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The Medicina Northern Cross Radio Telescope: potential and perspective in SETI

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Abstract. The powerful data processing algorithms and the very high resolution spectrometers, coupled with large radiotelescope, are now able to listen for very weak artificial signals coming from the deep space. We have only to identify the procedure to observe the sky, looking for extraterrestrial signals. In the past, researchers tried to find signals by pointing the antennas in a random way, but for example, now we know extra-solar planets in the ”habitable zone” and so we can point the antennas towards them. It is just an innovation in the ET signal research, as well as the idea reported in the following article, that permit to scan the sky by the use of one of the largest transit antennas in the world: the Northern Cross. The methodology proposed in this report permit to monitor continuously the sky by transit antenna array with large FoV and high sensitivity.

Key words. Multibeam – Northern Cross – Antenna Array – SETI

1. Introduction

The aim of this article is to present the features and the perspective in SETI research of the Northern Cross Radio Telescope infrastructure (Figure 1). In order to do so, technical details and its potential are described as follows: the first part provide an overview of the Northern Cross and its branches from a structural point of view, while the last part is focused on the observational modalities and backend, which represents an innovation in SETI.

2. The Northern Cross

The Northern Cross Radio Telescope is one of the largest UHF-capable antenna in the world, being located at the Medicina Radio Astronomical Station, near Bologna, in Northern Italy, Figure 2. It is owned by the University of Bologna but managed and operated by the Istituto di Radioastronomia at the Istituto Nazionale di Astrofisica (INAF-IRA). It is conceived to receive radio waves centered at a frequency of 408 MHz, the corresponded wavelength is 73.5 cm, in a band which is 16 MHz wide. It is a transit instrument, steerable only in declination, so it can solely observe those objects that are culminating on the local celestial meridian. It consists of two perpendicular branches, with orientation North-South and East-West. The total collecting area is 28.000 m^2, making it a very sensitive radio telescope.

2.1. The East-West branch

The Northern Cross East-West (E/W) branch is a single parabolic-cylinder shaped antenna,

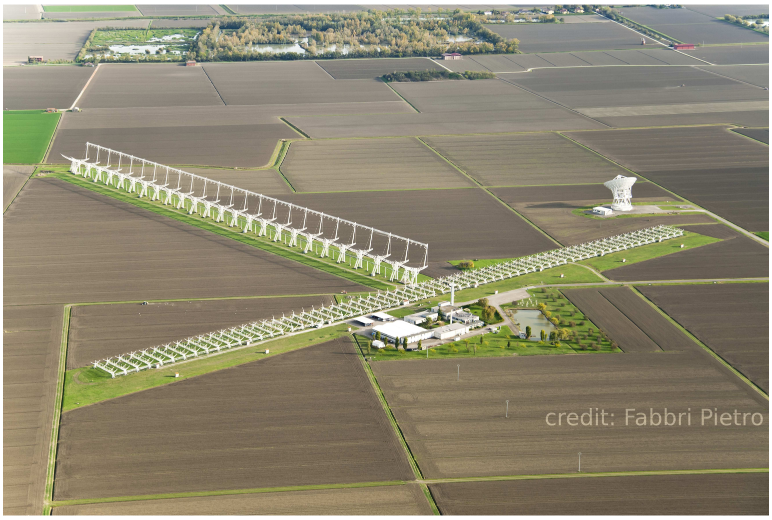

Fig. 1. A bird's eye view of the Medicina Radio Astronomical Station (credit: Fabbri Pietro)

Fig. 2. Medicina Northern Cross Location (credit: Fabbri Pietro)

with a length of 564 m and a width of 35 m. The collecting area is about 17.000 m^2, and it is composed by thin steel wires. About 1.200 km of wires were needed to cover the entire area to form the reflecting mirror. Figure 3 shows a view of the E/W branch.

The E/W branch is made by 24 focal lines and each one contains 64 dipoles, located near the geometric focus of the parabolic-shaped mirror.

Table 1 summarizes the principal technical characteristics of the E/W branch.

The E/W branch is currently unexploited due to structural issues, but it could be completely devoted to SETI after appropriate renovation.

2.2. The North-South branch

The North-South (N/S) branch is made by 64 parallel antennas for a total length of about 640 m and a width of 22,5 m. The collecting area is about 11.000 m^2. Figure 4 shows a partial view of the N/S branch. Each antenna focal line is composed by 64 dipoles. This branch has gone through different upgrade phases, since 2006 in the SKA (Square Kilometer Array) framework

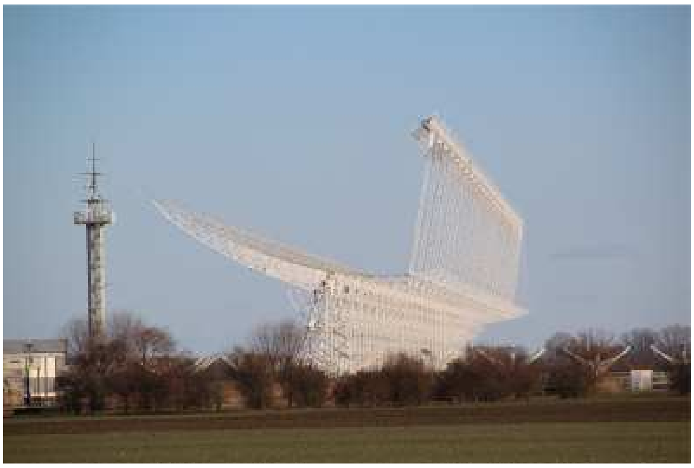

Fig. 3. Northern Cross East-West branch (credit: Fabbri Pietro)

Fig. 4. Northern Cross North-South branch (credit: Fabbri Pietro)

up to now, within the EUSST (European Space Surveillance and Tracking) program.

3. Potential for SETI: operativity and backend

3.1. Monochromatic signal at the same sidereal time

Until some years ago, SETI data acquisition and processing were performed using the SerendipIV system architecture provided by the University of California Berkeley. Several datasets were collected by means of the 32 m Medicina parabolic dish, without any evidence of SETI signals.

In order to facilitate data interpretation and to introduce alternative methods to search for possible extraterrestrial radio signals, the use of the large UHF Northern Cross transit telescope can be considered as well. In consideration of this goal, a preliminary study on the

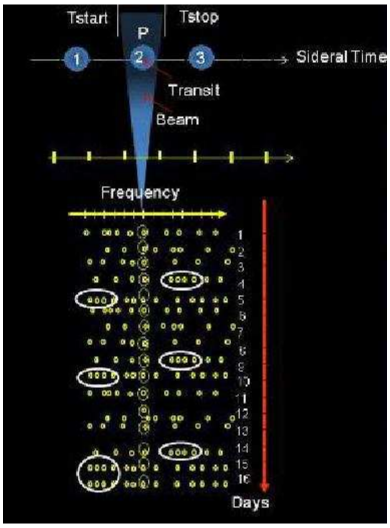

Fig. 5. Subsubmatrix related to the transit of the ET transmitter on the local meridian. (credit: Fabbri Pietro)

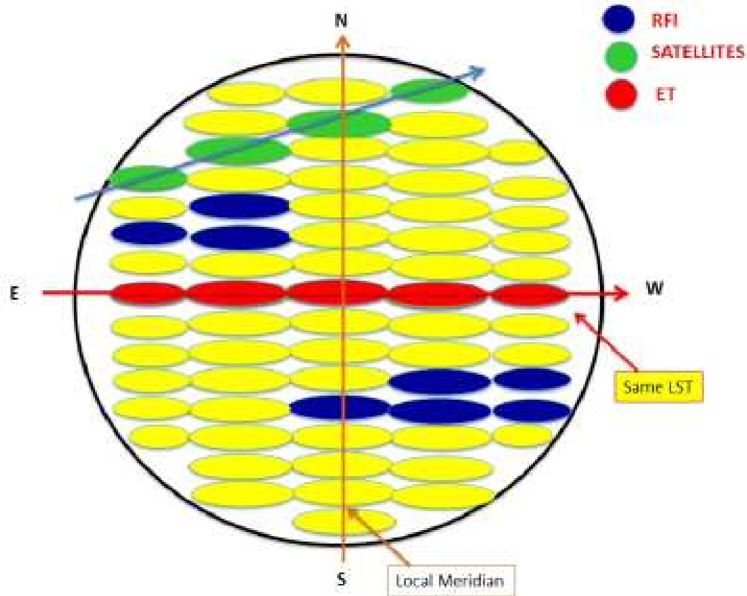

Fig. 6. ET passage in the FoV (credit: Fabbri Pietro)

possible observation and data reduction techniques has been carried out.

Sky observations could be performed and analyzed as follows. The aim is to identify whether a transmitting source is transiting the antenna beam, while rejecting RFIs. Observations are carried our parking the beam at a given Declination position and achieving data along several days, thus scanning a 4-arcmin-wide ring spanning 24 h of Right Ascension. The collected spectra are averaged in time intervals corresponding to the tran-

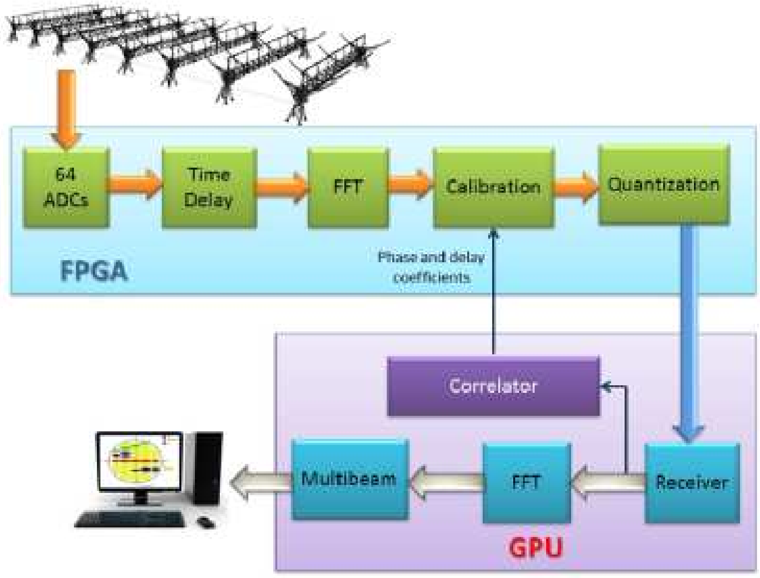

Fig. 7. SETI Back-end (credit: Fabbri Pietro)

Table 1. E/W characteristics

East-West Branch characteristics	
Antenna dimension	17.000 m^2
Frequency band	16 MHz @ 408 MHz
Scan Angle Declination (Mechanical Steering) Right Ascension (Electronical Steering)	 -30 ÷ +90 deg -0.5 ÷ +0.5 deg
Instantaneous FoV Declination Right Ascension	3 deg^2 1.8 deg 1.7 deg
Synthesized Beam Size Declination Right Ascension	3 deg^2 1.8 deg 4 arcmin
Availability for SETI observation	100 %

sit time across the beam; a flag is raised for those intervals bearing any meaningful detection (i.e. a monochromatic signal). The sequence of flags is then inserted in a matrix, where each row corresponds to 1 sidereal day. Plotting such matrix according to the Local Sidereal Time (LST), thus forming a waterfall display of the processed transits, a recurring coherent signal coming from the same celestial position would appear as a vertical line, as

Table 2. N/S characteristics

North-South Branch characteristics	
Antenna dimension	11.000 m^2
Frequency band	16 MHz @ 408 MHz
Scan Angle Declination (Mechanical Steering) Right Ascension (Electronical Steering)	 0 ÷ +90 deg -3.3 ÷ +3.3 deg
Instantaneous FoV Declination Right Ascension	30 deg^2 5.7 deg 6.6 deg
Synthesized Beam Size Declination Right Ascension	3 deg^2 4 arcmin 1.7 deg
Availability for SETI observation	Piggy-back mode

the transmitting source transits across the beam exactly every 24 hours LST, see Figure 5. It is extremely unlikely to have a man-made signal showing the same behavior.

If the ET transmitter is on the position of the sky labeled 1, the flag does not switch on into the spectrum of the relative submatrix. When it is in position 2 (transit on the local meridian) it switches on and then off when in position 3. In Figure 5 is clearly visible the flag switched on every day while the Radio Frequency Interferences (RFIs), highlighted by the white circles, are present in many subsequent spectra independently from the sky transiting through the beam. In addition this detection could also be considered already confirmed since it comes from the same region of the sky and observed regularly for many days (same sidereal time). An extremely powerful processing system acquisition based on a multi core pc and GPU is now under development, and it will eventually end up in a dedicated spectrometer with higher resolution (1 Hz) connected to a Serendip-alike detection system.

3.2. Multi-beam technique

An interesting alternative method is the use of a multi-beam system to detect transit signals. In this case, the Northern Cross radio telescope could be considered as an antenna array; putting a phase and amplitude coefficients in each receiver chain, it is possible generate a sort of radio-camera toward the sky. Part of the Northern Cross has been upgraded with 64 new receivers able to generate 48 independent beams inside the antenna Field of View (FoV). Considering to point the Northern Cross FoV to the local Meridian at a certain fixed declination, all the sky crosses the field of view (in its apparent movement from east to west) and the antenna receives signals from the transit of radio sources, including also transmission from satellites, interferences or echo radar scattered from space debris. If we consider only the astronomical objects, from where an ET signal can be transmitted, the beams inside the antenna FoV are illuminated in sequence during the transit of the object. The information about the sequence of illuminated beams allows to discern the ET signal from other kind of monochromatic signals: it is possible to recognize the ET signal from other manmade signals because it ”illuminates” a single row of beam in sequence, from east to west, in the multi-beam. For example, in the radio camera represented in Figure 6, only red sequence can be an ET signal (if it is monochromatic) the others are Radio Frequency Interferences (RFI) or satellites.

Of course, beams in the same row can be illuminated in sequence by the transit of natural radio sources, but in this case the signal acquired is not monochromatic as we would expect from ET. The acquired data is processed by means of a data acquisition system, using an high resolution FFT in order to calculate if the signal is present in each beam. Doppler shift, the illumination time, and measured power intensity associated to each beam will be thus computed as well to better understand the type of signal received. A back-end schematic block is reported in Figure 7.

4. Conclusions

The use of radiotelescope as an antenna array for SETI observation, it permits to have a very high sensitivity with a large field of view (beam of the single element of the array).

Transit antenna like the Northern Cross is able to scan all the sky in different days and it permits to discern ET signal from other kind of signals.

ET signal appear at the same sidereal time and, in a multi-beam system, it produces a sequence illumination of the beams in the horizontal line; this event occurs when the antenna is pointed far from the celestial pole and when the east-west field of view is not very wide. Otherwise the line of the illuminated beams tends to become a bow with maximum elongation (peak) on the local meridian. Anyway, also this eventuality could represent an ET transmission, so in case it occurs, it should be carefully investigated.

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