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PARANET: PAnama RAdiotelescopes NETwork

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ABSTRACT

In this paper we present a brief overview of a future project that consists on building a radio astronomy system using the parabolic dish antennas located at different Campuses of the Tecnological University of Panama (UTP). Our proposal is to implement the principle of interferometry to link these parabolic dich antennas to achieve the angular resolution that we would have with a much larger radio telescope.

Keywords: Radioastronomy, antennas, radiotelescopes, VLBI, VLBA.

1. INTRODUCTION

The project of a radiotelescopes network in Panama was first proposed, as an idea, by Delgado-Serrano (2011). However, in the present article we are going to present a more developed idea of such a project. The first idea was proposed just because it could be noted that each Campus of the UTP (spread within the 75 000 km^2 national territory) has, at least, one radio antenna. These antennas were a part of a communication project the UTP had several years ago. Nevertheless, with the increasing development of communication (internet), such antennas are not used anymore for what they were built, and most of them are not used at all. Furthermore, recently conversations with the UNACHI (another public university in Panama), has revealed they interest in building an antenna larger than 6 m diameter to be part of PARANET.

It is crucial to spend many hours of study and research to determine the final design, technical details and total cost of this project. Although, we expect a reduction of costs, since we are considering the utilization of the parabolic antennas we already have, there may be possible adverse implications to consider, such as the altitud and location of the antennas, replacement of damaged electronic equipment, new mounts for the antenna dishes, weather conditions, among others. In any case, as radioastronomy observations could be made without interruption because of clouds, it is a field very promising in Panama.

In the following, we present an analysis and description of the technical aspects of our project and also present possible practical solutions to the challenges we could face.

1.1 ANTENNAS

In order to determine if they are suitable for the project and the range of radio frequencies (or wavelengths) we can work with, we should consider several aspects such as diameter of the dish, atmospheric conditions, altitud, location, and distance from the observatory.

In radio interferometry, the antenna type used as primary elements of the array depends on the wavelength (λ) of the desired signal. For low frequencies with λ longer than 1 m, it is more convenient to use wire antennas like dipoles and spirals because their collecting area increases with λ^2 (Danielsson, 2007), but for smaller values of λ, the effective area of the dipole antenna decreases and it is more convenient to use parabolic reflectors that provide much higher gain.

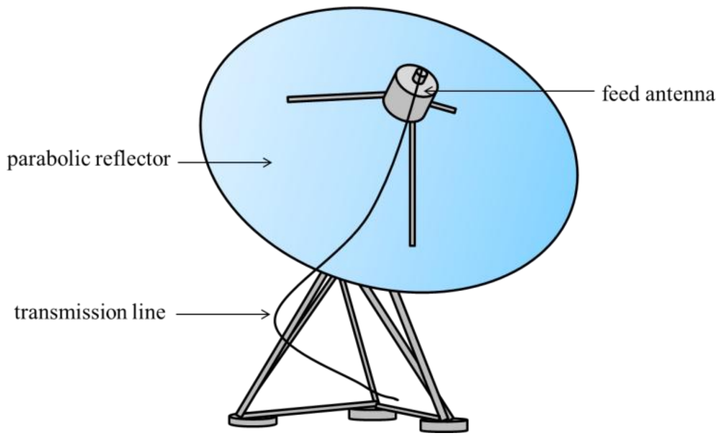

Figure 1: Structure of a parabolic antenna

Fig. 1 shows the typical structure of a parabolic antenna. The parabolic reflector, that can be solid or a wire grill, directs the incoming plane wave towards the focus of the parabola where the feed antenna is located. The feed antenna, usually a horn type, is connected through the trasmission line to the receiving equipment that will process the signal.

The frequency at which the antenna works is determined by the feed antenna, while the reflector can be adapted to broad range of frequencies. Nonetheless, the diameter of the reflector have to be larger than the wavelength, since the gain of the parabolic antenna is proportional to the aperture of the parabolic reflector and inversely proportional to λ, as shown in equation 1:

$$G = \frac{4\pi A_g}{\lambda^2}\eta_A \tag{1}$$

where $A_g = \pi r^2$ is the geometric apperture (i.e., the area of the reflector) and η_A is the apperture efficiency, an indicator of how much energy of the incoming signal is actually captured by the antenna. Usually, the value of η_A is between 0.50 and 0.70.

Table 1: Parabolic Antenna Characteristics

University Campus	Antenna Diameter	Dish Type	Feed Antenna System	Current working frequency
Main Campus	4.6 m	Solid	Prime focus	Ku, C bands
Colón	6,71m	Grill	Prime focus	Ku, C bands
Coclé	6,71m	Grill	Prime focus	Ku, C bands
Azuero	6,71m	Grill	Prime focus	Ku, C bands
Veraguas	6,71m	Grill	Prime focus	Ku, C bands
Chiriquí	3m	Grill	Prime focus	2 GHz

The characteristics of the parabolic antennas we have are presented in Table 1. As we can see, four antennas (Colon, Coclé, Azuero, and Veraguas) has the same diameter of 6,71 m, which is very convenient because the primary antenna elements used in interferometry should have configurations as similar as posible, besides this diameter size can provide sufficient gain to work at cm wavelengths. For example, if we compute the gain at the S-band frequency of 3000 MHz (λ = 10 cm) using equation (1) and asuming an apperture efficiency of 50% , the approx. gain would be of 33dB (i.e., more than 2000 times above the istropic level) while for 30 GHz (λ = 1 cm) the gain would be of 43 dB (i.e., more than 22,000 times above the istropic level). The importance of working at cm wavelenghts remains on the fact that our antennas are placed a few meters above sea level. Cm wavelengths are less perturbed by clouds (water molecules) than mm wavelengths.

Figure 2: Model of the parabolic antennas located in the campuses of Colon, Cocle, Veraguas and Azuero

Fig. 2 shows the model of the parabolic antennas located in the campuses of Colon, Coclé, Veraguas and Azuero. The grill reflector type is very common in these large dishes because it help to reduce the weight of the structure. They can direct the incoming waves as perfect as a solid dish, as long as the holes of the grill are smaller than $\lambda/10$. We also observe that the feed antenna type is primal focus; which means that the feed horn-antenna is located at the focus of the parabola. This configuration is simple and gives the possibility of adapting to a broad range of frequencies compared to secondary reflector systems like cassegrain or gregorian. The dissadvange of the prime focus is that noise from the ground can decrease sensibility (Taylor et al., 1999).

Appart from the gain of the antenna, it is important to consider the propagation properties of the atmosphere when choosing the range of wavelengths to work with, because these properties determine the range of frequencies of space signals that can pass through the atmosphere without being blocked, absorved or scattered. For example, radio signals with very high frequencies (300 GHz) can be highly absorbed and scattered by the molecules of the constituents of the atmosphere, such as nitrogen (N_2), oxigen (O_2), water vapor (H_2O) and carbon dioxide (CO_2). For radio astronomy and communications, the most important of these constituents is water vapor because its concentration can vary greatly with the high and the weather conditions and its effects can be observed at cm wavelength. For example, at sea level and normal conditions, H_2O has an absorption band of 22.2 GHz (Wilson et al., 2009), but rain clouds can cause serious atenuation at even lower frequencies.

Finally, we have to remember that there are frequencies assigned to services like radio, television, and mobile communicattions; and since, in our case, the antennas are not isolated from the civilization, it is necessary to search for frequencies clear from satelites and terrestrial transmitions and use of very good filters.

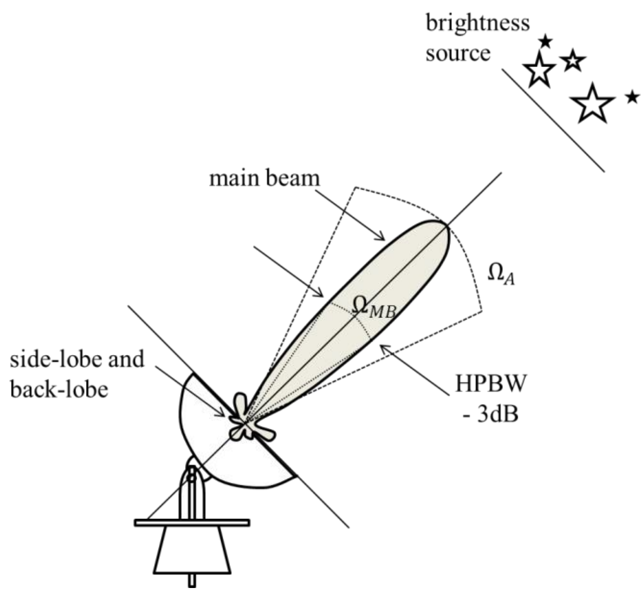

Figure 3: Power pattern of a parabolic antenna

Fig. 3 shows the characteristic power pattern of a parabolic antenna. As we see, the power concentrates in a main beam whose angular width is described in terms of the solid angle Ω_A; however, it is often measured in terms of the half-power beam width (HPBW) solid angle Ω_{MB}, which is the angular width where the power of the main beam drops to one half (-3 dB) of its maximum value and it is also the angular resolution of the antenna (Kraus, and Marhefka, 2001) and can be computed as

$$\Omega_{MB} = k\lambda/D \tag{2}$$

where k is a factor that depends on the shape of the reflector and the antenna ilumination. As we see, increasing the diameter of the antenna improves the angular resolution. Nonetheless, if we write λ in terms of the angular resolution and express equation 1 as

$$G = \left(\frac{\pi k}{\theta}\right)^2 \eta_A \tag{3}$$

we see that there is a tradeoff between field of view and sensitivity, and this has to be considered when choosing the antenna elements of an interferometry system and the type of research to be performed.

1.2 MOUNT ADAPTATION

The choice of the mount for the radio telescope is one of the most important decisions when designing a interferometry system. There are two common types of mounts which are shown in Fig. 4; the equatorial mount and the altitud-over-azimut mount (Taylor et al., 1999).

The equatorial mount is optimal to track astronomical objetcs because its polar axis is aligned parallel to the axis of rotation of the earth. However, it presents the dissadvantages of cost and complexity. For large parabolic reflectors, the alt-azimuth mount is prefered due to the simplicity and lower cost. This mount allow the radio telescope to be moved in altitud and azimuth and its performanced can be enhaced by digital tracking systems.

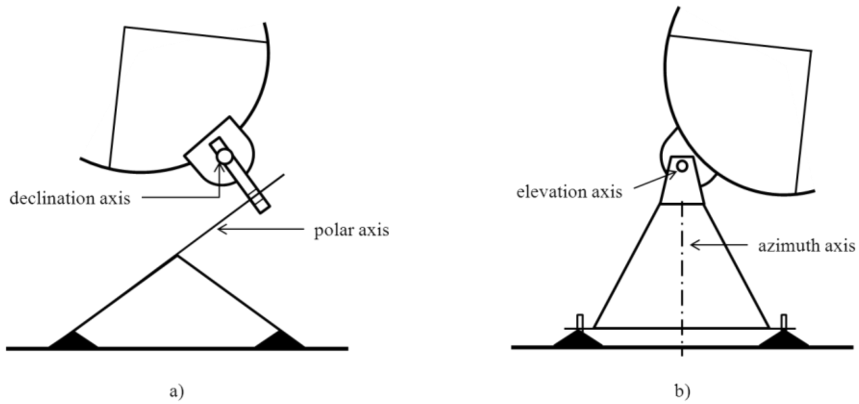

Figure 4: Typical mounts for radio telescopes. a) equatorial mount. b) alt-azimuth mount.

The mount of the antennas at UTP campuses are configured for satellite reception rather than radio astronomy, as we can see in Figs. 5 and 6. Therefore, it is necessary to design a totally new mount of this antennas; task that entails the colaboration of mechanical and electrical engineers and financial resources.

Figure 5: Mounts of the 6.71m diameter antennas

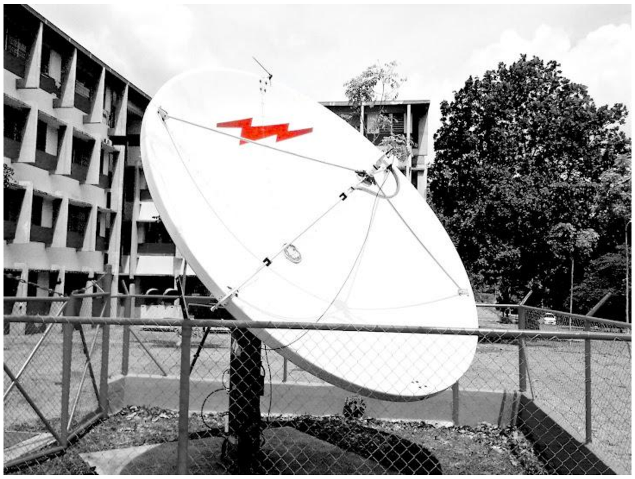

Figure 6: Mounts of the 4.6m diameter antenna at the main campus

1.3 CONCEPT OF INTERFEROMETRY

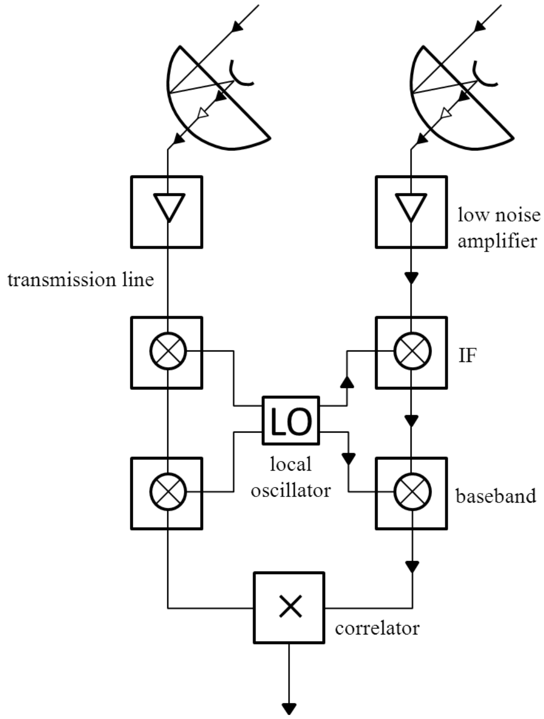

Figure 7: Two-elements interferometry system

The concept of Interferometry is to build a virtual huge radio telescope from combining the signals collected by smaller antennas. This antennas can be located relatively closed and connected directly or can be separated by many, even hundres of km. In this case it is refered as Very Long Baseline Interferometry (VLBI) (Middelberg and BachHigh, 2008). The more separated the antennas, the better angular resolution one can get. Fig. 7 shows a simplified diagram of two-elements interferometry system. Fig. 8 and 9 show the location of the antennas listed in table 1.

In tipical Very Long Baseline Arrays (VLBA) because of the distance of separation between the antennas, the different centers are syncronized with atomic clocks, the data is processed, digitalized and stored in hard disks and sent to the operation center where they will be correlated and processed. The sycronization with the atomic clock makes possible to identify and remove the delay from the signal to apply the digital correlation.

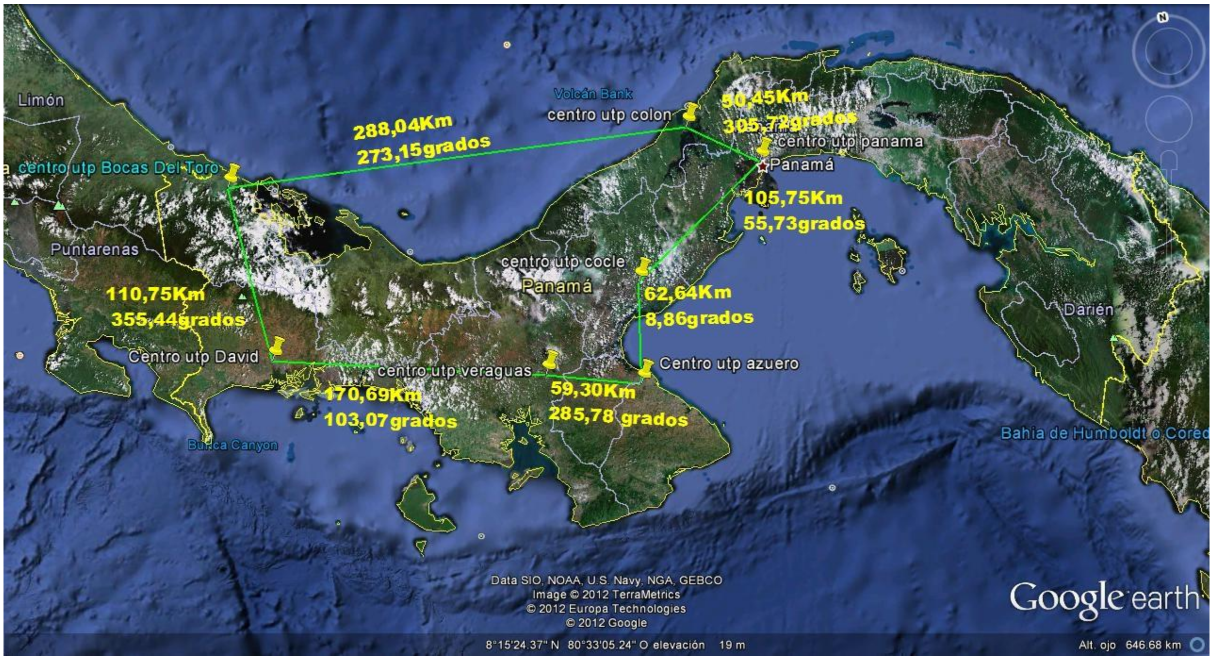

Figure 8: Location of the antennas listed in table 1.

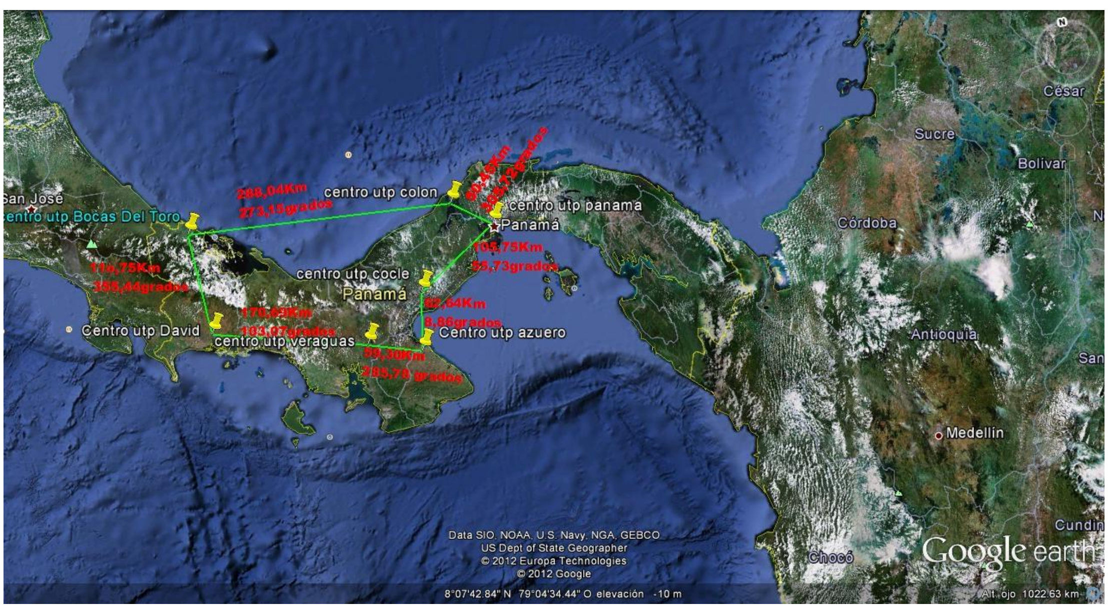

Figure 9: Location of the antennas listed in table 1.

Due to financial limitations, our first proposal is to build an VLBA with direct connections between the antennas using a very fast transmission medium such as optic fibers that will allow us to gather the data from the elements of the array in real time. This way, we could avoid the acquisition of an atomic clock and rely more on the local oscilators for syncronization. However, this will limit the distance between the antenna elements and the observatory to a few hundreds kilometers to guarantee phase stability of the signals. Therefore, we also have to evaluate the data presented in Table 2 and Fig. 8 and 9, to consider which parabolic antennas are suitable for the project.

Table 2: Approximate Distance from the Observatory in Penonome to the Antenna Elements of the VLBA

University Campus	**Approx. Distance from the Observatory in Penonome to UTP campuses**
Main Campus	104 km
Colón	107 km
Coclé	-
Azuero	60 km
Veraguas	82 km
Chiriquí	227 km

Note: *To collaborate with this project, to be part of the team or to get more information, please contact the PI: RDS (*rodney.delgado@utp.ac.pa*).*

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