UNIVERSIDAD DISTRITAL
FRANCISCO JOSÉ DE CALDAS

REVISTA UD Y LA GEOMÁTICA
https://revistas.udistrital.edu.co/index.php/UDGeo/index

UD y la GEOMÁTICA

REVISIÓN

The very long baseline interferometry (VLBI) technique and its applications in contemporary geodesy

La técnica de interferometría de línea de base muy larga (VLBI) y sus aplicaciones en la geodesia contemporánea

Bruno de Oliveira Lázaro * ***y Maria Lígia Chuerubim*** **

Para citar este artículo: de Oliveira-Lazaro, B. Y Chuerubim, M.L. (2018) . The very long baseline interferometry (VLBI) technique and its applications in contemorary geodesy. *UD y la Geomática*, 13, 96-105

Fecha de recepción: 11 de noviembre de 2018 **Fecha de aceptación:** 20 de diciembre de 2018.

ABSTRACT:

Very Long Baseline Interferometry (VLBI) is, nowadays, one of the most accurate geodetic techniques in the field of Radio Astronomy at service of Geosciences. This technology is based on the elaboration of observations and calculations about the interference of electromagnetic waves in the radio frequency, captured by antennas aimed at Quasars located in the space beyond the terrestrial atmosphere. The VLBI is responsible for the generation of studies highly complex and precise in the sciences of determination of distances, displacements, images and positions on the surface of Earth in many areas of the human knowledge. Today, VLBI interferometry is configured as a most modern and efficient alternative to the positioning by GNSS (Global Navigation Satellite System) systems and begins to assure its applications in Digital Cartography, GIS, Remote Sensing, Surveying and Engineering. Within this context, this work carries out a contextualization study and explores the main theoretical foundations of the VLBI interferometry technique. Thus, this work carries out the history of development of VLBI, its operational fundaments and physical principles, the current legislation on its use, and lastly, lists the main exponents of application of the technique in the scope of Spatial Geodesy.

Keywords: Geosciences, geodesy, geotechnologies, interferometry, very long baseline interferometry.

RESUMEN

La interferometría de línea de base muy larga (VLBI) es, en la actualidad, una de las técnicas geodésicas más precisas en el campo de la radioastronomía al servicio de las geociencias. Esta tecnología se basa en la elaboración de observaciones y cálculos sobre la interferencia de las ondas electromagnéticas en la radiofrecuencia, capturadas por antenas dirigidas a los quásares ubicados en el espacio más allá de la atmósfera terrestre. El VLBI es responsable de la generación de estudios altamente complejos y precisos en las ciencias de determinación de distancias, desplazamientos, imágenes y posiciones en la superficie de la Tierra en muchas áreas del conocimiento humano. Hoy en día, la interferometría VLBI se configura como una alternativa más moderna y eficiente al posicionamiento de los sistemas GNSS (Sistema de navegación global por satélite) y comienza a asegurar sus aplicaciones en cartografía digital, SIG, sensores remotos, topografía e ingeniería. En este contexto, este trabajo lleva a cabo un estudio de contextualización y explora los principales fundamentos teóricos de la técnica

* Graduado em Engenharia Civil pela Faculdade de Engenharia Civil (FECIV) / Universidade Federal de Uberlândia (UFU). Pesquisador em Engenharia Urbana e Geotecnologias Aplicadas. Coordenadora de Comunicação e Marketing - CREA Jr Núcleo Uberlândia / MG. Diretor do Departamento de Extensão e Extensão da Diretoria Acadêmica de Engenharia Civil (DACIV / UFU). Membro do Conselho da Faculdade de Engenharia Civil (CONFECIV). Membro do Colégio de Extensão da Faculdade de Engenharia Civil. brunodeoliveira38@hotmail.com

** Possui graduação em Engenharia Cartográfica pela Universidade Estadual Paulista Júlio de Mesquita Filho (2006). Mestrado realizado junto ao Programa de Pós- Graduação em Ciências Cartográficas da UNESP (2007-2009).Tem experiência na área de Geociências, com ênfase em Geodésia, atuando principalmente nos seguintes temas: Posicionamento GNSS, Integração de Redes Geodésicas. De 2009 a 2010, atuou como Analista de Desenvolvimento Fundiário no Programa Cadastro de Terras e Regularização Fundiária no Brasil realizado pelo Ministério do Desenvolvimento Agrário (MDA) em parceria com o Instituto de Terras do Estado de São Paulo (ITESP). De 2010 a 2011 foi Professora de Ensino Básico, Técnico e Tecnológico no Instituto Federal do Espírito Santo (IFES) junto à Coordenadoria de Geomática. Atualmente, é Professora da Faculdade de Engenharia Civil (FECIV) na Universidade Federal de Uberlândia (UFU), além de se dedicar à pesquisas em diferentes àreas das Geociências como Geodésia, Fotogrametria e Sensoriamento Remoto. mchuerubim@gmail.com

de interferometría VLBI. De este modo, este trabajo muestra la historia del desarrollo del VLBI, sus fundamentos operativos y principios físicos, la legislación vigente sobre su uso y, por último, enumera los principales exponentes de la aplicación de la técnica en el ámbito de la geodesia espacial.

Keywords: Geosciences, geodesy, geotechnologies, interferometry, very long baseline interferometry.

Introduction

According to the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística–IBGE, 2016*) and NASA (National Air and Space Administration, 2016), Geodesy is understood as the science responsible for studying and determining the shape, dimensions and spatiotemporal variations of the gravitational field of the Earth's surface. Also in that sense, the National Air and Space Administration (2016) added to this concept that Geodesy is based on studying and understanding the three basic variables of Earth planet: its geometric form, its orientation in space and the variations of its gravimetric changes.

In that sense, Geodesy bases several other areas of human knowledge, basing its studies on mathematical calculations (algebraic, geometric and numeric) in order to give reference and scope to other Geosciences, such as Geomatics, Geographic Information Systems (GIS), The Multipurpose Technical Cadaster (MTC), Urban Planning and Construction, Civil and Urban Construction Engineering, air, sea and road navigation, military applications and space programs, among many others areas.

However, Geodesy has always come up against the fundamental problem of precise representation of its variables. Because they are parameters with high dimensions and variations, an accurate and accurate geometric and/or numerical representation of the earth's surface becomes practically impossible. In this scenario, numerous methods of geodetic representation have been proposed by researchers and professionals of Geosciences over the years with the objective of better represent the basic parameters of the planet and its dynamics. In this sense, the emergence and development of Global Navigation Satellite System (GNSS), Remote Sensing, GIS and high precision positioning systems have been configured as a major advance within Geodesy and its applications in the activities Human beings.

Within these methodologies, one of the most recent and accurate is Very Long Baseline Interferometry (VLBI), or simply Interferometry. According to Walker (2002), the VLBI is a radio astronomy technique that seeks to calculate the Euclidean distance between distinct points of space. For this calculation, the VLBI is based on the difference between the propagation time of electromagnetic waves in the radio frequency, emitted by an extraterrestrial Quasar and captured by one or more receiving antennas or stations on the earth's surface.

Also according to Walker (2002), the VLBI Interferometry technique was developed in the 1960s and, currently, due to its high degree of precision, has been gaining space in the scientific community as a system of geodetic positioning alternative to GNSS. In addition, VLBI Interferometry also makes it possible to carry out more detailed research and studies on, for example, tectonic parameters of the earth's crust, geodynamics, environmental impacts and monitoring of civil structures, thus ensuring a broad application of the methodology.

Currently, the International Association of Geodesy (IAG) uses VLBI as the sole and standard methodology for the determination and maintenance of the International Celestial Reference Frame (ICRF) and Earth Observation Parameters (EOP), Networks responsible for the determination of the celestial poles and their angular variation. In addition, IAG is also the primary and most accurate technique for the maintenance of the International Terrestrial Reference Frame (ITRF).

However, the number of researchers and practitioners is still small when compared to the wide range of VLBI applications. In this way, it is necessary to elaborate contextualization studies and scientific basis of the VLBI methodology in order to meet the theoretical needs and guarantee the universalization of knowledge in Very Long Baseline Interferometry.

With this type of study, one can better understand the operation and the functions of the VLBI technique and, with this, promote discussions, policies and actions that aim to further improve the methodology and the VLBI network around the world. Thus, practitioners and the scientific community can work to assist in the evolution of VLBI in various aspects of human activity.

In that scenario, the present work carries out a bibliographic survey about the history of development and the fundamentals of operation and functions of the VLBI technique in its various instances. In addition, this article also raises the main applications of Very Long Baseline Interferometry in the scope of contemporary Spatial Geodesy in order to provide the professionals of that science studies that are more precise, and which have a constructive influence on life in society.

Therefore, this paper aims to present the theoretical foundations of the operation and operation of the Very Long Base Line Interferometry (VLBI) technique. In this way, it is intended that both the scientific community and other branches of society can better understand the physical principles of VLBI operation, improve the interpretation of the results obtained through the application of this technique and raise new possibilities of using Interferometry in areas of human activity.

Objectives

This work aims to carry out a theoretical contextualization study of the main historical, technical and operational fundaments of the Very Long Baseline Interferometry technology. In addition, this article also aims to offer scope to the body of professionals, academics and researchers regarding the acquisition of scientific knowledge related to VLBI technology, in order to ensure the full evolution of this technique in its most diverse areas of activity.

Literature review

Introduction to VLBI

In the scope of Geosciences, numerous methodologies and techniques of analysis have been proposed over the years with the objective of improving the accuracy and accuracy of the studies carried out by researchers and professionals in the area. These technologies are being implemented from this the emergence of the geodesic sciences and, often, they undergo constant improvements, thus guaranteeing the technological evolution of them (HETEM, 2000).

However, it was not until the 1960s that geodetic methodologies and techniques became an object of intense study and refinement by the international scientific community. This culminated in the rapid promotion of technological inputs in the field of Geosciences, characterizing the post-1960 period as the time of greatest investment in state-of-the-art technology for the physical sciences.

In this sense, as of 1970, the techniques of Remote Sensing, Photogrammetry and Global Navigation Systems by artificial satellites began to be developed and implemented. However, in order to achieve more precise results than those promoted by the aforementioned techniques, scientists and researchers started to use innovative techniques within Geodesy, such as Interferometry (SCHÜLTER, 2016).

According to the European Space Agency (ESA, 2015), Interferometry comprises science and technique where two or more waves are superimposed, generating a new and different wave. This wave generated by interference mechanisms can be used to calculate differences relative to primordial waves. In this sense, since interference is a general phenomenon between waves, Interferometry can be applied to a wide spectrum of scientific fields, including Astronomy, Optical Metrology, Oceanography, Seismology and Quantum Mechanics.

Despite this wide range of applications, the Interferometry gained greater prominence with respect to its applications in Astronomy and Geosciences. In these, the Interferometry began to be used to combine electromagnetic waves from different sources (extraterrestrial objects, antennas, satellites) to improve the optical and digital resolution of telescope images.

However, it was not until the mid-1960s that the interferometry method underwent a major revolution and refinement. At that time, the VLBI (Very Long Baseline Interferometry) was created by NASA astronomers (National Air and Space Administration), with the goal of improving the resolution of radio telescopes used by local scientists. With this, astronomers intended to guarantee extraterrestrial images with a high degree of detail and more precise information than those already in use. In addition, NASA also aimed to detail the geometric and behavioral structure of Quasars (Quasi-stellar radio sources), extraterrestrial objects that are source of intense emission of electromagnetic energy (Fig. 1 and 2).

According to Blandford (1996), Quasars are space objects located outside the Earth's atmosphere, at extremely large distances from planet Earth, and behaving similarly to stars with high emission of electromagnetic energy in the form of light. More complex definitions cite the Quasars as compact regions surrounding a supermassive black hole emitting enormous amounts of electromagnetic energy.

These objects are moving away from the Earth with great speed, a fact that can be concluded through measurements of the Doppler Effect. In this way, many scientists believe that such speed is due to the very speed of expansion of the universe. Thus, since the velocity and distance of the Quasar are extremely large, its motion is considered despicable, making it an ideal inertial frame at rest.

Thus, in VLBI, an electromagnetic signal from an astronomical source emitting waves at the radio frequency, such as a quasar, is collected at various radio telescopes located on the Earth's surface. The distance between the emitting object and a receiving telescope, as well as the distance between the radio telescopes, are calculated using the time difference between radio signal arrivals in different telescopes (FARINA, 2013).

After the development of the VLBI technique, from 1967, through the consortium between the American space agency, some private universities and other government agencies, the first tests were carried out using interferometric technology to determine the geodetic parameters of the planet Earth. As a result, scientists have observed extremely accurate and highly reliable results in order to effectively implement the VLBI methodology in several NASA programs since then (NASA, 2016).

Due to the high degree of accuracy and accuracy, since 1980, the VLBI technique has been used as the ideal geodetic positioning method by a large part of the scientific community around the world. Nowadays, Very Long Baseline Interferometry is employed in studies and works that aim at obtaining extremely precise geometric parameters (sub-millimeter scale) about geodetic variables on Earth, such as the variations in the axis of rotation and orientation of the planet, tectonic dynamics and Movement of the lithosphere plates, positioning and geolocation, structural deformations in dynamic analysis of structures, among others.

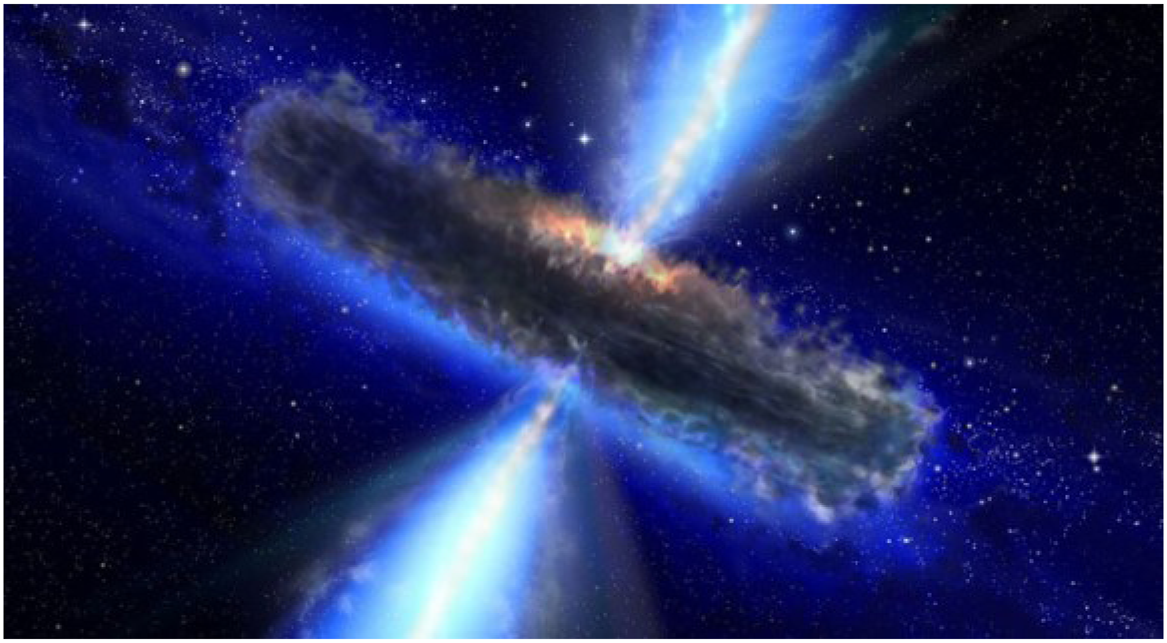

Figure 1 – Concept art of a Quasar captured by Hubble Telescope. NASA Gallery, 2016.

Figure 2 – Concept art of an electromagnetic emission inside a Quasar. ESA Gallery, 2016.

In addition, large astronomical organizations have adopted the VLBI methodology as the basis for their work. In this sense, we can highlight NASA, which currently uses the VLBI in the POLARIS (Polar Motion Analysis by Radio Interferometry Surveying), NEOS (Nation Earth Orientation Service), IRIS (International Radio Interferometry Service) and CORE (Continuous Observation of The Rotation of the Earth).

In the scope of Applied Geodesy, VLBI was also adopted by several organizations, including IGS (International GNSS Service) and IAG (International Association of Geodesy). In addition, in Brazil, IBGE (Brazilian Institute of Geography and Statistics) and INPE (National Institute for Space Research) have also been using Very Long Baseline Interferometry to support their studies (European Space Agency–ESA , 2016).

Technical functions of Very Long Baseline Interferometry

As previously discussed in this paper, Very Long Baseline Interferometry uses radio astronomy techniques (part of astronomy that studies extraterrestrial phenomena through the analysis of electromagnetic waves in radio frequency), in which several antennas observe a certain point in space, the so-called Quasars. Fig 3 exemplifies the process of operation of the art.

Signals from a radio frequency source (usually random signals from a Quasar or other compact extragalactic object) are received by the antennas of two or more radio telescopes located on the surface of the Earth. Therefore, these signals are amplified and transformed into a low frequency band.

This stage of acquisition and transformation of electromagnetic bands is controlled by a Hydrogen Maser. The transformed signals are scanned, recorded in time and recorded on a magnetic tape with broadband frequency through the MARK III System.

Usually, the bands frequency used in the VLBI geodetic applications are the called S and X bands, with a frequency of 2.3 GHz and 8.4 GHz and a wavelength of 13 cm and 3.6 cm, respectively. These tapes are then routed to a central station where the VLBI data will be processed again by a cross correlator. The correlator is controlled by a computer that strategically exchanges the data streams of two telescopes against each other by crossing and multiplying them until both signal streams are perfectly aligned. Thus, the correlator output data shows an interference pattern with maximum amplitude for an aligned signal.

However, although it operates in a relatively simple way, the Very Long Baseline Interferometry differs from other interferometry investigation methodologies, since it presents a higher occurrence of noise in obtaining the signal emitted by the Quasars. The noise is nothing more than a distortion in the geometric shape of the electromagnetic wave emitted, at great distances from the receiving antennas, caused by phenomena and / or external bodies located in the line of action between the Quasar and the receiving antenna (Fig 4).

Nevertheless, VLBI is able to reduce the effects caused by noise by means of mathematical and numerical formulations, ensuring measurements with high accuracy, being able to measure displacements and deformations with precision of 1 mm vertically and 2 mm to 3 mm horizontally.

Operational components and equipment

The VLBI technique consists basically of a receiving station containing extraterrestrial signal reception antennas and a processing center composed of three main operational components: a Cryogenic Receiver, a MARK III Recording System and a Hydrogen Maser (Fig 5). The Cryogenic Receiver is a high sensitivity receiver that operates at very low temperatures, operating to ensure the stability of the received signal.

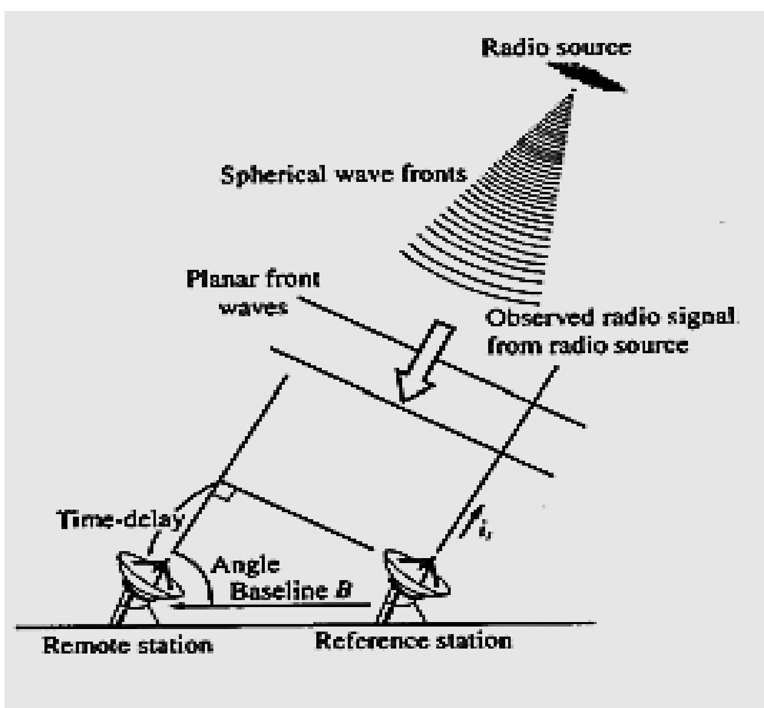

Figure 3 – Functioning of VLBI technique. European Space Agency, 2008.

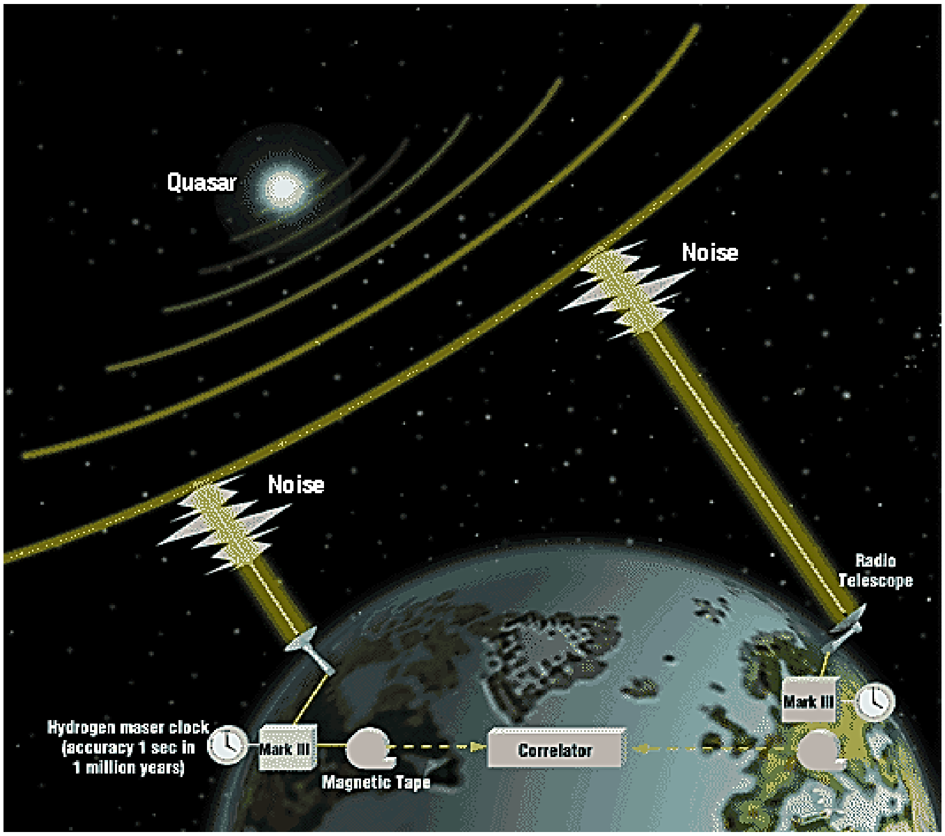

Figure 4 – VLBI technique of receiving electromagnetic sources by a Quasar. NASA, 2016.

Figure 5 – Cryogenic Receiver, Mark III System and Hydrogen Maser. IBGE, 2015.

The MARK III Recording System is an operating system that stores the digital data, recorded in time and makes its recording on a magnetic tape with broadband frequency. And, finally, the Hydrogen Maser is an apparatus responsible for the control of the amplification of the signals coming from the Quasars and transformation for bands of low frequency, has high stability of data processing. Currently the VLBI network has about 40 stations, spread across 17 countries, two in South America, Chile and Brazil. Fig 6 shows the stations distributed across the globe.

Numerical principles of functioning of VLBI technique

Like the other geodetic positioning methodologies, Very Long Base Line Interferometry is based on mathematical calculations about a study variable and, in the case of VLBI, this variable is called Group Delay (or only delay). The Group Delay corresponds to the numerical value of time required for an electromagnetic wave signal emitted by a Quasar to be received by at least two receiving antennas on the Earth's surface. In this way, the group delay is a variable magnitude as a function of time alone.

However, the group delay can be divided is influenced indirectly by factors external to the temporal magnitude and, when added together, cause significant swings in the Group Delay calculation. Among these factors, the following stand out:

- Geometric Delay: a variable that measures the time difference between emission and reception of signals taking into account geometric effects of diffuse path, path output and signal loss between the transmitter and the receiver;
- Daytime aberration: an astronomical phenomenon that causes an apparent movement of celestial objects in the vicinity of their locations and is due to the rotation of the Earth itself around its axis;
- Tropospheric Refraction: corresponds to the Troposphere property in promoting curvatures in the trajectory of electromagnetic waves that propagate in its environment. It is a phenomenon extremely influenced by climatic factors, such as humidity, wind speed, insolation and precipitation.

Numerically, the Group Delay can be calculated based on the following equation:

$$\tau = \frac{\overrightarrow{|b|}.\overrightarrow{|s|}}{c} = \frac{b.s.\cos\theta}{c} \quad \text{(Equation 1)}$$

Where we have:
$\vec{b}$ = Vector baseline between VLBI signal reception stations;
$\vec{s}$ = Unit vector in the direction of the emitting source
c = Light speed.

However, Equation 1 deals with the calculation of the Group Delay in a very simplified way and without taking into account the interactions and influences caused by the tropospheric refraction factors, daytime aberration and geometric delay. These factors can be overlooked when their values are small and when it comes to stationary data. Thus, for a more in-depth and accurate calculation of Group Delay, the VLBI methodology takes into account these other factors, according to the following equation:

$$\tau = \frac{-1bs(t)}{c} + \Delta\tau_{AB}(t) + \Delta\tau_{in}(t) + \Delta\tau_{atm}(t) \quad \text{(Equation 2)}$$

Where we have:
b = Module of the vector base line between stations;
s = Module of the vector in the direction of the emitting source;
c = Light speed;
$\Delta\tau_{AB}(t)$ = Correction term for daytime aberration as a function of time;
$\Delta\tau_{in}(t)$ = Term for drift correction between station clocks as a function of time;
$\Delta\tau_{atm}(t)$ = Correction term for tropospheric refraction as a function of time.

Also in this sense, the VLBI methodology proposes the mathematical calculation of the correction terms of daytime aberration, the difference between clock time and tropospheric refraction. These calculations follow the following equations:

$$\Delta\tau_{AB}(t) = \frac{-s.\tau(t)}{c} \quad \text{(Equation 3)}$$

$$\Delta\tau_{in}(t) = a_1(t) + a_2(t) \quad \text{(Equation 4)}$$

On what:
$a_1(t)$ = time variation of a station;
$a_2(t)$ = time variation of another station.

From this, if we replace Equations 3 and 4 in Equation 2, we have the complete formulation for the Group Delay calculation through the application of the VLBI methodology, as can be seen in the following equation:

$$\tau = \frac{-1.b.s}{c}(t) - \frac{s.\tau}{c}(t) + [a_1(t) + a_2(t)] \quad \text{(Equation 5)}$$

Finally, since the correction factors of Equations 3 and 4 are mathematically expressed by a rate of change of magnitude as a function of time, a differential behavior can be assumed for these calculations. Thus, Equation 5 can be rewritten in differential form, giving rise to the so-called Fundamental Observation Equation in VLBI.

$$\tau = \tau(t) = \left[\frac{-1.b.s}{c}(t)\right] - \left[\frac{s}{c}.\frac{d\tau}{dt}(t)\right] + \left[\frac{da(t)}{dt}\right]$$

(Equation 6 – *Fundamental Observation Equation in VLBI*)

Thus, if the parameter τ, or Group Delay, is determined, the VLBI technique can promote measurements of distances and displacements between points relative to the extraterrestrial inertial frame (in this case, Quasar). This measurement is given by the correlation of the group delay with its respective vector components of distance and length.

Advantages, disadvantages and applications of VLBI in Sciences

Currently, Very Long Baseline Interferometry has been widely used as an alternative methodology to GNSS global positioning and navigation systems, in the scope of Applied Geodesy. Thus, VLBI is used to promote basic calculations in the context of Geosciences, such as rotation angles, translation, determination of geodetic coordinate systems and geodetic reeferences, navigation and positioning by satellites, calculations of land parceling, surveying and cartography.

In the scope of Spatial Geodesy, VLBI is used as the ideal positioning system, thus guaranteeing an almost negligible error in the calculation and determination of important reference parameters for the cosmos. Among these parameters, the determination of the variables of the nutation and precession axis of the planet, the International Celestial Reference Frame (ICRF) and the International Terrestrial Reference System (IERF–International Earth Reference Frame).

In addition, the use of VLBI technology in the context of Geodynamics is also notable. The application of Very Long Base Line Interferometry in studies aiming at observing the variation of the movements of the lithosphere and differential plates in the earth's crust (Fig 7) is increasingly increasing. With these studies, assisted by VLBI, it is possible to analyze the occurrence of rocky landslides, earthquakes, volcanism and other events that significantly impact both the structure of the planet and the life of its populations.

Currently, VLBI technology has been secured as an alternative to traditional geodetic surveys using GNSS systems. Thus, a great evolution in the process of acquisition, processing and interpretation of geodetic, geographic and spatial data was promoted, since through interferometry this information could be treated with extremely high precision.

However, the recent use of VLBI technology is not limited only to the scope of geosciences. Today, there is a growing use of the Long-Term Baseline Interferometry methodologies in Engineering, mainly in Cartographic and Surveying Engineering, Agronomic Engineering, Civil Engineering and Urban Engineering. In this sense, the VLBI has been used, for example, for the following purposes:

- Development of digital elevation models;
- 3D Mappings
- Updating cartographic bases;
- Accurate delimitation of river basins and areas susceptible to flooding (Fig 8);

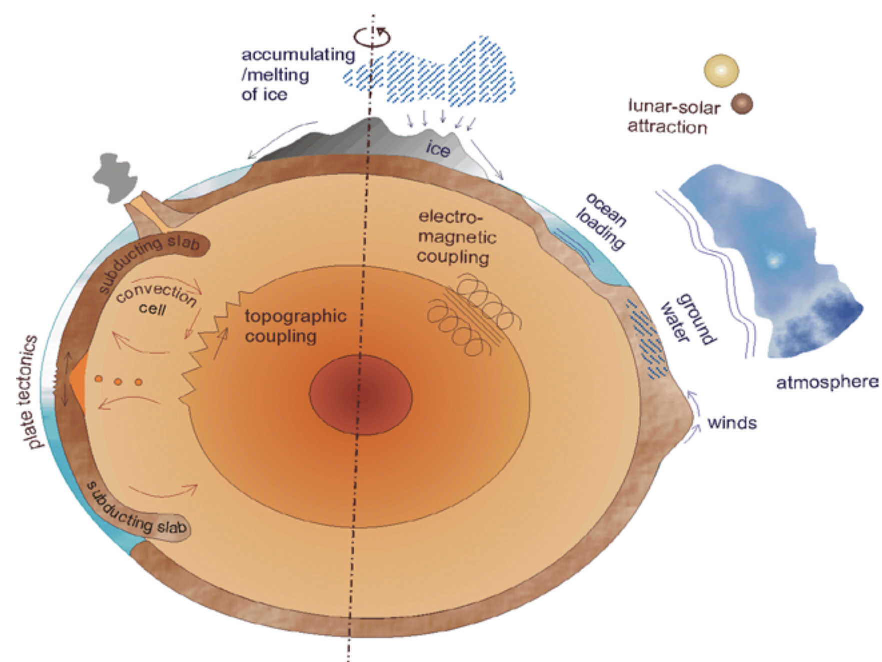

Figure 7 – Tectonic displacements and others movements analyzed by VLBI. IVS, 2015.

- Forest administration;
- Monitoring of precision farming regions and activities;
- Environmental territorial planning;
- Combating deforestation and other environmental impacts;
- Coastline monitoring;
- Oceanography;
- High accuracy bathymetry;
- Mapping and interpretation of geological features of terrain;
- Analysis, planning and guidelines of use and occupation of urban soils;
- Monitoring of deformations and displacements in buildings (Fig 9);
- Planning of special works of art on highways;
- Urban infrastructure (sanitation, geotechnics and transport);
- Design of geotechnical works (tunnels, retaining walls, foundations, dams);
- Structural monitoring of dams.

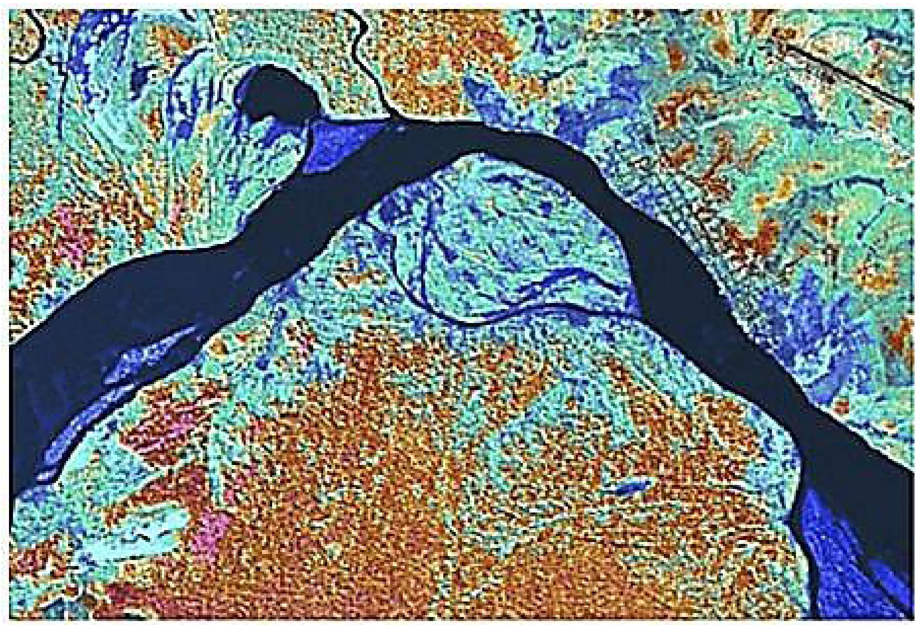

Figure 8 – Use of VLBI to delimit Watersheds areas. NASA, 2015.

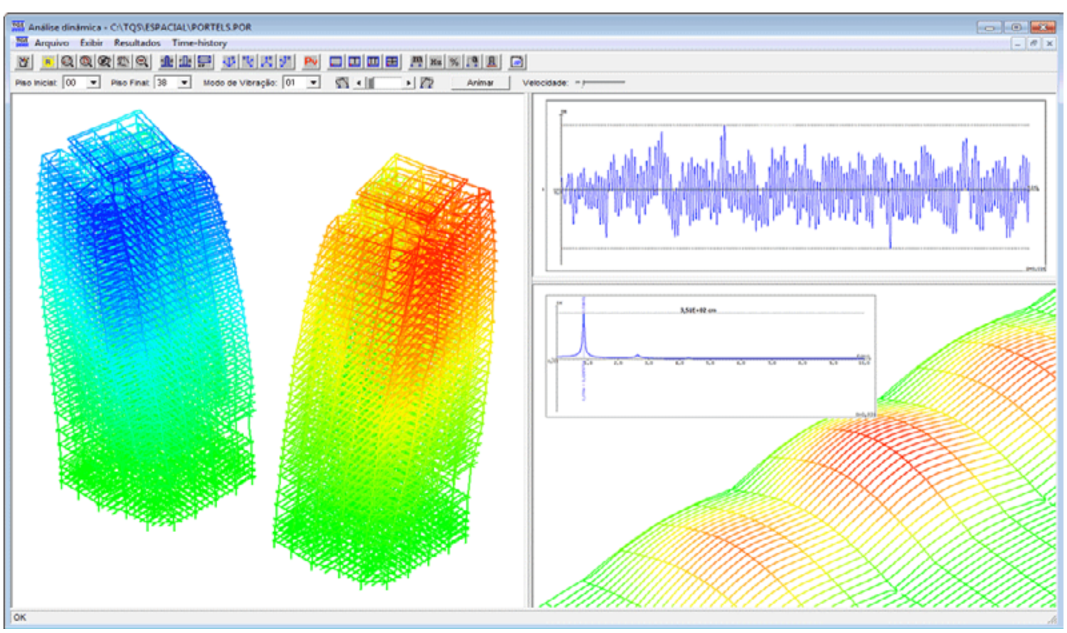

Figure 9 – Application of VLBI and Structural Analysis Software to modeling a building. TQS,2016.

Future scenario of VLBI technology

As explained in the previous subsections of this paper, the Very Long Baseline Interferometry has been consolidated as an alternative methodology to the traditional analyzes within Geosciences. With this, the researches and works that use the VLBI perform, more often, studies, calculations and analyzes more precise and with better detailing. In this sense, the main pretension of VLBI technology in the future is to continue improving the accuracy of its measurements and calculations, so that interferometry can be considered as the most accurate study technique in favor of the various human activities.

In addition, VLBI stations also aim to increase and amplify the physical extension of the system for capturing, processing and interpreting interferometry data throughout the world. Thus, in the short to medium term, the installation of new VLBI stations and densification of the already existing network, as well as the training of more professionals to work with hardware and software in the scope of interferometry.

Finally, it is also intended a greater financial investment in the development of equipment and programs for the use of the VLBI technique. With this in mind, it is intended to ensure that VLBI technology is accessible to all spheres of the world scientific society in the not too distant future, thus guaranteeing the universalization of the knowledge promoted by this methodology and its full insertion in the most varied sectors of the world. human life.

Conclusions

The VLBI (Very Long Baseline Interferometry) technology is a geometric technique that precisely measures directions in space using the reception of signals from the Quasars, extraterrestrial objects emitting electromagnetic waves at the radio frequency. The VLBI system was initially developed with the objective of studying and detailing the structures of these same Quasars and improving the resolutions of the radios telescopes.

However, over time VLBI has been incorporated into the most diverse branches of human sciences and activities. The system has several applications in the areas of Geodesy and Geosciences, and it is possible to combine the VLBI method and the positioning by GNSS satellites to obtain various information of interest for the geodetic sciences, surveying, engineering, geodynamics, geology, among others.

VLBI offers many advantages in its use, among which we can highlight the fact that the technique is currently considered the highest precision system for geodetic measurements, reaching 1 mm horizontally and 2 to 3 mm vertically. However, VLBI also has some disadvantages, such as the high cost of deployment / maintenance and the demand for highly trained professionals.

Therefore, the work carried out a study of contextualization, historical survey and fundamentals of operation of the VLBI technique, taking into account its development and its numerical, geometric and computational characteristics, with the objective of promoting scope to those who are interested in the area and theoretically base the Scientific community using the VLBI. Finally, this work also contemplated the tendency to use Very Long Base Line Interferometry in the daily life of modern man and as an alternative to the traditional GNSS systems within the scope of Contemporary Space Geodesy.

References

Blitzkow, D.; Matos, A. C. C (2002). *A evolução dos referenciais usados em Geodésia: a era moderna*. Boletim de Ciências Geodésicas, Curitiba, v. 8, nº 1, 3-16.

European Space Agency (ESA). *Very Long Baseline Interverometry Observations and Project*. < http://www.esa.int/Our_Activities/Space_Science/Observations_Very_Long_Baseline_Interferometry_VLBI> .

Hetem, J. G.; Pereira, V. J (2000). *Fundamentos de Astronomia*. Departamento de Astronomia do Instituto de Astronomia e Geofísica (IAG) ministrado ao curso de Bacharelado ou Licenciatura em Ciências Exatas da Universidade de São Paulo (USP). São Paulo: IAG, 2000.

Monico J.F.G (2005). *Posicionamento pelo NAVSTAR-GPS: Descrição, fundamentos e aplicações*. São Paulo, Editora da UNESP.

National Air and Space Administrations (NASA). *VLBI Programs*. <http://lupus.gsfc.nasa.gov/vlbi.html >.

Oliveira, E. B. *Satelitte Laser Ranging – S.L.R. (2001*) Seminário da disciplina Posicionamento por Satélites do programa de Pós-Graduação em Ciências Cartográficas da Universidade Estadual Paulista – Unesp. Faculdade de Ciências e Tecnologia – F.C.T. Departamento de Cartografia. Presidente Prudente: UNESP/FCT.

Pimenta, A. F; Ferreira, L. D. D.; Afonso, G. B. *A variação da velocidade de rotação da Terra*. Anais do III Colóquio Brasileiro de Ciências Geodésicas.

Schlüter, W.; Vandenberg, N. (2007) *International VLBI Service for Geodesy and Astrometry (IVS)*. Journal of Geodesy. Vol 81. http://www.springerlink.com/content/v760312v657v/?p=cf1d0d1bf2c1471390db3f07ca25a2a8&pi=0