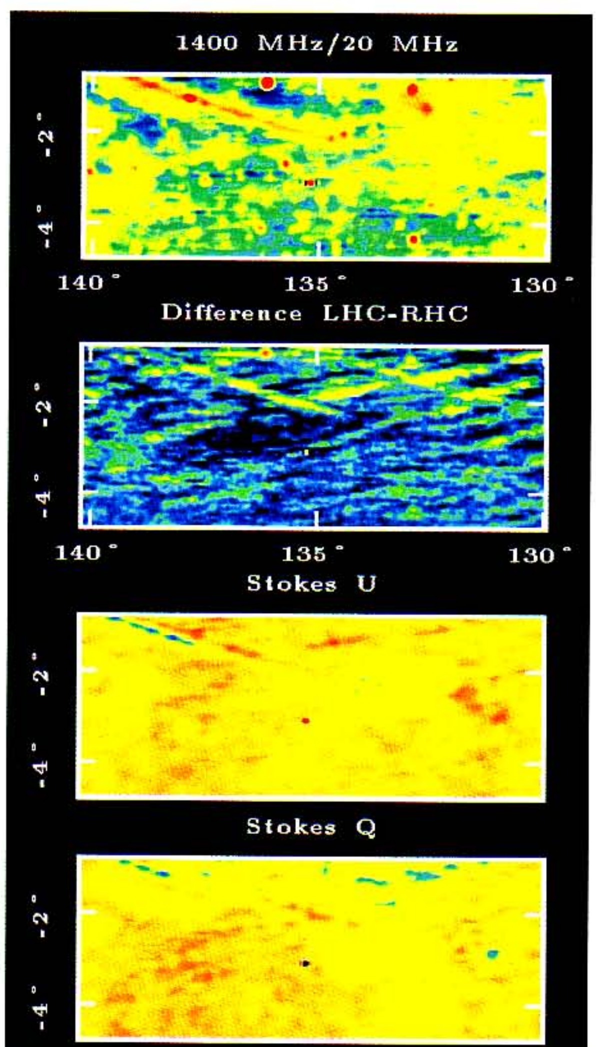

Fig. 5: From top: LHC map, difference map between the LHC and RHC map (not shown here), Stokes U- and Q-map. The intensity range is 1.5 K for the LHC map and 1 K for the other maps.

Summary of interference problems at the Effelsberg 100-m telescope

- The site of the telescope is well shielded by surrounding hills
- UHF (~865 MHz): ~90% (~10%) loss of observing time without (with) narrow HF-filter in front of the receiver
- L-band: maximum loss of observing time. Much interference below 1.4 GHz (redshifted HI-lines and continuum observations), DAB service above 1.45 GHz, strong satellite signals between 1.6 GHz and 1.7 GHz.
- 2.7 GHz: spiky cloud radar in a narrow frequency band.
- 4.85 GHz: interference is rare. 500 MHz bandwidth are presently usable.
- 10.6-10.7 GHz: The protected band is lost by TV-transmission from the geostationary satellite ASTRA 1-D. The observing frequency was shifted to 10.45 GHz and the bandwidth was reduced to 300 MHz. Some new interference of unknown origin shows up since 2001.
- higher frequencies: no problems so far

In general spiky interference can be mitigated by software and by using multi-channel narrow band backends. Interference entering via the far-sidelobes of the telescope are more difficult to handle and most times the data are lost or at least reduced in sensitivity.

References

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