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PROTOTYPE OF BDA PHASE STABILIZATION SYSTEM

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ABSTRACT

This paper describes the Prototype of BDA phase stabilization system. The stabilization system provides attenuation of factors larger than 10 for high frequency temperature perturbations in the cable and electronics box and can provide great stabilization of phase delays in the system. The results of the tests performed showed the maximum rate of change of temperature was of about 1^{o}C/hour.

INTRODUCTION

The BDA – Brazilian Decimetric Array is a radio-telescope formed by an array of antennas dedicated to the study of Solar Physics. Individual antennas are provided with a LNA (Low Noise Amplifier) amplifier and a double conversion receiver along with the electronics for tracking and control movement of the antennas. The reference frequency signal to the receivers local oscillators is generated centrally and is distributed to the receivers through coaxial cables at 10 MHz frequency. Using PLL (Phase-Locked Loop) circuits the individual receivers generate their necessary LO frequencies signals. The down converter signals, at 70 MHz, corresponding to the received signal for the individual antennas, are them transmitted, through coaxial cables to the analyzing circuitry in the control room.

Figure 1 shows the simplified block diagram of the receiving section of BDA.

Due to the large dimensions of the array (some hundred meters) and to its components being located far apart and exposed to the sun, different operating temperatures and difference temperature variations are expected to occur during observations. Temperature variations may cause differential delay variations in the signal transmitted in the cables and also cause differential delay variations in the receiver electronics. Also, due to long distance between the antennas and the long lengths of the cables, the relative phase between the signals coming from different antennas can be totally masked by the temperature induced drifts.

STABILIZATION TECHNIQUES

Several different stabilization techniques are simultaneously employed to cope with temperature induced phase instabilities: temperature compensation of phase delay variations, thermal insulation, and temperature stabilization.

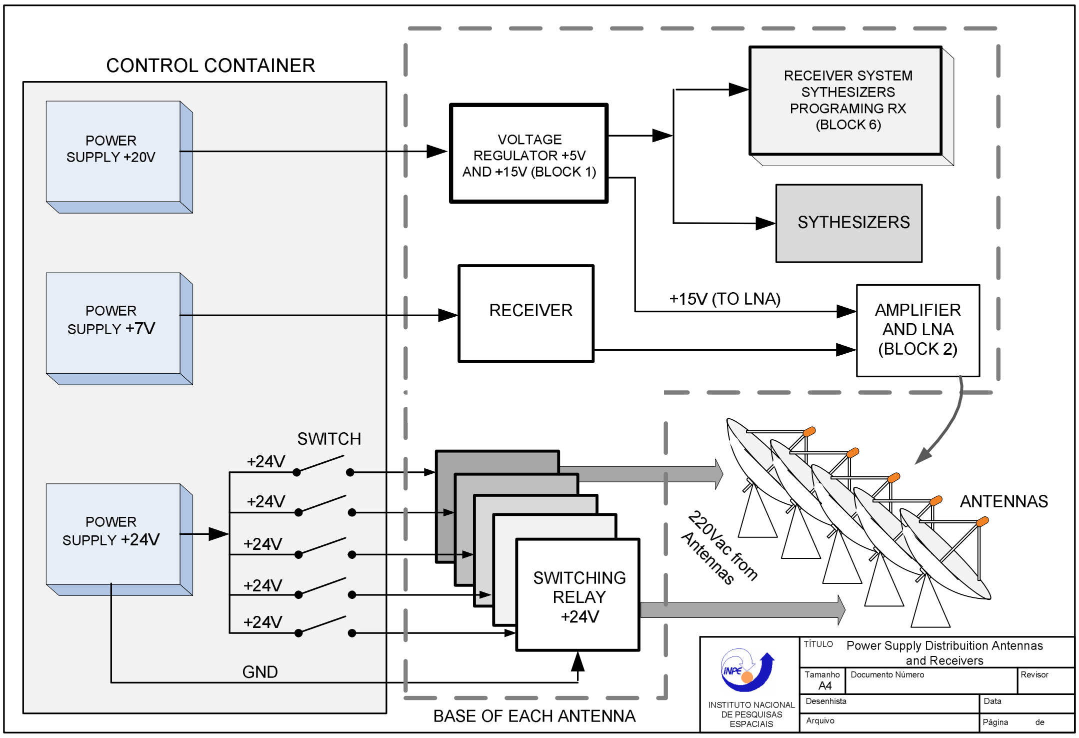

Figure 1 - BDA’s receiving section simplified block diagram

TEMPERATURE COMPENSATION OF PHASE DELAYS

Propagation speed in coaxial cables is heavily dependent on its temperature. Given the large differences in the distances between the antennas and the analyzing circuitry room, the temperature induced differential phase shifts between cables can be very large, even if using phase-stable cable.
A simple technique is used to compensate for such differential delays among different cables. The technique consists is cutting, to the same electrical length, all cables carrying the same type of signal from different antennas, regardless of the distance between the antenna the and analyzing circuitry room. All cables are cut to the same length of the longest cable, the remaining length of cable being kept at the same temperature as the used length. Assuming the cables are from the same manufacturer and have the same temperature coefficient of the propagation speed, the differential delays among the different cables are compensated for any temperature variation because the delays will track equally among them.

As an illustration of this, measurements of phase delays were carried-out for a length of 48 meter of the cable type intended to be used in the BDA (coaxial RGC 213 manufactured by Datalink Telecomunicação).

Phase delay measurements taken using an HP8510 Network Analyzer and a climatic chamber are presented in the Figure 2.

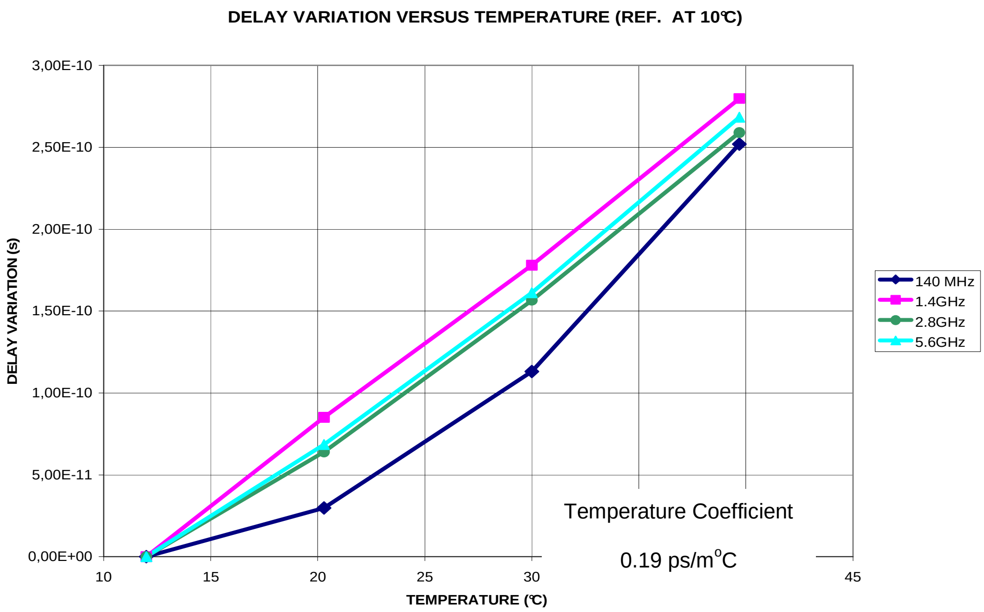

Fig. 2 - Phase delay measurements for cable datalink RGC213.

THERMAL INSULATION

Temperature compensation technique of cutting the individual cable to the same electrical length is not enough to assure delays stability if the temperature change seen by the cables is large. So, in order to reduce the temperature changes in the cables, the cables are buried at 1.0 meter depth. It was determined by tests that the temperature variations at this depth is only a very small fraction of the ambient temperature variations, this effect being caused by the high thermal impedance of the soil, i. e., high mass and low thermal conductivity.

The cable lengths that are not used, because they come from an antenna distant from the control room, are coiled and kept at the basement floor of the control room. The basement is also built underground, has thick walls, no windows and no parts above the surface. The cable bundle comes directly from the underground conducts to inside the basement floor.

Figure 3 shows actual ground temperature measurements, at different depths, performed at the site of the BDA during a period of one month. The graph shows that the temperature variation, at a depth of 1.0 m, during a period of one hour is negligible. The one-day period noise, clearly visible in the measurements taken at 0.5 m and 1.0 m, is caused by interference on the measurement system from the condensation prevention heater turn-on/turn-off during night-time.

GEOTHERMAL COUPLING

There are parts of the system that, despite being built identical, are difficult to compensated and difficult to insulate from the environment temperature changes because they must be installed above ground due to required maintenance, etc. These are the receiver box, the LNA amplifier and the interconnecting cables. Those parts are difficult to stabilize because they have low thermal inertia and are exposed to the atmosphere and to the sun. The temperature stability of those parts are assured by insulating them from the environment by using insulation foam material and coupling them to the thermally stable ground temperature by a geothermal heat exchanger using air as a heat transport fluid.

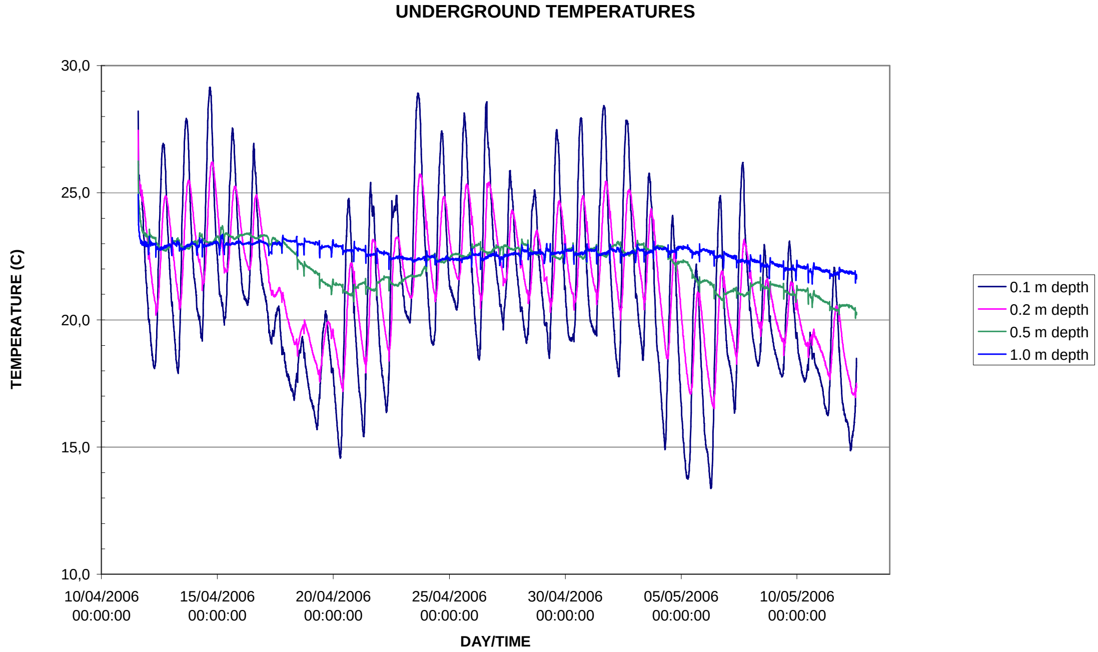

Fig. 3 - Actual temperature monitoring at different depths.

PROTOTYPE OF BDA PHASE STABILIZATION SYSTEM

Description

Instead of starting taking measurements of ground thermal conductivity, thermal capacity, etc, for the proper dimensioning of the stabilization system, it was decided to build a prototype of the system in one antenna and, after some tests, adjust its characteristics (insulation thickness, air speed, etc) to meet our requirements. It was agreed that this could save time in the development of the system.

The prototype design is of a closed type, i.e., the same air is used to transport the heat to/from the antenna system and the underground heat exchanger. This would prevent condensation inside the system caused by the prevalent high humidity conditions at the site, which would occur if an open system was used.

Several difficulties have arisen during the search of the necessary material for building the prototype. The most difficult problem to solve was to find an adequate air blower. It was found that it is possible to find in the market several types of axial flow blowers with several different sizes and capacities but, radial flow blower, the most adequate for the prototype, could be found only in a very small number of different capacities. The prototype was built only using commercial available parts. Coaxial cables are running inside regular electrical conduits and are thermally insulated using closed cell polyethylene foam tubing used in hot water system for residential buildings. Thermal insulation is improved by the use of aluminized adhesive tape. The receiver electronics is installed inside a rigid

PVC box insulated with polystyrene foam. The air blower case and the LNA box were insulated using closed cell synthetic rubber foam (Armaflex). The use of different materials for different applications was required because some materials are only available in rigid sheets, inappropriate to insulate boxes of cylindrical or irregular shapes.

The underground heat exchanger was built using thin walled 40 mm diameter rigid PVC piping commonly used for residential sewer system. The underground heat exchanger has a total length of 12 m and was buried at 1.0 m depth. No action was taken to improve the heat conductivity of the soil in the region of the heat exchanger. The total length of the external (above ground) system is about of the length of the underground heat exchanger. Considering the soil temperature absolutely stable, it is foreseen that the attenuation of the external temperature variations must be in direct proportion to the ratio between the internal-to-external thermal resistance and the internal-to-soil thermal resistance. Figure 4 presents a sketch of the heat exchanger and piping system.

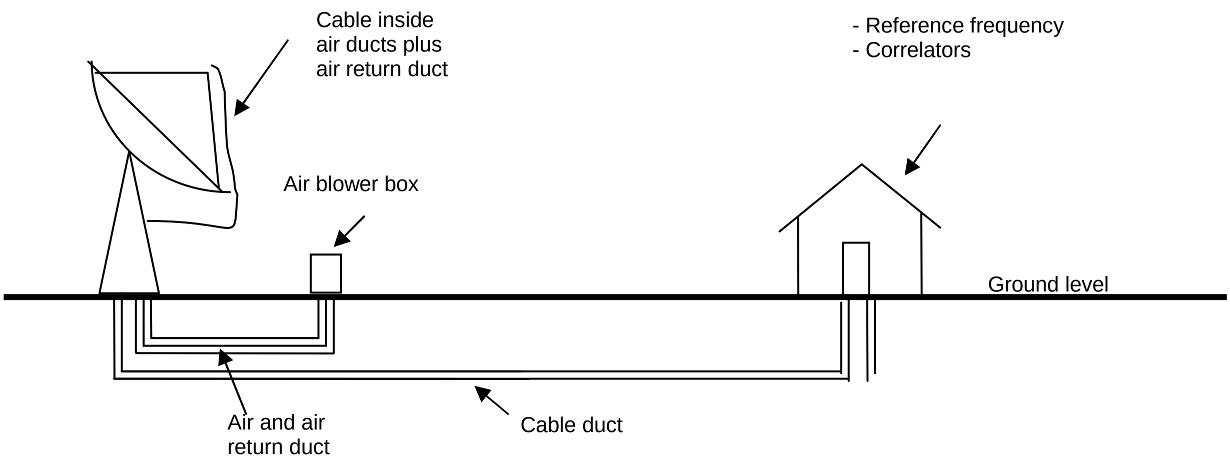

Fig. 4 - Sketch of the heat exchanger and piping system.

EXPERIMENTAL RESULTS

Test of July 16th, 2008

The test performed in July 16th, 2008, was done before the planned configuration for the prototype had been fully completed. There were some lengths of piping not insulated with polyethylene foam, aluminized film was not applied over the thermal insulation, and the blower motor was not thermally insulated from the blower. Figure 5 shows the temperature evolution during the test.

It can be seen from the graph that the internal temperature was closer to the external temperature than to the soil temperature. This effect is caused by poor thermal insulation in the above ground system parts. Some filtering of the external variations can be seen due to higher thermal impedance of the system. It is clearly visible that the internal temperature was rising with a rate greater than the external temperature. This effect was probably caused by the heating introduced by the blower motor. Another test was planned after the system thermal insulation was improved.

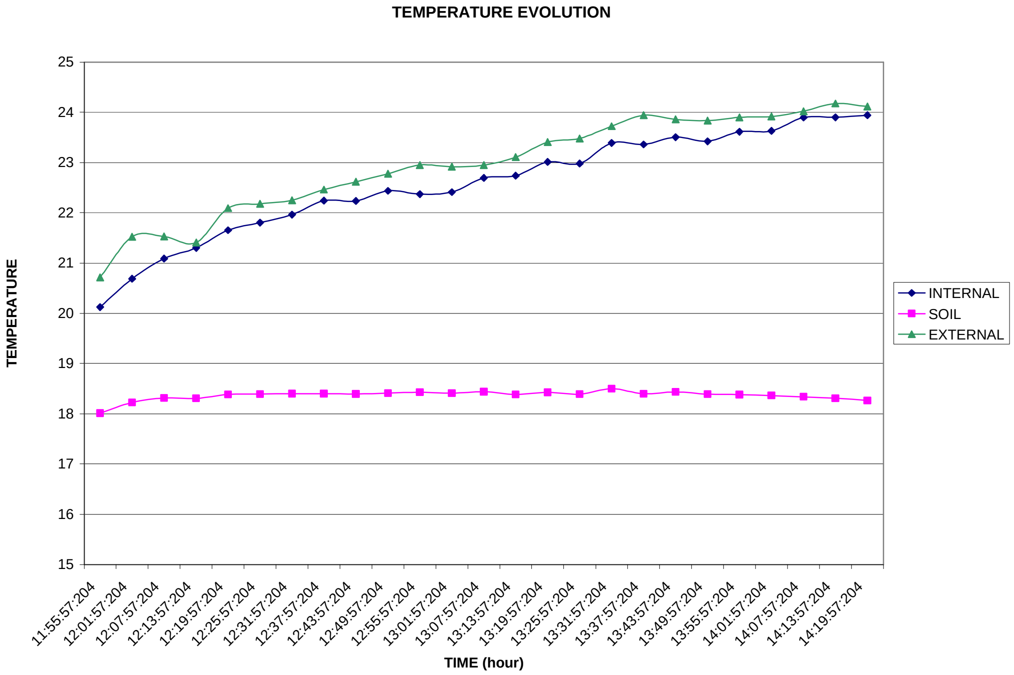

Fig. 5 - Temperature evolution during the first test.

Test of July 25th, 2008

The second test was done after better insulation of the external piping, the installation of aluminized adhesive tape over the expose piping and the better insulation between the electric motor and the blower. Measurements taken during the second test are presented in the Figure 6.

The results of the second test show that is much better uncoupling of the external environment temperature and the internal system. The maximum rate of change of temperature was of about 1^{o}C/hour.

CONCLUSION

Measurements taken without any stabilization system, presented in Figure 7, show that temperature variation of more than 10^{o}C/hour can occur. The stabilization system provides attenuation of factors larger than 10 for high frequency temperature perturbations in the cable and electronics box and can provide great stabilization of phase delays in the system. It is planned to carry-out measurements of the phase variations caused by the observed temperature variations to verify if upgrades are still required in the prototype.

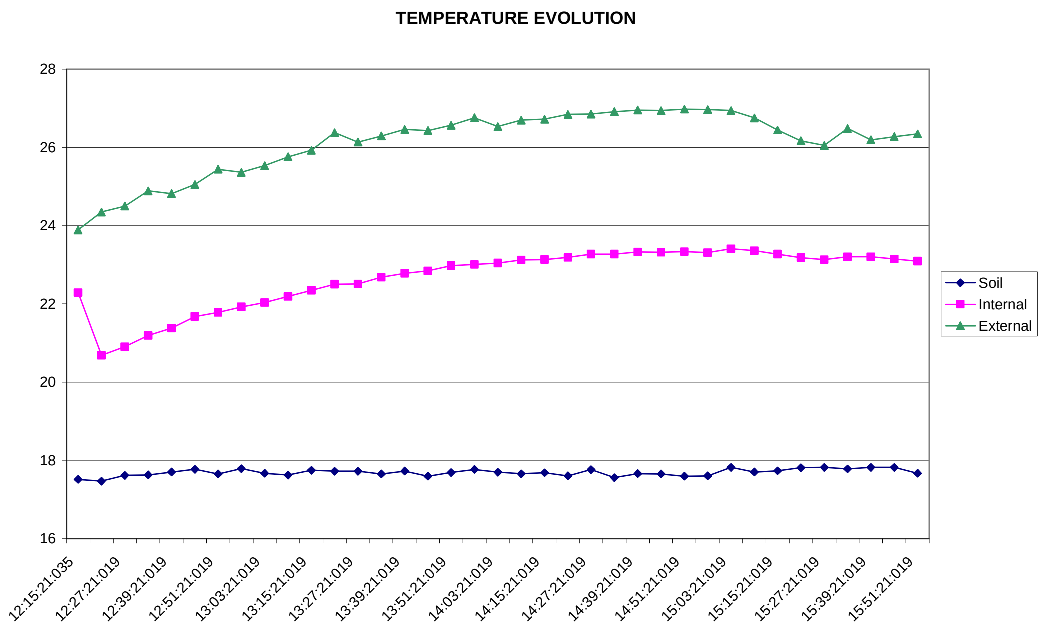

Fig. 6 - Temperature evolution during the second test.

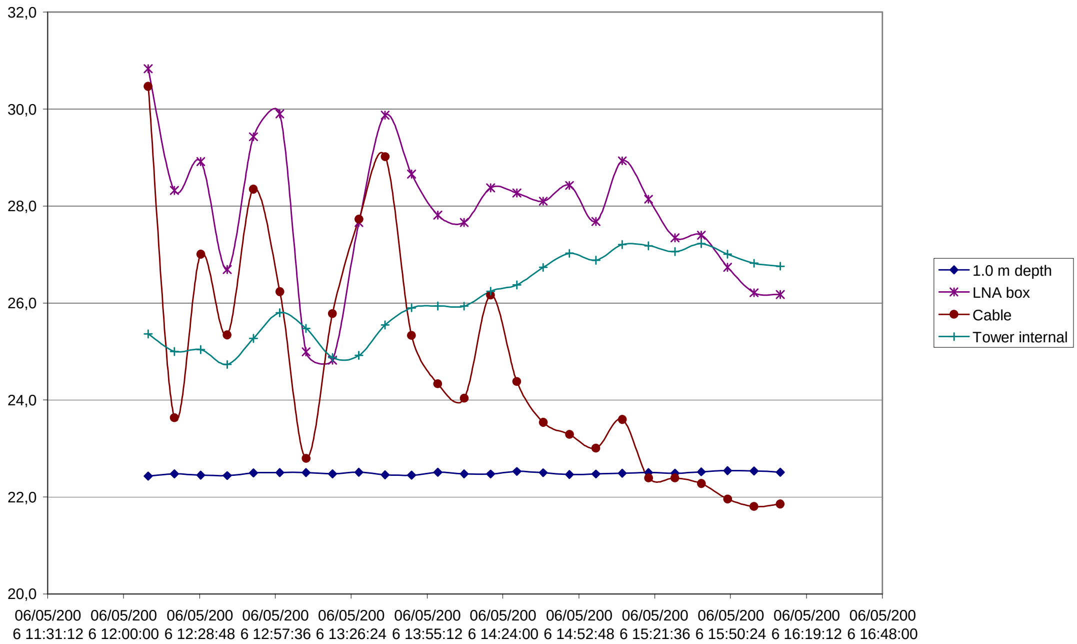

Fig. 7 - Temperature measurements without stabilization system.

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