

## ANTARR – ETNA LOW FREQUENCY ANTENNA ARRAY

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A project called AntArr as a new application of the DBBC3 (Digital Base Band Converter, 3rd generation) is under development. A group of antennas operating at low frequency, in the range from 10 MHz up to 1500 MHz, are phased up for VLBI, pulsar and more recently for FRB observations. Part of the scientific programme is also dedicated to SETI activities in piggy-back mode. Dedicated elements can even be added to reach still lower frequencies to observe the range down to kHz frequencies. The DBBC3 manages the array operations in a selected portion of the band and the main characteristic is to synthesize a beam with an innovative approach. The final product of the array is a single station standard VLBI data stream for correlation with other antennas, or a synthesized beam for single dish observations. A number of antennas and array prototypes are under test at a location on the Etna volcano slope, with the aim to form a complete radio telescope of up to 1024 elements in 2020 and beyond. This project completes the lower part of the frequency spectrum covered in VLBI by the BRAND EVN project. The project AntArr is hosted and financed by HAT-Lab Ltd., which is the manufacturer of the DBBC family backends.

**Keywords:** *Antenna array, BRAND EVN, DBBC backend, VLBI*

## 1. INTRODUCTION

A project called AntArr as a novel application of the DBBC3 [1], [2] (Digital Base Band Converter, 3rd generation) is presented in the study. It is development under construction on the Etna volcano slopes at low altitude (about 600 meters). A group of antennas operating at low frequencies, in the range from 10 MHz to 1500 MHz, are phased up for VLBI or pulsar observations. Moreover, dedicated elements can be added to reach still lower frequencies to observe the range down to kHz frequencies. The DBBC3 manages the array operations in a selected portion of the band and the main characteristic is to synthesize a beam with an innovative approach. The final product of the array is a single station standard VLBI data stream

for correlation with other antennas, or a synthesized beam for pulsar observations. A number of different antennas, receivers and array prototypes have been implemented since the 2014 and have been under test at two locations for measurements and evaluation. In the end, the most suitable architecture has been selected in terms of performance, dimensions and cost. Such selected configuration is then used to build the array in a sufficient number of elements to allow for the complete functionality.

The selection of the antenna type considered the possibility to have add-on elements to reduce a lower range of frequency the array can receive up to a lower limit of few KHz. Such additional elements are under development and a number of prototypes are under evaluation.

## 2. ARRAY ARCHITECTURE

The general architecture of the AntArr instrument is schematically indicated in Figs. 1, 2 and 3. Each green circular element represents a single antenna. Most of such antennas are organized in arms to form a matrix whose rows are subject to the progressive formation of the array signal that is finally forwarded to one of the inputs of the DBBC3. A maximum number of 32 inputs are available for a maximum number of 32 elements in a single arm, bringing the maximum number of elements of the array to 1024. The arms are disposed in E-W oriented rows having any row in both ends allows operating as an independent array of ‘level one’. Groups of rows are organised in a further ‘level two’ array, and finally the entire set of groups is organised as ‘level three’ of array, which is the final arrangement. This distinction is motivated by the fact that separated elements in the array matrix can be selected, making use of cross correlation of the combined received signals to simplify the array calibration.

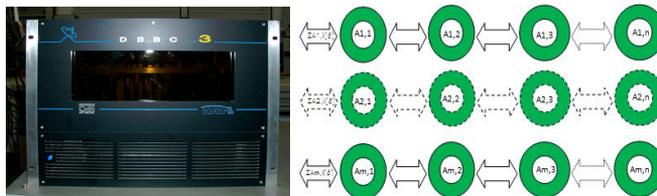


Fig. 1. Antenna array managed by the DBBC3.

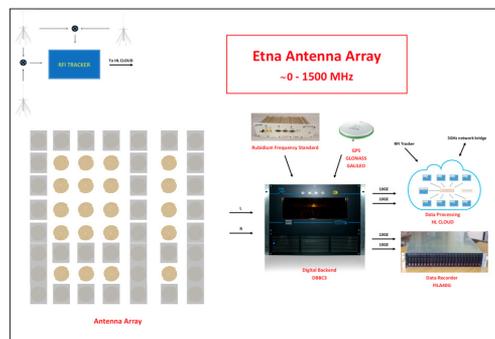


Fig. 2. Schematic structure of antenna array with its main components.

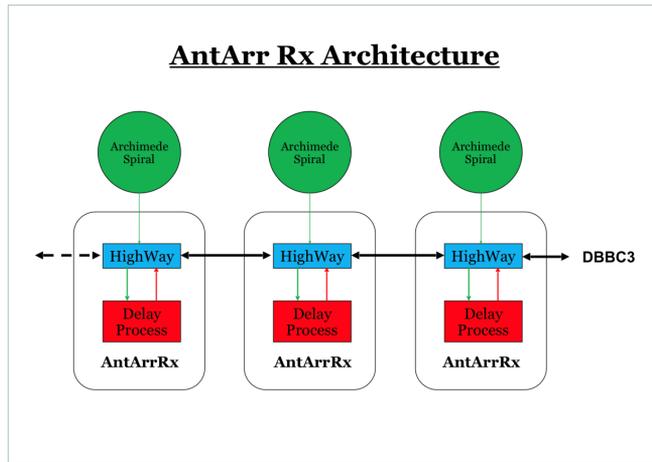


Fig. 3. Array signal distribution.

### *General features of the array and beam synthesis*

The main general features of the instrument are as follows:

- Antenna prototype frequency range: 15 MHz–1500 MHz;
- Max. number of antennas in a single arm: 32;
- Max. number of arms with a single DBBC3: 32;
- Max. observation bandwidth of each arm: 1500 MHz;
- Analogue delay compensation digitally controlled at every antenna;
- Analogue summation for each arm at every antenna;
- Digital correlation between elements of the array;
- Digital correlation between elements of the array and the synthesized beam.

### 3. ANTENNAS AND RECEIVER

The signals of the developed antenna array are processed by the VLBI backend DBBC3L [3]. As mentioned above, a set of antennas is organized in arms, in groups managed by a single ADB3L-CORE3H in order to create one or more synthesized beams. The signal from each antenna has the model delay applied to compensate the path length difference of the incoming radiation relative to its direct neighbour antenna. The delayed signal is summed to this next neighbour.

The resulting signal has again the model delay applied relative to its next neighbour and the combined signal is added to it and so on, up to the DBBC3 processor. Any single beam is also available to be correlated with either the synthesized beam or with any other element in the array to precisely determine the delay residual with respect to the model of single elements as a function of the time. The signal of the source is then tracked with a mix of theoretical geometric model and the residuals determined with the array itself.

Figures 4a and 4b show the prototype of the selected antenna in double and single circular polarization, respectively, while its 3D beam is reported in Fig. 5.



Fig. 4a. Antenna in double polarization.



Fig. 4b. Antenna in single polarization.

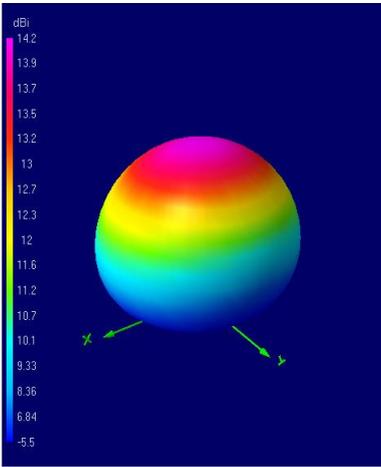


Fig. 5. Single antenna beam.

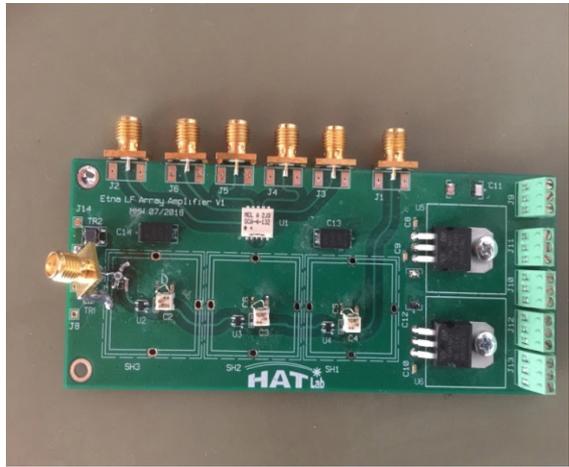


Fig. 6. The receiver, three amplification stages.

The receiver (Fig. 6) is a low-noise amplifier of three amplification stages with a high dynamic range. The receiver is composed of two boards, one for the amplification stages and the other for the delay control. The latter is included in the distribution cables and is controlled by the DBBC3. The entire single receiver with the antenna enclosure behaves at a system temperature in the order of 300 K at 500 MHz.

Particular care is to be applied for the implicit RFI crowded environment the array is asked to work in. Figures 7a and 7b show the RFI condition in the site where the array is under construction, the monitors for pointing and total power detected. Even in a severe environment portions of band can be selected where observations are still possible. In order to take into account this aspect, three wide range antennas looking at the terrestrial emissions have been dedicated to track and identify the direction of the worst case emissions: such information is considered in the beam forming so to make minimum contribution of side lobes of the synthesized beam. Dedicated software entirely developed by HAT-Lab research merges pointing beam forming and RFI minimisation. Then a two-way tracking is implemented, one

pointing to the extra-terrestrial source to be observed, and the other to the counterpointing on the terrestrial emissions. This method is still under study and until now could provide attenuation of the RFI in the total power regime of up to 25–30 dB, resulting in a promising method when optimised.

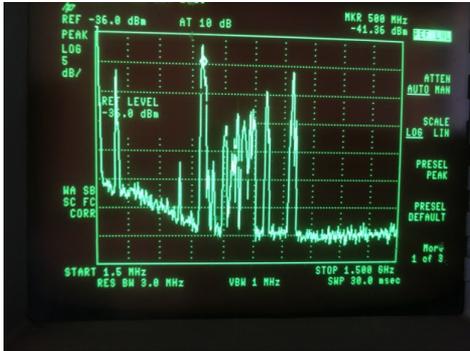


Fig. 7a. RFI environment in the Etna site

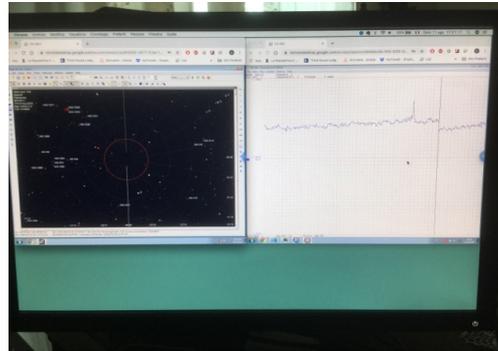


Fig. 7b. Monitors: array pointing, total. power.

#### 4. STATIONS AND ARRAY CHARACTERISATION

At the early stages of the project development, two stations have been equipped with a few prototypes for testing the network capability: one in the vicinity of the Noto radio telescope, the other on the northern slope of the Etna volcano at low altitude, the site where now the array will be fully installed. Figures 8a and 8b show a view of the relative position of the sites in Italy, in the Sicily Island, and one of the prototypes close to the Noto radio telescope.



Fig. 8a. Baseline Noto – Etna site.



Fig. 8b. Antenna prototype at the Noto radio telescope.

A drone equipped with a multi-frequency transmitter is used to test and characterise a single antenna and groups of antennas in the far-field regime. The vehicle can be placed in the sky at fixed positions controlled by an on-board GPS and an altimeter in order to determine the 3D complex beam of a single antenna and the part of the array under analysis. This method allows performing holographic measurements of the physical position of the single array element to make a map for the beam synthesis. Figure 9 illustrates the calibration method.

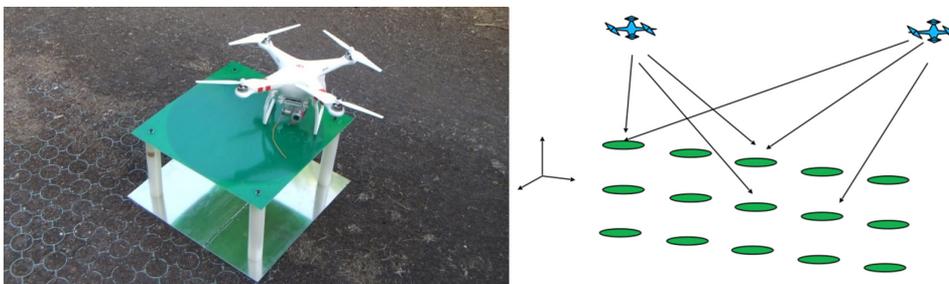


Fig. 11. Drone with a transmitter for 327, 654, 981 MHz is used for the array calibration.

## 5. CONCLUSIONS

The new antenna array named AntArr operating with a synthesis beam is under construction on the Etna volcano and mainly dedicated to VLBI observations. The array is an innovative demonstration prototype expected to operate in a low frequency range, starting at around 10 MHz and extending up to 1.5 GHz. Such frequency is a lower boundary of the BRAND EVN receiver, which is a project under development, financed under Radionet4 Horizon2020 and expected to cover the range between 1.5–15.5 GHz. Thus, the AntArr project is virtually extending a lower portion of the frequency spectrum for VLBI observations. The project is fully financed by HAT-Lab Ltd., the Italian company producing the DBBC VLBI backend family.

## REFERENCES

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## ANTARR – ETNAS ZEMFREKVENCES ANTENU MASĪVS

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### Kopsavilkums

Projekts ar nosaukumu “AntArr” tiek izstrādāts kā jauna lietojumprogramma DBBC3 (3. paaudzes ciparu bāzes joslas pārveidotājs). Antenu grupa, kas darbojas zemo frekvenču diapazonā no 10 MHz līdz 1500 MHz, tiek pakāpeniski salāgota it īpaši lielas bāzes interferometrijas (VLBI), pulsāriem un nesen ātro radio uzliesmojumu (FRB) novērojumiem. Daļa no zinātniskās programmas veltīta arī SETI aktivitātēm. Antenas masīvam var pat pievienot klāt specializētus elementus, lai sasniegtu vēl zemākas frekvences un novērotu diapazonu līdz kHz frekvencēm. DBBC3 pārvalda antenu masīva operācijas izvēlētā joslas daļā, un galvenais uzdevums ir sintezēt staru ar inovatīvu pieeju. Antenu masīva gala produkts ir vienas stacijas datu straume VLBI standarta korelācijai ar citām antenām vai sintezēts stars novērojumiem vienas antenas režīmā. Vairāki antenas un bloku prototipi ir realizēti, un tie tiek pārbaudīti Etnas vulkāna nogāzes vietā ar mērķi 2020. gadā sāk veidot strādājošo radioteleskopu, kas sastāvēs no līdz pat 1024 elementiem. Šis projekts nosedz frekvenču spektra apakšējo daļu VLBI vajadzībām un ar to papildina BRAND EVN projektu. Projektu AntArr vada un finansē SIA “HAT-Lab”, kas ir DBBC saimes aparatūras ražotājs.

*Atslēgas vārdi: VLBI, DBBC ciparotājs, antenu masīvs, BRAND EVN*