BRAND: A Very Wide-band Receiver for the EVN

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Abstract BRAND stands for BRoad bAND EVN, a project to build a prototype primary focus receiver with the very wide frequency range from 1.5 GHz to 15.5 GHz, to investigate secondary focus solutions, and to make a survey of the EVN telescopes in order to set the stage for equipping all EVN stations with such a receiver as soon as possible. The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730562 and is a Joint Research Activity (JRA) in the RadioNet programme. We present the motivation, aims, scope and status of the project which was started on January 1st, 2017.

Keywords VLBI, EVN, radio astronomy receiver, digital backends, digital receiver

1 Introduction

The aim of the RadioNet JRA BRAND EVN is developing a wide-bandâ "digital" VLBI-receiver for the EVN and also other telescopes. The frequency range of the BRAND receiver protoype will be from 1.5 GHz to 15.5 GHz. Up to date a radio astronomical receiver with a frequency ratio of 10:1 has never been realised before. The project engineer is Gino Tuccari from INAF/MPIfR, the project manager is Walter Alef from MPIfR. BRAND EVN is a truly European project with partners in Germany (MPIfR), Italy (INAF), Sweden (ONSALA), Spain (IGN), The Netherlands (ASTRON), and Latvia (VIRAC).

Initially we will develop and build a prototype for prime focus, as wide-band prime focus feeds are much more advanced than similar feeds for secondary focus. But, as EVN has a lot of antennas which can only mount secondary focus receivers, another work package will also do research in a wide-band feed for secondary focus. The timeline for a first VLBI test at Effelsberg is summer 2020, which is ambitious but not unrealistic. The aim of BRAND EVN for the next decade is to enable all EVN stations to install a BRAND receiver as soon as possible!

2 Scientific opportunities and advantages

Assuming that all telescopes of a network are equipped with wide-band BRAND receivers, simultaneous multi-frequency observations will be possible similar to VGOS, but with much wider frequency coverage. While it is expected that such a wide-band system will be less sensitive than modern narrow-band receivers, the enormous bandwidth and data-rate of the BRAND receiver will overcompensate the sensitivity losses.

To make full use of this bandwidth, fringe-fitting has to be done over the very wide frequency range, thus integrating coherently all the data. Of course a precondition is that the ionospheric contribution to the delay is determined by fringe-fitting a quadratic term over frequency in addition to the traditional linear slope. This

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problem has been solved already for VGOS. A solution for astronomy will be developed in the framework of CASA (McMullin et al., 2007) by the RadioNet JRA RINGS.

Another advantage of this coherent fringe-fit is that precise registration of simultaneous images at different frequencies will become possible, as the phases as a function of frequency are all related to each other, which is not the case for fast frequency switching.

The BRAND approach will also be superior to VGOS due to the quasi continuous frequency coverage which will result in smaller gaps between sub-bands, which eases the fringe-fitting over the full band. Gaps will be caused by RFI which will be treated in two stages. The strongest RFI will be suppressed right after the receiving horn by High Temperature Super Conducting (HTSC) filters. Remaining weaker RFI will be suppressed in the digital stage.

The UV-coverage will also be vastly improved due to wide frequency band. This still holds even though images will have to made for several frequency ranges.

Joint observations with geodetic VGOS antennas will become possible, so that the long-standing collaboration between astronomy and geodesy can be continued in a somewhat limited scope. But astronomers will still be able to measure precise positions of astronomical antennas, and can contribute to the determination of the radio celestial reference frame. Occasionally huge arrays for special astronomical observations can be formed by adding VGOS antennas to a "BRAND array" when needed.

With a full "BRAND EVN" astronomers can measure variations of polarised emission as a function of frequency over a very wide frequency range with very precise, unambiguous rotation measures.

Studies of several different maser types in different frequency bands can be made simultaneously with proper alignment of the different maser species.

Further opportunities arise for flux variation studies in several bands simultaneously, which is especially interesting for intraday variability investigations. Pulsar searches and observations can be performed over a wide frequency range without timing ambiguities.

3 Technical Feasibility and proposed technical realisation

Broad-band receivers for VLBI with a frequency range of 1.5 GHz to 15.5 GHz have become the next technical challenge in building radio astronomy receivers. Broadband LNAs and feeds have become available for instance for the VGOS project. But also in the RadioNet3 JRA DIVA a receiver from 1.5 GHz to 5.5 GHz was developed.

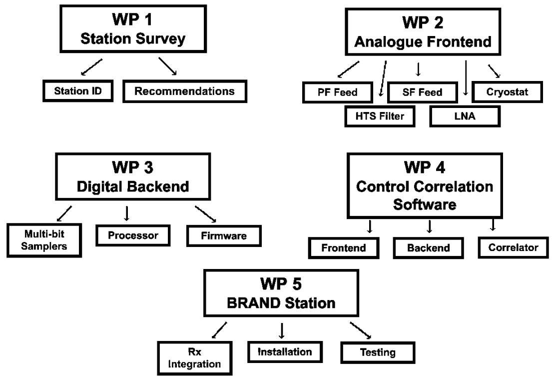

Fig. 1: Block diagram of the work packages.

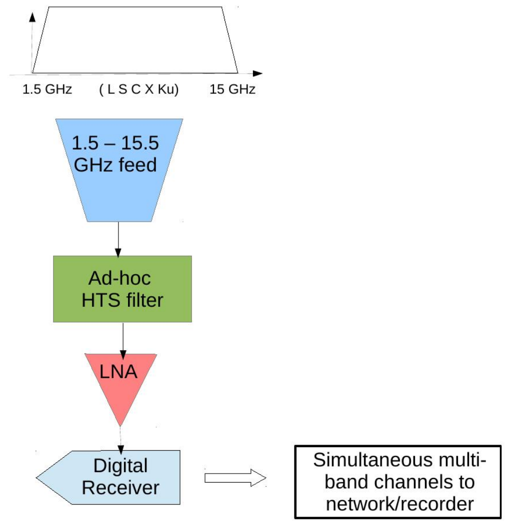

Fig. 2: Schematic view of the proposed BRAND receiver.

Backends with very high data rates have been developed for for example by JRA DIVA — DBBC3 with 2×4 GHz input and 32 Gbps output. Now DBBC3s with 8×4 GHz have been produced for VGOS antennas.

High bit-rate recorders exist, either as stationary Flexbuff recorders or as up to four Mark6s with up to 64 Gbps for the EHT, or as FiLA40G recorder/postprocessing units at Onsala (see JRA DIVA).

The proposed technical realisation (see Fig. 1 for an overview of the WPs) starts with a survey of the characteristics of the antennas in the EVN and the RFI situation. This information will be assembled in a document which can serve EVN stations in proposing for resources for a BRAND receiver. It will also be used as a start to define standards for the prototype which should fit most antennas.

BRAND EVN will be a single cooled receiver for astronomy covering the band from 1.5 GHz to 15.5 GHz with a linear polarisation feed (see Fig. 2), followed by

HTSC filters to protect the LNA and samplers from the strongest interference, so that both will not be saturated.

After the usual analogue amplification the signal is digitised by a sampler which can handle the 14 GHz wide band in one chunk in 8-bit representation.

The digitised RF signal will be processed by high-performance FPGAs. Firmware will be written to convert the linear polarisation to circular, to remove remaining RFI signals, to form sub-bands with polyphase filter-banks, digital down-conversion or a mixture thereof. The total output bit-rate will be up to 128 Gbps for 2-bit samples onto Ethernet for local recording or transfer via the Internet.

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