Measurements of radio frequency interference in the 400-1500 MHz range at selected sites in Colombia

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Abstract. We present results of an RFI survey at pre-selected equatorial sites. This work is part of our effort to conduct observations of galactic emission at low frequencies (400 to 1500 MHz). Data on weather conditions, infrastructure, altitude and horizon elevation had previously been evaluated for five sites; in-situ measurements were conducted during August 1992. We conclude that two of the sites offer acceptable RFI conditions and could be suitable for radioastronomy: Morro Negro (Villa de Leyva) and Ubaté, both in Boyacá.

1 Introduction

The detection of structure in the Cosmic Background Radiation by the *COBE*-DMR experiment (Smoot et al. 1992) has shown the importance of and necessity for a complete map of the galactic radiation in the radio frequencies. Measurements of the diffuse emission from the galaxy at few frequencies (e.g. 408, 820, 1420 MHz) will provide sufficient knowledge of the synchrotron emission so that it can be extrapolated to higher frequencies (microwave) and thus separated from the Cosmic Background Radiation.

The possibility of conducting a calibrated survey of the galactic brightness temperature at several sites, including an equatorial one, was discussed by De Amici et al. (1993). The need and advantages of an Equatorial site for radio-astronomy along with preliminary results of a site search in the region have been presented by Hoeneisen et al. (1992) and Torres (1991). Here we give additional information on these sites consisting of measurements of the use of the electromagnetic spectrum in the frequencies of interest for radio-astronomy. The requirements for a good site are: a) to minimize atmospheric emission the site needs to be dry, or have two dry seasons during the year, and be at a high altitude (at least 2,500 m above sea level for frequencies less than 2 GHz); b) the site must have low wind speeds to minimize the torque on the support structure of the antenna; c) the site must be free of radio interference at least in a 50 MHz window centered at the chosen frequencies, d) adequate infrastructure (roads, electric power, and telephone or radio); e) low horizon (mountains on the horizon must be below 10°) is essential in order to avoid ground emission and diffraction. The five places we inspected include: 1 - Parque Natu-

ral de Chingaza (Cundinamarca), 2 - Chía-Sopo (Cundinamarca), 3 - Morro Negro (Boyacá), 4 - Ubaté (Boyacá) and 5 - Cerro del Son (Boyacá).

2 The experimental setup

A movable RFI detection unit with a spectrum analyzer, a polaroid camera, a 2.5 KWatt power generator, an RF amplifier, three dipole antennas (410, 820 and 1,000 MHz), one Kandoian omni-directional antenna (300-3,000 MHz) and one aluminum reflector were prepared. The measurements were conducted on the 20, 21 and 22 of August 1992. Measurements of interference by the power generator were carried out on the sites by moving one of the directional antennas in a circle around the power generator and verifying that the signal was coming from the same direction no matter the relative location of the power generator.

The measurements were made first with the omni-directional antenna and then independently on each band (408, 820, and 1,420 MHz) with the appropriate dipole antenna. A reference signal level was obtained by connecting the RF amplifier input to a terminator at ambient temperature.

3 Measurements

Motivated by the obvious advantages offered by a site near Bogotá, we selected Chingaza and Chía-Sopo as potential good places. Knowing that locations near mayor urban areas are usually poorly suited for astronomy, we have also considered and investigated other sites further away from the capital, but still within a reasonble close distance.

1 – *site*: Parque Natural de Chingaza. *Description*: This is a natural park owned and maintained by the Acueducto de Bogotá and Inderena. The site has electricity and there is a small ($\approx$ 3 m tall) telecommunications antenna in the plateau where the measurements were conducted. The park has good roads. *Distance from Bogotá*: 35 Km from the north of the city. *Place of measurements*: Within the park we made measurements in the "Mina el Palacio" site at 3,900 m above sea level which is one of the highest peaks in the park and has direct access by road. *Time of measurements*: August 20 between 1:10 pm and 3:00 pm. *Results*: Because of its closeness to Bogotá the level of RFI exceeds the maximum tolerable level. As can be seen in Table 1, the bands reserved for radio-astronomy are too crowded.

2 – *site*: Chía-Sopo. *Description*: The site in Chía-Sopo is a peak at 3,000 m above sea level on the mountains that separate the Chía and Sopo Valleys, it can be reached by road, has electricity within few kilometers of the peak and there are many houses nearby. *Place of measurements*: The measurements were carried out at few meters from one house near the peak. *Distance from Bogotá*: 40 Km from the

north of the city. *Time of measurements*: August 20 between 5:00 pm and 6:00 pm. *Results*: The data show that radio-astronomical observations will be too difficult in the 408 MHz band, however the 820 and 1,420 MHz bands do have a 50 MHz window free of interference which can be exploited.

3 – *site*: Morro Negro. *Description*: This mountain peak at 3,250 m above sea level is located 2 hours by car from Villa de Leyva, a touristic town which offers excellent accommodations for technicians and scientists and favorable weather conditions characterized by being a very dry region. *Distance from Bogotá*: 180 Km. *Place of measurements*: A low horizon plateau (≈ 1 Km^2) on top of the mountain. *Time of measurements*: August 21 between 4:00 pm and 5:00 pm. *Results*: There is an 8 MHz window centered at 404 MHz free of interference. Although it is not as wide as desired, it is acceptable. There is a signal at 409 MHz. It is very directional, coming from around 15°W (in the direction from Barrancabermeja) and having a minimum at 80°W and 190°W. The 820 and 1,420 MHz bands are free of interference.

4 – *site*: Ubaté. *Description*: Is a valley at 2,500 m above sea level. The horizon is within the requirements ($< 10°$). *Distance from Bogotá*: 120 Km. *Place of measurements*: The measurements were conducted at a farm 10 minutes from the town of Ubaté. *Time of measurements*: August 22 in two sets: one between 9:36 am and 10:30 am at a few meters from the house and one between 2:00 pm and 3:00 pm on a clear field at ≈ 1 Km from the house. *Results*: The measurements (see Table 1) show a 46 MHz window free of interference around 408 MHz. The 820 and 1,420 MHz bands are clean for observations. An evaluation of the combined conditions for the five sites studied here makes the Ubaté site the most favorable one.

5 – *site*: Cerro del Son. *Description*: This is a peak at 3,000 m above sea level with very good infrastructure. On the peak there is a TV relay station of Inravisión with a house, electricity, phone, and a road that goes to the peak. *Distance from Bogotá*: 126 Km. *Place of measurements*: On top of the peak. *Time of measurements*: August 22 between 11:55 am and 12:30 pm. *Results*: The presence of the TV antennas makes it very unsuitable for radio-astronomy: the spectrum in the bands of interest here are totally populated. One of the operators of the station was asked to turn off one of their transformers but no effect was seen on the signals detected. We discard this site for radio-astronomy.

4 Analysis and Conclusions

The RFI measurements presented here highlight the fact that the requirements for an acceptable site for radio-astronomy are very hard to meet and in fact some of the requirements exclude each other. While RFI level decreases with the distance to a mayor city, the infrastructure costs increase with the distance. A final site selection

will have to result from a careful weighting of all characteristics with the compromises that this process may dictate. From the data one can see that it is too difficult to find a completely clean region of the spectrum, which may force a change in the design of the receivers: addition of special filters or a correlator.

Two of the sites originally identified as possible locations for observations were directly underneath communication antennas, therefore posing insurmountable difficulties of control and reduction of the interfering radio signals. A third one has

Table 1: Summary of RFI signals found. Site numbering is the same as used in section 3. The "Error" column indicates the uncertainty in the frequency determination and is the best resolution that can be obtained from the polaroid photos; it depends on the resolution/band-width used by the spectrum analyzer for the measurement. For the site assessment we have used: 1 = not suitable, 3 = barely suitable, 5 = suitable, and corresponding evaluations in between.

Site	Range (MHz)	Error (MHz)	largest contiguous usable frequency span (MHz)	assessment
1	403 - 413	0.4	0.5 at 407.4	1
	770 - 870	2	10 at 835	1
	1320 - 1520	4	50 at 1450	3
2	159-759	10	10 at 385	1
	70 - 1070	10	50 at 770	4
	1170 - 1670	10	100 at 1370	5
3	380 - 430	1	8 at 404	3
	570 - 1070	10	50 at 820	5
	1170 - 1670	10	100 at 1420	5
4a	383-433	1	15 at 408	5
	570-1070	10	100 at 820	5
	1170-1670	10	100 at 1420	5
4b	358-458	2	10 at 408	3
	570-1070	10	100 at 820	5
	1170-1670	10	100 at 1420	5
5	157 - 657	10	none	1

unobstructed line-of-sight contact with the Bogotá International Airport, and its radio and radar facilities. It should come as no surprise that these three sites showed extremely crowded RFI spectra. The fact that there was no attempt to select or filter the incoming signals should be noted, impling that in the presence of several strong emitters (like at Chía and Cerro del Son) the beating of one frequency over another could have led to the unrealistically high number of detected signals. Even if we discard 80% of the RFI as spurios and harmonic signals of out-of-band frequencies, the remaining is several orders of magnitude too large to allow the use of these sites for radio-astronomy.

Of the remaining sites, Morro Negro has a higher altitude, drier weather and better horizon than Ubaté but its location on the top of mountain makes it more likely to be affected by any development in the use of the RF spectrum in Colombia.

The Ubaté site could be a better one because of the wider 408 MHz window, and especially because of the existing infrastructure which will reduce costs significantly. There are many other places in Colombia, far from Bogotá, that might have very

good conditions for radio-astronomy. For example, La Zona de los Nevados, in the Central Andes Mountain Chain, and La Serranía del Cocuy, in the Oriental Andes Mountain Chain, which have peaks with altitudes higher than 5,000 m above sea level and are very dry. However, as this study has shown, metereological and geographical conditions alone should not be taken as a base for accepting a location as a potential site, and further investigation is needed on the land-use pattern, before it becomes worthwhile to conduct an RFI survey in-situ. Because these places are not accessible they were not considered in this study. For long wavelength maps of the galaxy (less than 1,000 MHz) the atmospheric emission is not a critical factor. The oxygen is well mixed and very stable, while the highly variable content of water vapour affect the antenna temperature only at the 0.1 K level or less (when clouds are not present). As the observing frequency reaches 1.4 GHz, however, an undetected 0.1 K change in the atmospheric signal would introduce an unacceptable level of uncertainty in the galactic maps. Although this effect can be reduced by repeating the observations over several days, it is advantageous to select a site where the climate is dry and stable. Above 2 GHz, the atmosphere becomes the most important factor, so if the site is thought to be used later for observations at greater frequencies, the site should be much higher than 2,500 m above sea level and in a dry area.

The RFI data were taken only during few minutes of one particular day. This does not give a complete survey of the use of the spectrum during the year, however, for the sites far from Bogotá the use of the spectrum is not expected to change drastically in the next few years because this is a rural area populated by peasants and farmers. It is also important to mention that the data were acquired during day hours when radio communications are more active. During the night, when radio-observations usually take place, it is expected to find better conditions. However if one of these sites is selected additional systematic RFI measurements are needed.

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