Geoda: unitary cell distribution, composition and working properties.

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Abstract

Nowadays, satellite communications are basic for the human lifestyle. In this way, a smart, conformal and multi-array antenna (GEODA) is being developed in order to receive signals from several satellites simultaneously in the 1.7 GHz working band. An adaptive [3] beam system is able to follow the signals from the satellite constellation. The complex structure of the antenna is based in similar arrays of triangular shape. These arrays are divided in sub-arrays of three elements called *Cells* composing the single control element for the array's main beam direction management. In this paper, the working properties and the design of one cell will be shown and discussed.

1. Introduction

First of all, it is necessary to introduce the structure of the complete antenna in order to understand the required shape and working properties of these cells. The GEODA antenna consists in two different parts. First one is based in a cylinder 1.5 meters height. The second one is a polyhedron of thirty triangular-shaped faces based on a dodecahedron. Each face of a dodecahedron has pentagonal shape, but, in order to obtain triangular arrays, pyramids have substituted pentagons. According to that, every face of the Geoda is covered by similar triangular arrays of circular stacked patches. Each triangular array has active pointing direction control and leads the signal to a digital receiver through a RF conversion and filtering process. An adaptive digital system allows the adequate signal combination from several triangular antennas. The main patch is fed in two points with a phase shift of ninety degrees in order to obtain circular polarization. So, a branch line circuit is required to achieve this phase difference between feeding ports. Only one of the output ports of the branch line circuit is used, being matched the other one. The signal from the balanced power divider is amplified by means of a LNA. At this frequency, the signal is increased 12dB.

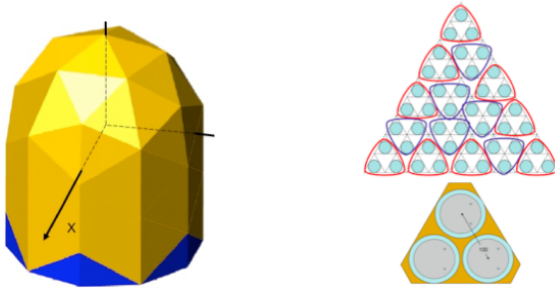

Figure 1: global antenna structure, panel array and cell.

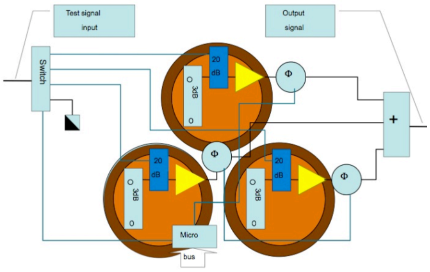

Figure 2: detailed cell

To follow the signal from the satellite, the main beam direction has to be able to sweep an angle of sixty degrees. In this way, it is needed a phase shifting in the feeding currents of the single radiating element. Previous calculations have demonstrated that six steps of sixty degrees are needed to achieve the required sweeping angle. So a digital controlled phase-shifter circuit has been developed and will be shown in its corresponding paragraph. There are three elements per cell and their signals are summed by means of a 3-way balanced Willikinson circuit.

Once the three satellite signals are received, phase shifted and combined, it is amplified again by means of LNA amplifier which output will constitute the RF output of the cell. From each branch-line circuit, a test signal will be extracted by means of a 25dB coupler. Therefore, in addition to the main RF output signal, each cell has three outputs for testing the proper behavior of the cell.

Besides the RF system, the electronic control sub-system has to be taken into account, since the space dedicated for each cell is really limited. In this way, a microprocessor, four control buses, four pairs of connectors and their connections to the phase shifters control pins should be included in the cell design.

Each part of the cell, its working requirements, its behavior and actual design will be presented in the next paragraphs of this document.

2. Single radiating element and Branch-Line Coupler.

The single radiating element consists in two stacked patches fed in two points located at the same distance from the center of the disk but ninety degrees separated. Patches are printed on glass fiber and are separated each other by a foam layer. The feeding biases start in the hybrid layer, cross the ground plane layer and join the main disk. This disk is bigger than the coupled one, in order to obtain two resonance points and therefore, a wider working band. In this way, the bandwidth is increased and circular polarization with really good axial ratio is achieved.

Measurements of the electrical properties of hybrid coupler and of the assembly patches – Hybrid coupler have been taken and they reveal a really good behavior. Radiation measurements have been also taken and show that in a wide range of angles, the axial ratio is less than one, since maximum difference between branch-line outputs is 0.6dB in module and 0.7º in phase at 1.7GHz. In addition, the radiation pattern in both polarizations has very low cross-polar levels in the main planes (φ = 0º, 45º, 135º, 180º).

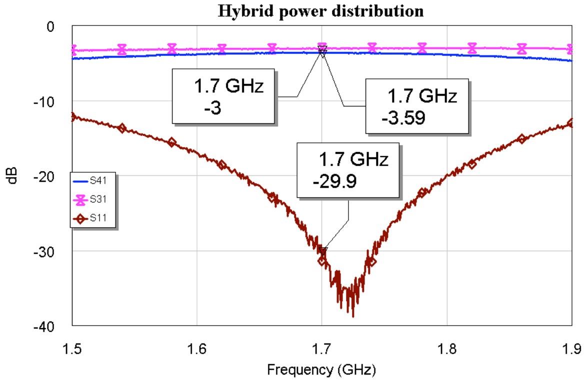

Figure 3: power distribution and return losses

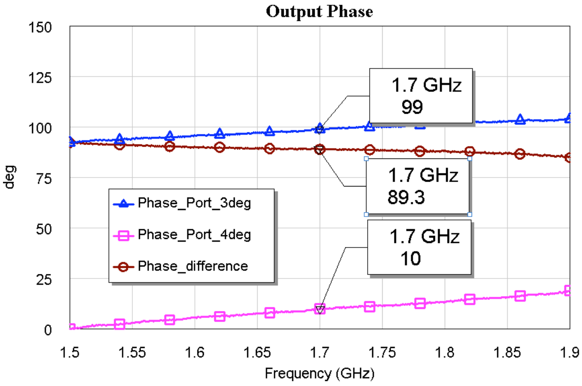

Figure 5: phase difference in branc-line outputs

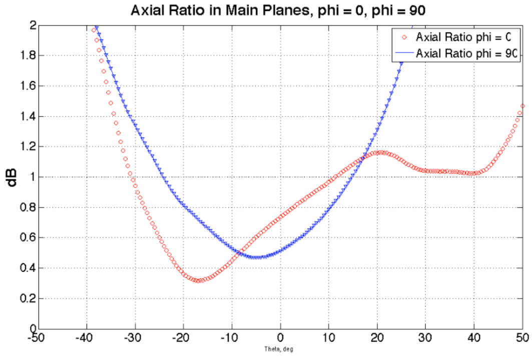

Figure 4: axial ratio of the assembly patches - Hybrid circuit

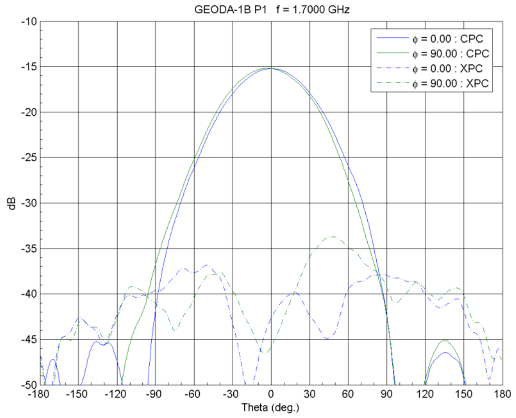

Figure 6: radiation pattern of the assembly patches - Hybrid circuit

3. Low noise amplifier and 25dB - coupler

Once the signal is received from each patch and delivered from the branch-line, the first element of the reception chain is a Low Noise Amplifier (LNA) which noise figure is better than 1.38dB at 1.7GHz. In this band, the scattering parameters announce that the device is only conditionally stable, so the maximum amplifier gain could not be obtained. The implemented circuit optimizes the noise figure, gain, input intercept point although matching level is worse than 7dB in both ports. By improving the input port return losses, noise parameter became worse. The commercial device used is MBC13720 from Freescale Semiconductor that has a low current consumption for the selected working mode, (5mA in low Input IP3).

In order to examinee the received signal from each patch, a portion of it is extracted from the main RF system by means of a microstrip coupler. It is placed throughout the Branch-Line circuit and it consists in a microstrip line with one end matched and the output in the other. The extracted signal has a -25dB less than the original.

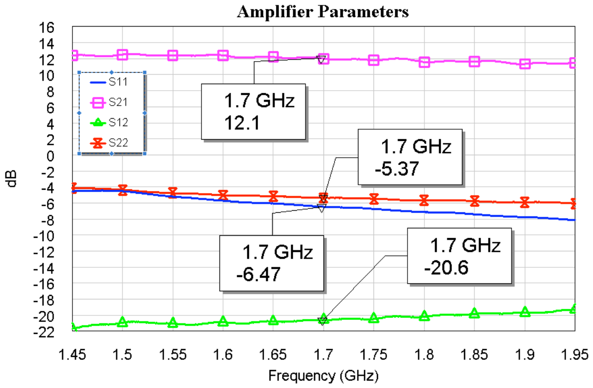

Figure 7: LNA behaviour

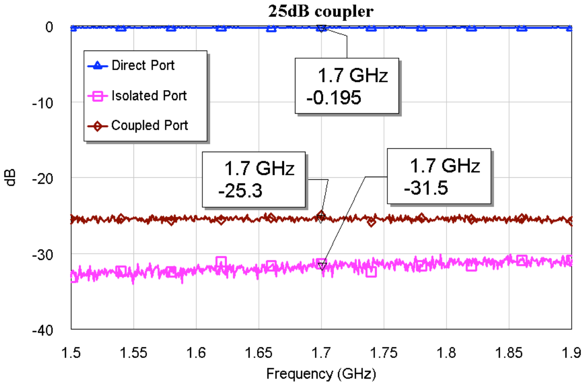

Figure 8: 25dB coupler behaviour

4. Wilkinson Combiner

The RF output signals from each patch are summed in this device. It s purpose is to isolate each input from the others and transmit directly all the incoming power to the common output. The resistors are placed in star configuration connecting each branch with a common point, since it was easier to build and the required space is smaller than in other configurations. In this first design and implementation, the input ports isolation is better than 25dB, although the optimum adaptation point in the output is displaced to lower frequencies.

Figure 10 shows the balanced power distribution of the device, since the maximum difference is 0.15dB. In the other hand, the phase shifting of the combiner is similar in all branches. In the final design, one Wilkinson will be use tu sum all the RF signals from the cell antennas and a secondary Wilkinson will be used to combine the extracted test signals.

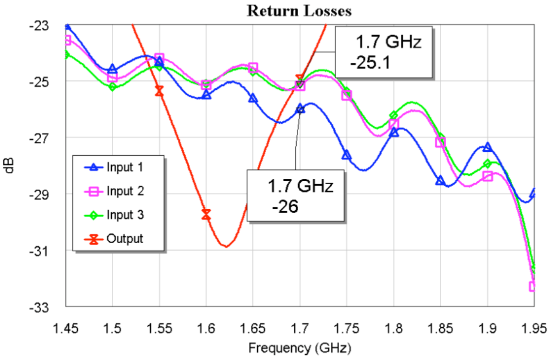

Figure 9: Wilkinson reflection losses

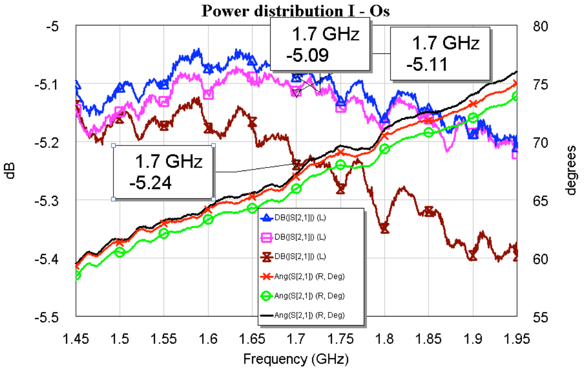

Figure 10: Wilkinson power distribution and output phases

5. Phase shifting subsystem

The main beam direction depends on the phase of the antennas feeding currents. In this way, controlling this phases, the pointing direction can be managed. Between the LNA and the wilkinson, the phase system is placed. By means of several adaptive algorithms, the antenna can modify itself its own radiation pattern.

This device consists in two switches situated face-to-face, which pins are linked through six microstrip lines with different electrical lengths. It has been shown in previous papers ([1], [2]) that the phase step needed to properly track the satellites is sixty degrees, so that is the difference in electrical length from one microstrip line to the next one. It is required a device that has one input and six outputs, so three control pines are also required. Therefore, the integration space constitutes the main limitation of the design, besides the RF circuit, the DC control must be taken into account. The selected switch of the phase shifting subsystem is PE4268 (Peregrine Semiconductors) which switching losses are relatively low in the working band.

6. Electronic Subsystem

The purpose of the control system is the management of the different items that constitute the array. The phase shifters for composing the main lobe direction, calibration signals and the LNA feeding currents are some of the most important aspects to control. All of these must be supervised and controlled; therefore a dedicated microprocessor per cell should be included. Due to this, we need to connect these with the master microprocessor of the planar array. Some proposals have been studied and the standard bus I^2C has been selected, since it allows a high level addressing capabilities.

This standard is a serial bus that needs another cable, since data and clock are sent separately. It uses a 7-bit addressing system with 16 reserved addresses, what implies 112 nodes. It can work in four ways: low-speed mode, 10kbits/s; standard-mode, 100 kbits/s; fast-mode, 400kbits/s; high-speed mode, 3.7 Mbits/s. Normally, there is only one master processor in the bus but it is possible to find more than one in special configurations.

In addition, a connection and control bus is needed, from a PC to the master array microcontroller. The control of the entire antenna phase system will be managed through an adaptive algorithm. Nowadays, the USB bus standard has been chosen in order to control the main chipset of the array from a computer since it is fast and flexible enough for the necessities of the satellite link.

5. Conclusion

A new complex, smart, adaptive and conformal antenna is being developed. The first step has been concluded: the reference device of one array, the cell, has been designed and all of its components have been tested and measured in real working conditions. In this paper the measurements of these devices and the planned control system have been presented. Next papers will follow the complete improvement of the planar array of cells and, consequently, the antena growing.

6. Acknowledgments

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7. References

[1.] I. Montesinos, J. L. Masa, J.L. Fernández-Jambrina, and M. Sierra-Pérez. *Pyramidal adaptive antenna of plannar arrays for satellite comunications*. Proceedings of the Second European Conference on Antenna and Propagation, November 2007.
[2.] M. Sierra-Pérez, A. Torres, J.L. Masa, I. Montesinos. Geoda: *Adaptive antenna array for satellite signal reception*. Proceedings of the Second European Conference on Antenna and Propagation, November 2007.
[3.] Miguel Salas, Ramón García-Martínez. *Preliminary analysis of the calibration procedures for a geodesic antenna array (GEODA)*. Proceedings of the Second European Conference on Antenna and Propagation, 2007.