

Radio Astronomy and VLBI in Brazil

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Abstract

The first VLBI experiments in Brazil were carried out in the 70's using the Itapetinga 13.7-m radio telescope, near São Paulo, southeast Brazil, by the Mackenzie group, who had pioneered radio astronomy in the country more than a decade earlier. The world wide interest in geodetic VLBI resulted in the installation of the Eusébio facilities, State of Ceará (Fortaleza Station), northeast Brazil, in the early 90's. We summarize the major steps to attain these accomplishments and discuss the supporting needs and requirements to foster academic cooperation.

1. Brief Historical Introduction

Radio astronomy activities in Brazil have been carried on by the Mackenzie group since 1960 at sites located in São Paulo State. Permanent facilities were built at Mackenzie's Itapetinga Radio Observatory, Atibaia, in 1970, where a 13.7-m radome-enclosed radio telescope was built in 1971 (Figure 1, [1,2]). Several international cooperative programs were carried out since then in various research areas including solar physics, ionosphere radio propagation, solar-terrestrial physics, radio astrophysics and instrumentation.

An intensive collaboration was established with MIT Haystack Observatory in the early 70's with the aim of obtaining the first north-south VLBI observations. Two sensitive K-band maser receivers were developed under the leadership of S. H. Zisk and installed at Haystack's 37-m radio telescope and at the Itapetinga radio telescope. Several new water vapor celestial masers were discovered with Itapetinga single dish observations [3]. The first successful VLBI tests were obtained on celestial water vapor line sources with Haystack Observatory in 1978 in one of the last runs using the Mark I system [4]. The Itapetinga VLBI facility was upgraded with a Mark II terminal and was successfully used in the 1974 Venus flyby Vega balloon tracking experiment at 1.7 GHz [5]. The first quasar imaging results adding a long north-south baseline with Itapetinga were obtained at 11 GHz in 1984 [6], showing the dramatic improvement in the resolution of the celestial object (Figure 2).

2. Cooperation for Exploring Geodetic VLBI

The interest of the global geodetic VLBI community to have a complete station in Brazil was discussed during the 1988 XXth Baltimore IAU General Assembly by several international groups, in particular NOAA's NGS, NASA, U.S. Naval Observatory and Germany's IfAG (now BKG). An agreement was made in 1989 between NOAA and the Brazilian institutes of São Paulo University (USP), National Space Research Institute (INPE), Campinas State University (Unicamp), and Mackenzie Presbyterian University (CRAAM). The first site considered was Mackenzie's Itapetinga



Figure 1. The Itapetinga Radio Observatory, Atibaia, near São Paulo city, with the 13.7-m radome-enclosed antenna built in 1971.

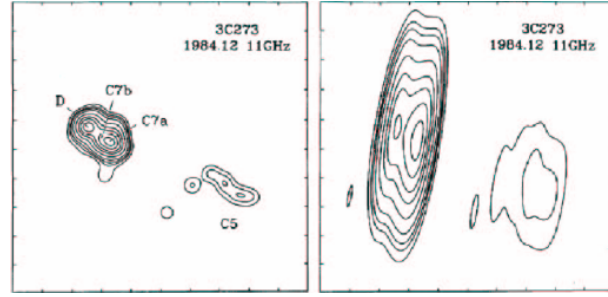


Figure 2. 3C273 images at 11 GHz obtained using Effelsberg (100-m), Haystack (37-m), Green Bank (43-m), Ft. Davis (26-m) and Owens Valley (40-m) with Itapetinga (13.7-m) at left, and without at right [6].

Radio Observatory, near São Paulo, with an existing local infrastructure; but the notion was discarded due to visibility limitations (at low elevation angles) for the existing 13.7-m antenna. Then the USP site at Pirassununga, São Paulo State, was taken into consideration. However, in view of the international community's preference for having a VLBI site as far east and equatorial as possible, the attention was directed to coastal northeastern Brazil despite known difficulties with limitations in local infrastructure. The site named Barreira do Inferno, Natal, Rio Grande do Norte, a former launching site for sounding missiles, had good infrastructure available; but its selection had to be dropped because of difficulties to get the necessary government clearance for using it as a site for a VLBI station. The next and ultimately selected site was located at INPE facilities near the town of Eusébio, in the metropolitan area of Fortaleza, State of Ceará.

3. The North-East Space Radio Observatory at Eusébio (Fortaleza Station)

NOAA arranged for the relocation of a TIW 14.2-m radio telescope antenna from NRAO at Green Bank to Eusébio (Figure 3). Other subsystems (Mark III terminal, H-maser, cryogenic radiometers for X- and S- bands) were made available by NOAA, USNO and NASA. A continuously tracking GPS receiver was added to the site by NOAA. Brazil has contributed with substantial human, material and cash resources. The Ministry of Science and Technology has provided US\$250K for erecting the radiotelescope. Other contributions came from the four initially involved institutes, the local Ceará Foundation for Meteorology and Water Resources (FUNCEME), and the Brazilian Institute of Geography and Statistics (IBGE, the national geodetic institute): for the site adaptation, the antenna final assembly with instrumentation, the first complete geodetic survey, training of local people, fixing and renewing of the buildings, the stand-by generator, communications, etc. The Eusébio (Fortaleza) station was named the North-East Space Radio Observatory (ROEN).

ROEN started operations in 1992 and was officially dedicated in 1993. Since then regular VLBI observations were carried out with a relatively small number of shut down periods for major maintenance. Important mechanical repairs were done in the first years, e.g. to fix pedestal drives misalignments and gear box damages, which were done by local people and mechanical workshops. The station's operational costs were shared between NOAA and the Brazilian partners involved.

In 1999 the International Association of Geodesy (IAG) gave a recognition award to the Fortaleza team for the quality of their geodetic VLBI observations.



Figure 3. The 14.2-m radio-telescope antenna being installed at Eusébio (Fortaleza area), Ceará State, in 1992, part of the supporting team, from left: Edmilson (INPE), Joaquim (CRAAM), J.D. (NOAA), João Batista (Funceme), Macilio (INPE), Wellington (Funceme) and Avicena (INPE).

In addition to the geodesy services of the international and Brazilian (IBGE) communities, the principal justification of the geodetic VLBI operations in Brazil were the prospects of academic cooperation in astrophysics, geophysics, geodesy and related fields. Several studies on time variations of quasars and BL Lac spatial structures were done using data processed at the Washington correlator [7]. Other proposed collaborative efforts, however, did not materialize as expected.

4. Brazilian Space Geodesy Program Support

In view of NOAA's decision to discontinue their activities in geodetic VLBI in 1997, the program was reviewed by all parties involved at a visit to Eusébio (Fortaleza station) site, and a meeting at Mackenzie Presbyterian University. All Brazilian partners were present at the meeting as well as international participants from NASA, USNO and IfAG (now BKG). It was agreed that there would be a regular international contribution to the annual program cost, comparable to the Brazilian share. Major instrumentation additions, replacements or repairs would be sponsored by

NASA, while the Brazilian partners should raise funds for complementary improvements at the observatory. Since time was needed for a new formal agreement between NASA and the Brazilian Space Agency (AEB), the existing agreement with NOAA was used to transfer necessary funds in the meantime. The NASA-AEB Agreement was signed in 2002, and the NASA—Mackenzie contract was signed in 2004. The ROEN operations in the intermediate five years were difficult, due to poor and irregular funding because of NOAA administrative difficulties. However, despite these difficulties, ROEN never interrupted operations in any scheduled geodetic VLBI experiment or GPS data recording and transmission, thanks to the professional dedication and responsibility of the observatory team, led by A. Macilio Pereira de Lucena. Mackenzie Presbyterian Institute many times advanced their own resources in order to keep the observatory running.

The support conditions for the ROEN operations have improved in 2004 as a consequence of the NASA-Mackenzie Contract. However the necessary resources from the international partners dropped below the needs because of two major reasons: a) the U.S. dollar lost a substantial part of its value with respect to the Brazilian Real: from May 2004 to January 2006 the devaluation was on the order of 50%, and even more compared to previous years, when the original agreement was established; b) the contribution of the international partners to the maintenance remains considerably under-dimensioned even without taking into account the foreign currency devaluation, and no additional funds are available to complement and upgrade the instruments as planned.

5. Recent Developments and Prospects

A Mark 5 recording system has been recently received and installed. New funds are now necessary to build the Mark IV video converters, to add auxiliary and test instruments needed for developments and maintenance, and to replace defective units. NOAA has recently replaced the GPS receiver and antenna (Figure 5).

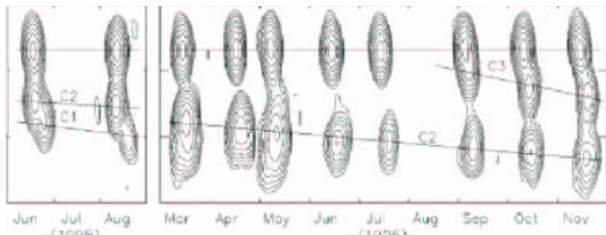


Figure 4. Superluminal BL Lac source expansion as observed at 8.8 GHz [7].



Figure 5. The new NOAA GPS antenna installed on the roof of the main ROEN building.

A new high data rate optical fiber connection is now under construction and will link ROEN at an initial rate of 2.5 Gbps in the first semester of 2006 enabling e-VLBI capabilities in the course of the year. This new connection is part of the GigaFor network [8] sponsored by the Brazilian

Ministry of Science and Technology and the Ministry of Education, corresponding to an investment of US\$1.5M for ROEN. The maintenance cost of about US\$75K/year will be shared among five academic institutions in the Fortaleza area.

The Ceará State University (UECE) and Mackenzie Presbyterian University signed a cooperation agreement in 2005 intended to support the UECE research program on atmospheric physics, in collaboration with ROEN, exploring the meteorology parameters inferred from GPS and VLBI measurements [9].

In addition to the dramatic international funding deficit indicated above, the fostering of academic cooperation with international institutions on research subjects related to the VLBI and GPS geodetic observations carried out at ROEN, is another requirement to be fully implemented in order to justify the Brazilian institutes' involvement and their investments in the program.

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