Work package number [9]	WP6	Lead beneficiary [10]	1 - MPG
Work package title	BRAND EVN		
Start month	1	End month	42

Objectives

The main objective of BRAND EVN (BRoad bAND EVN) is to develop and build a prototype broad-band digital receiver, which will cover a frequency range from 1.5 GHz to 15.5 GHz (1:10 range, chosen to include the 2 cm VLBA band). The BRAND frontend can be adapted to different EVN antennas. The backend part can also be used for other receivers with a RF frequency or IF range between 0-16 GHz. The BRAND receiver when deployed at a majority of EVN telescopes will:

- Open a range of new scientific opportunities like multi-wavelength: VLBI mapping, spectroscopy, polarimetry, and single-dish, as well as geodetic VGOS (VLBI2010 Global Observing System) compatibility, due to its enormous simultaneous bandwidth.

- Catapult EVN to new levels of performance not achievable with any other astronomical VLBI network.

- Influence cost for maintenance and energy for cooling by replacing multiple VLBI receivers in the frequency range of 1.5-15 GHz.

- Increase the available observing time offered by EVN, as more than one frequency can be observed simultaneously.

- Offer even greater sensitivity, as the reduction in sensitivity of such a broad-band receiver compared to narrow-band receivers will be more than compensated by the enormous data-rate resulting from the wide bandwidth.

- Have an impact on the design of new telescopes, which could be optimized for a BRAND receiver, and would profit from a smaller number of required receivers.

The BRAND receiver might even become the next generation VGOS receiver due to its superior sensitivity, its wider bandwidth, and the possibility to choose parts of the spectrum still uncontaminated by RFI. In order to boost the utilisation of the new receiving system at a large number of EVN telescopes the BRAND EVN project will provide a detailed implementation document that will contain all specifications to build a BRAND receiver, which will also include a list of suppliers and industrial partners who will be able to deliver parts or even complete frontend/backend systems. In addition each EVN station for which the BRAND specifications were collected will receive an interface document describing the specific local adaptations required to locally integrate the BRAND system. The BRAND receiver prototype will be commissioned and tested at the Effelsberg 100-m telescope. The fringe-fitting software developed by WP7 complements the technical development of BRAND receiver.

Description of work and role of partners

WP6 - BRAND EVN [Months: 1-42]
MPG, ASTRON, INAF, OSO, UAH, VUC
WP6.1: Feasibility survey of EVN antennas [UAH, OSO, INAF]

The specifications for the installation of a BRAND receiver at the EVN antennas will be collected. All EVN stations will be contacted and encouraged to provide the required information about the optical configuration etc. as well as the local RFI situation. To mitigate the risk of low response, BRAND will assist at least the set of EVN stations, which committed purchasing of the BRAND receiver, in collecting the requirements and measuring the usable part of the spectrum with a set of standardised equipment. The feasibility survey will result in an implementation document for each EVN stations for which the information has been collected. The report will give recommendations with respect to the receiver layout, dewar specifications, optimal optical arrangements, IF cabling infrastructure, required HTS (High Temperature Superconducting) RFI filters, etc.

WP6.2: BRAND receiver frontend [MPG, INAF, OSO, UAH]

6.2.1: Primary focus feed including RFI filters – Different broad-band feeds for prime focus will be evaluated (e.g. Quad-ridge feed horn - QRFH, Eleven-feed, Dyson conical quad-spiral array - DYQSA). Possibilities for injecting noise-calibration signals at the feed level will be investigated. An optimal feed for the prototype Effelsberg system will be chosen. Appropriate filters for suppressing the strongest RFI, which would saturate the amplification chain, will

be identified and the corresponding low-pass, high-pass and notch high-temperature superconductor (HTS) bandpass filters will be manufactured.

6.2.2: Solutions for secondary focus – Feed solutions for EVN telescopes, which will not be able to mount a BRAND receiver at their primary focus will be investigated. The performance and suitability for available secondary focus feeds will be studied. Results and recommendations will be summarized in a report that will be available to all interested partners/observatories.

6.2.3: Low Noise Amplifier (LNA) – An Indium Phosphide (InP) MMIC single broad-band LNA optimized for the 1.5–15.5 GHz frequency range will be designed and manufactured. The design will be based on the existing designs of, e.g. the RadioNet3 and VGOS receiving systems. It is planned to produce two LNA prototypes.

6.2.4: Cryostat and integration and testing of receiver frontend – A dewar for the prototype frontend system to be installed at the Effelsberg antenna will be manufactured. All frontend components will be integrated. Characterization and testing in the laboratory will be done.

WP6.3: BRAND backend [INAF, MPG, ASTRON, VUC]

6.3.1: Sampling board – Before the wide-band frontend signal can be sampled, it has to be amplified and equalized; an analogue board for this task has to be built. The BRAND backend will require sampling devices, which transfer the analogue signal to the numeric domain for a very wide band. Suitable sampling chips have just appeared on the market and are available in small numbers only. Demonstration boards, available from the manufacturer containing these chips, have already been tested and have shown to suffice for the BRAND project. Sampling boards making use of the sampling chips will be designed and manufactured. Additionally firmware for configuration and control of the boards will be developed.

6.3.2: High data rate processing board – A board with a single FPGA processor will be developed including the hardware platform with its firmware engine. The board will have an input data rate of 896 Gbps and 128 Gbps as output and will be one of the most powerful data processors available to radio astronomy in the next few years.

6.3.3 FPGA firmware – For processing linearly polarized feeds, digital linear to circular polarization conversion will be realized in firmware, starting from work previously done at ASTRON and MPG. Additional firmware will be developed for the various VLBI modes like direct sampling conversion (DSC), digital down-conversion (DDC), polyphase filterbank (PFB), etc. For this purpose the firmware developed under the RadioNet3 project (DBBC3) will be adapted and extended.

6.3.3 Backend integration and tests – All backend components will be integrated and tested in the laboratory. The firmware will be installed and tested on the integrated backend system. In order to test the VLBI capabilities a zero-baseline test between the two independent IF signal processing chains of the backend will be performed.

WP6.4: Control, recording and correlation software [INAF, MPG, OSO, ASTRON]

Control software for the BRAND frontend and backend systems will be developed, which will allow users to perform various setup and configuration tasks, e.g. choose receiver setups, switch between processing modes etc. taking into account the compatibility with the VLBI Field System.

The BRAND receiving system will interface with various standard software components utilized when doing VLBI observations and adaptions to these will need to be made in order to allow processing of data produced by the BRAND receiver:

- VLBI Recording: existing VLBI recorders are limited in data rate and hence bandwidth that a single unit can record. Thus for very high bandwidth observations multiple recorders will have to be used in parallel to be able to record the huge output data rate of the BRAND receiver. This task will provide a software layer that will distribute the data stream and control and monitor the data recorders.

- Correlator input and output: the correlator software will be extended to allow unpacking of the data format delivered by the BRAND backend. In addition, the data products delivered by the correlator will need to be compatible with the post-processing software. In particular, post-processing of broad-band data as produced by BRAND will require special fringe-fitting capabilities as the ones, which will be provided by the WP7-RINGS (e.g. ionospheric treatment). Appropriate interfaces to the RINGS software will be defined.

WP6.5: Integration at telescope and test observation [INAF, MPG, OSO, UAH]

The BRAND prototype receiving system will be installed at the Effelsberg antenna. In the first step of commissioning the single-dish capabilities of the new system will be tested, including RFI mitigation capabilities. After the successful completion, the VLBI capabilities will be tested in a second step by performing test observations together with a second antenna equipped with a comparable receiver system. The first choice will be the VGOS receiver having four 1GHz-wide bands in the range of the BRAND receiver. Two of the activity partners will have VGOS antennas and will strive to participate in the proposed test observations. In case of unavailability of the VGOS antennas during the commissioning period a fallback position is to use several EVN stations where the different telescopes will use different receivers covering some parts of the BRAND frequency range.

The WP6 management will be located at MPG. The INAF project engineer will partly perform the work at MPG too, to optimise the efficiency and cost of the work. Each partner institute will appoint a central responsible person for the implementation of the local work, who will be in regular contact with the WP leader. Project controlling will be implemented via monthly teleconferences. Additionally BRAND face-to-face meetings will take place twice a year. A project wiki page will serve as project management platform, for sharing progress, problems, discussions and general information including minutes and other activity documents.

Participation per Partner

Partner number and short name	WP6 effort
1 - MPG	72.00
2 - ASTRON	9.00
4 - INAF	22.00
7 - OSO	27.00
12 - UAH	51.00
20 - VUC	0.01
Total	181.01

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D6.1	Report on recommendations for individual EVN antennas.	12 - UAH	Report	Public	6
D6.2	Description and evaluation of the analogue part of the prototype (frontend) of the BRAND receiver for one selected antenna	7 - OSO	Report	Public	36
D6.3	Description and evaluation of the digital part of the BRAND receiver (backend)	4 - INAF	Report	Public	36
D6.4	Description and evaluation of the	2 - ASTRON	Report	Public	36

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
	Control, Recording and Correlation software.				
D6.5	Test results of the integrated BRAND receiver.	1 - MPG	Report	Public	42

Description of deliverables

Report on recommendations for individual EVN antennas.Description and evaluation of the analogue part of the prototype (frontend) of the BRAND receiver for one selected antenna, of the digital part of the BRAND receiver (backend) and of the Control, Recording and Correlation software. Test results of the integrated BRAND receiver.

D6.1 : Report on recommendations for individual EVN antennas. [6]

Report on recommendations for individual EVN antennas.

D6.2 : Description and evaluation of the analogue part of the prototype (frontend) of the BRAND receiver for one selected antenna [36]

Description and evaluation of the analogue part of the prototype (frontend) of the BRAND receiver for one selected antenna

D6.3 : Description and evaluation of the digital part of the BRAND receiver (backend) [36]

Description and evaluation of the digital part of the BRAND receiver (backend)

D6.4 : Description and evaluation of the Control, Recording and Correlation software. [36]

Description and evaluation of the Control, Recording and Correlation software.

D6.5 : Test results of the integrated BRAND receiver. [42]

Test results of the integrated BRAND receiver.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS33	Completion for primary focus feed prototype for a selected station	7 - OSO	24	Report complete
MS34	Prototype feed evaluation	7 - OSO	30	Operating
MS35	Completion of the report describing the secondary focus solution	12 - UAH	24	Report complete
MS36	Completion of the HTS filter prototype	4 - INAF	18	Report complete
MS37	HTS filter evaluation	4 - INAF	24	Operating
MS38	Completion of the LNA prototype	12 - UAH	24	Report complete
MS39	LNA testing results	12 - UAH	30	Operating

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS40	ADC converter prototype ready	4 - INAF	26	Report complete
MS41	ADC converter prototype testing with the basic functionalities	4 - INAF	32	Operating
MS42	Processing board prototype ready	4 - INAF	26	Report complete
MS43	Processing board testing with the basic firmware	4 - INAF	32	Operating
MS44	Basic software initial version ready	2 - ASTRON	26	Report complete
MS45	Basic software testing for the basic functions	2 - ASTRON	32	Released and validated
MS46	Laboratory integration	1 - MPG	40	Operating