The MITRA as a solar and ionospheric instrument

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Abstract The MITRA is an international/pan-African radioastronomy project which aims to do extremely wide field imaging with heterogeneous non coplanar arrays. It can be used for solar and ionospheric studies.

Keywords: radioastronomy, solar and ionospheric studies, MITRA

Introduction

The Multifrequency Interferometry Telescope for Radio Astronomy (MITRA) is a collaboration led by the author, Stuart David MacPherson and Gary Peter Janse Van Vuuren, from the Durban University of Technology (DUT)(Beeharry et al 2013).

The frequency range, in the prototype (MITRA 1.0), is 200 to 800 MHz. Baselines will range from a few meters, in one station, to some 250-500-1000-3000 km for the whole instrument. The instrument is modular in nature and consists of stations. A station will be able to function in its own right. Subsets of the whole instrument could also be used. The desired final technical specifications of the whole instrument are a function of the number of participants. Table 1 gives the typical characteristics for a baseline with correlation between groups of 16 antennas.

Frequency (MHz)	Effective antenna area(m^2)	Beam width(^{0})	Sensitivity /baseline(Jy)
200	1.1	90	7
300	0.5	80	15
400	0.28	74	27
500	0.18	82	42
600	0.12	76	61

Table 1: Array characteristics(Paardefontein tests)

Two identical prototype arrays, of 16 antennas each, have already been built at the Mauritius Radio Telescope(MRT) site in Bras d'Eau, Mauritius(Figure 2) and at the DUT site, in Durban, South Africa. In a second stage(MITRA 2.0), a 256 element array is being designed, and built, at the Mauritius site.

Each station is planned for observations on its own. Hence, sufficient sensitivity and resolution are built in so that primary calibrators, like Hydra A and Fornax A, and strong to medium sources can be detected. The front-end and the back-end is integrated with the data acquisition locally. The data pipeline should also cater for intra-station as well as inter-station correlation. Local hub managing system which will be synchronized, by the central hub, with other stations. Computing and data management will be a crucial and complex issue.

Antenna and front end system

Figure 1: The MITRA antenna

Figure 2: The MITRA array in Mauritius

The MITRA uses dual linearly polarised log-periodic antennas(Figure 1). These antennas have been designed for the frequency range 200 to 800 MHz. They have been tested at the The South African National Antenna Test Range, http://www.paardefontein.co.za/ Paardefontein, South Africa. Figures 3 and 4 show the VSWR, for each polarization, between frequencies of

100 and 1000 MHz. The antenna performance starts degrading below 175 MHz and above 650 MHz. This fact is confirmed by the gain versus frequency plot in Figure 3. The expansion of the MITRA node will integrate this issue(Ingala 2015). The antenna shown her is a preliminary design. The design process will be furthered to ensure much better performance. Any further expansion of the front end of the telescope will be conducted only after a much better basic antenna system has been developed.

The antenna and front end path of the present prototype set up is shown below in Figure 6 (Shibchurn 2013, Armoogum 2013). Two groups, of 8 antennas each, are aligned in a North-South direction. The antennas are 2.5 m apart. The groups are separated by 8 m.

The signals from 8 antennas are amplified by 30 dB and combined. The radio signal is modulated to an optical one and transmitted by a fiber optic cable to the receiver room.

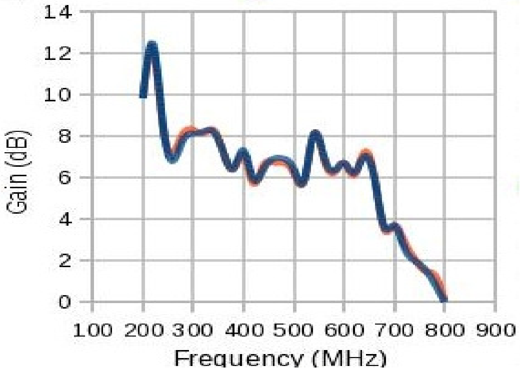

Figure 3: Antenna gain v/s frequency

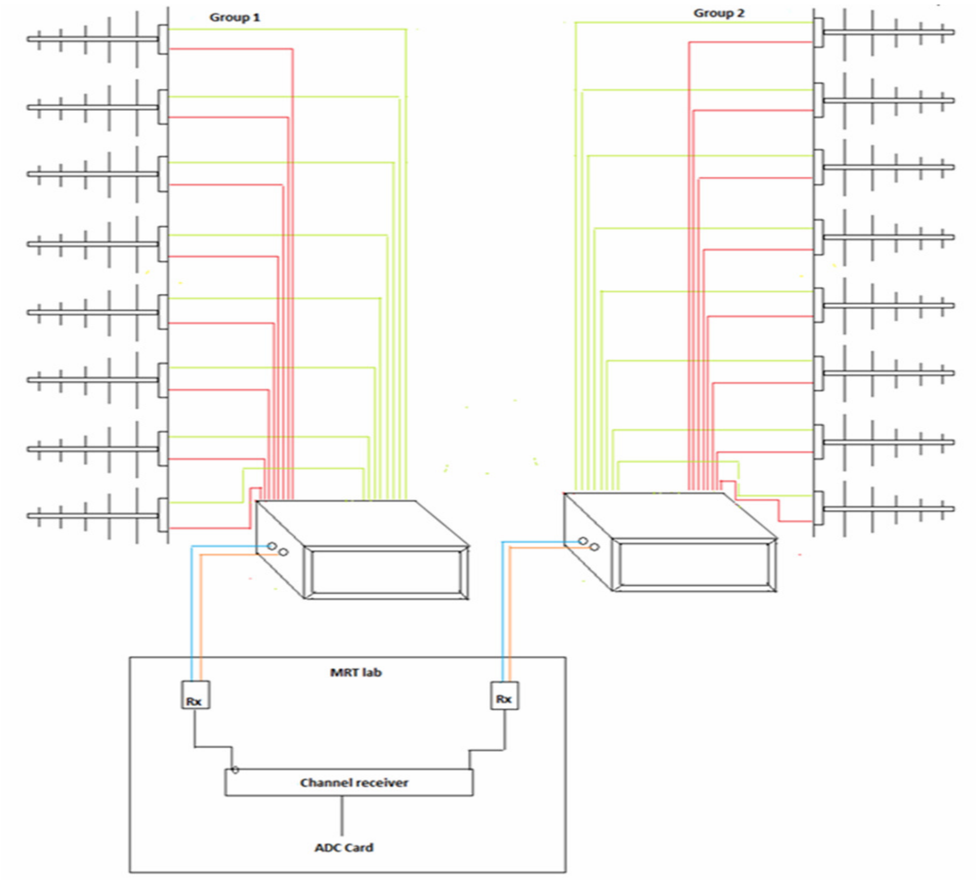

Figure 4: Antenna and front end

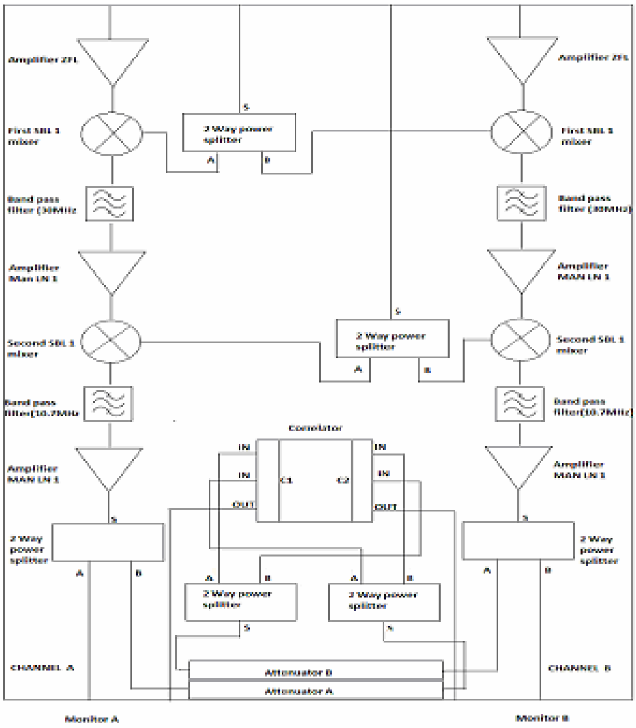

Figure 5: Front end and receiver

Receiver system

The block diagram of the Mauritius receiver system is given in Figure 5.The optical signal is demodulated in the receiver room. The radio signal is then amplified, double down converted (heterodyned) to a final Intermediate Frequency(IF2) of 10.7 MHz.

In South Africa, the signal is up converted before digitization(Ingala 2015).

In Mauritius, the signals from the two groups, is correlated using an analogue correlator. The correlated signal is then digitised and analysed.

In South Africa, the digital back-end consists of USRP N200 devices with SBX RF daughter boards(Ingala 2015).

A Rubidium GPS disciplined Time standard is used to distribute the time in the MITRA digital back-end.

Solar observations using MITRA antenna

Observations of low frequency (<1 GHz) solar flares in Mauritius(Ramesh et al 2010), has been going since 2009, as integral part of the e-CALLISTO network(Benz et al 2009). Mauritius hosts 3 e-CALLISTO stations.

The first station, MRT1, observes in E linear polarization, and the second one, MRT2, in the orthogonal H polarization, using linear single polarized log periodic antennas (Prayag 2011). The third one, MRT3, uses the same of linear dual polarized log periodic antenna as the MITRA (Prayag 2012, Shibchurn 2013).

The performance of the MRT3 antenna can be compared to a dish antenna in actual solar observing conditions. Figure 6 shows a Type 2 solar flare observed, using the MRT3 antenna, as part of the e-CALLISTO network, at 8:13 UT. The spectrogram ranges from 50 to 460 MHz. The same flare, observed with the Bleien 7 m dish is shown in Figure 7. Although the frequency ranges are not the same, it can be seen that the MRT3 antenna response is very similar to the Bleien 7 meter dish. The cable type and length, as well as amplification from the front end LNAs are similar in both cases.

Solar and ionospheric observations using the MITRA

The MITRA is designed to observe galactic and extragalactic sources. Therefore, it will be able to study the quiet Sun as well as solar flares and coronal mass ejections with a high level of sensitivity and resolution. The ionospheric effects are an important issue at low and mid frequency. The process of calibration will produce ionospheric maps in near real time.

The MITRA prototype array is well designed to observe the Sun over a wide range of frequencies. Thus, the MITRA could start addressing some of the crucial problems at the low and mid frequency limits. The routine observation of the quiet Sun at a number of frequencies is crucial. The other problems include the coronal magnetic field; magnetic energy production and acceleration are open issues, as are shocks. The problems of heating and the thermal structure could be studied. The impact on the ionosphere can also be studied.

The study of the solar corona is particularly interesting in the MITRA frequency range. One common type of flare observed is the Type 3.

This type of flare can help in finding the height and size of the acceleration region from which Type III-like electrons propagate, using a coronal density model.

It can also be used to investigate the beam current and return current profile of type III-like electrons in the solar corona (Reid et al 2014).

Weak, circularly polarized, structureless type III bursts from the solar corona have been observed in the absence of Hα and X-ray flares (Ramesh et al 2010).

Another example is the Type 2 flare. It can be used to determine the magnetic field strength in the solar corona. The shock density jump as well as the Alfvén Mach number can be estimated. Using the plasma frequency relation to height, the variation of these two quantities at different heights can be found (Vasanth et al 2014). The ionosphere is a nuisance to radio astronomy. It causes a number of effects which include opacity due to the plasma, varying refraction, scintillations, phase distortion, dispersion, and Faraday rotation.

Ionospheric effects have been seen, even at 151.5 MHz, in the Mauritius Radio Telescope southern sky survey (Daiboo 2012). A constant monitoring over a range of frequencies will help model the ionosphere in greater spectral detail.

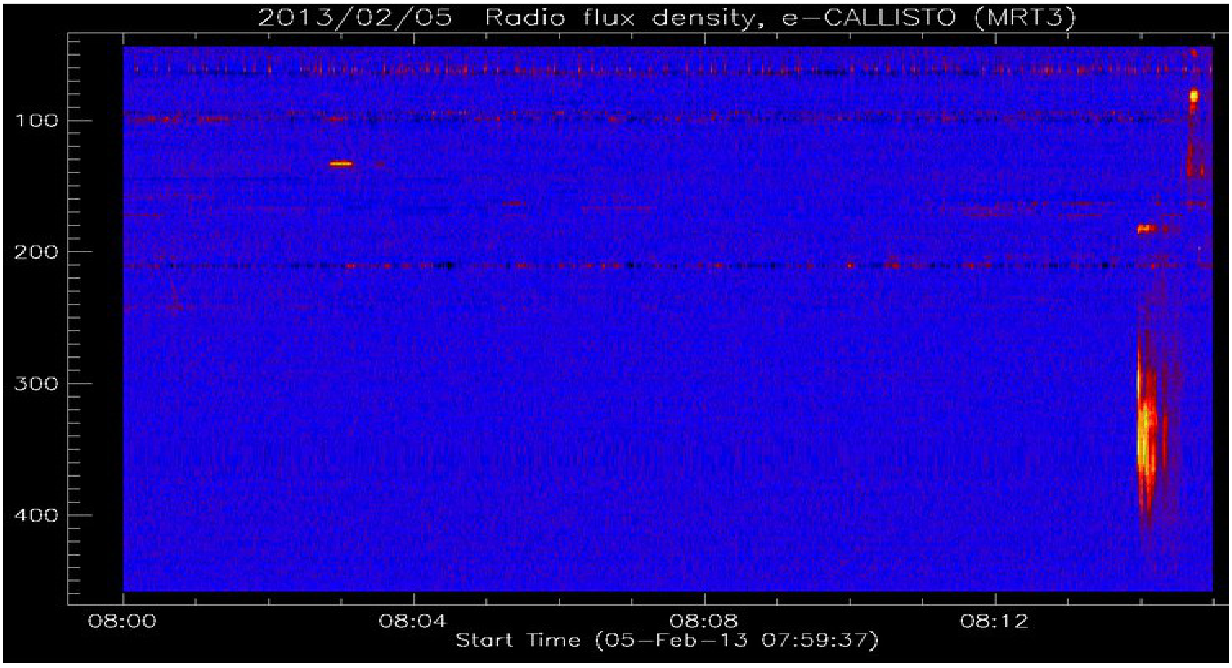

Figure6: SpectrogramMRT3 50-460 MHz 8-8:1

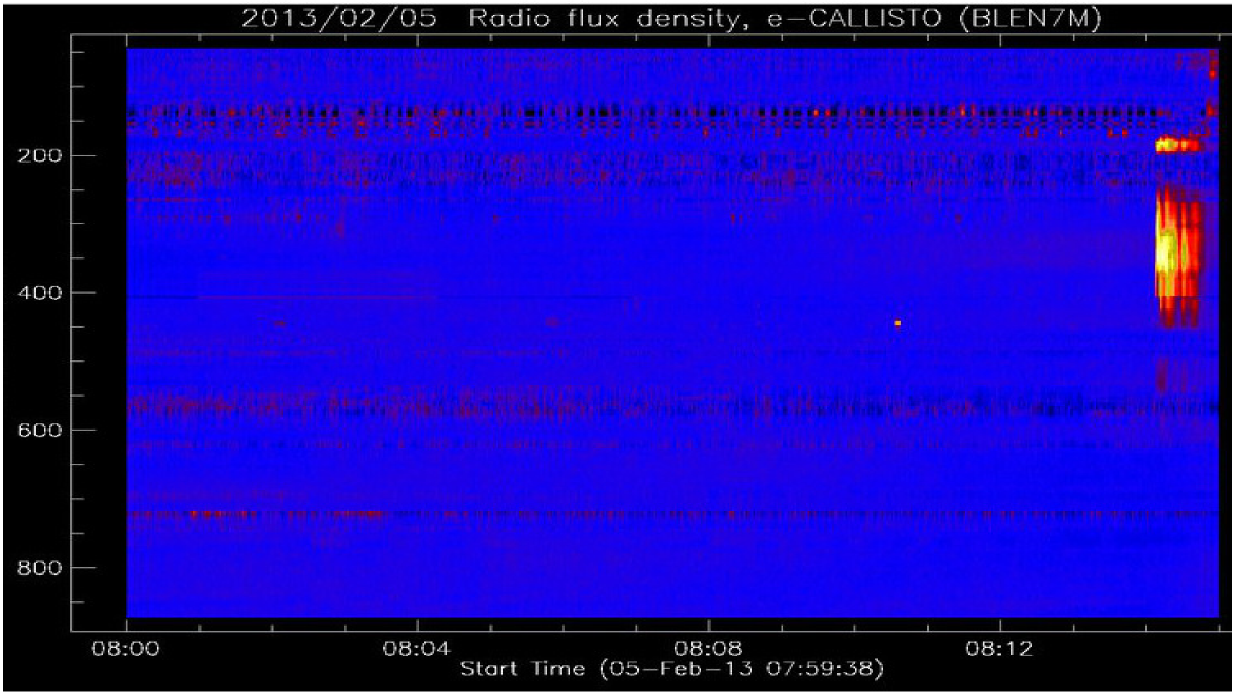

Figure 7: Spectrogram Bleien 7 m dish 50-870 MHz 8-8:15UT

Conclusion and Future work

The MITRA is going to be a useful instrument for mid frequency solar and ionospheric observations.

The next stage of the MITRA is being planned and built. It will expand to a 256+ antenna array in the next two years. Its sensitivity and resolution will be significantly improved.

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