Passive Microstrip Transmitarray Lens for Ku Band

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***Abstract*— The aim of this paper is to introduce a novel 12 GHz radiating design based on the idea of transmitarray lens device. In this document, an overview of the functioning of this kind of devices is given and the proposed transmitarray lens is studied, with architecture discussion and selection, as well as some ideas about the design, and manufacturing. In the document, some design, manufacturing and validation of the constituting elements of the lens (radiating elements, transmission circuits and transitions) are presented, together with a complete prototype of assembled transmitarray lens. Radiation pattern measurements in anechoic chamber, as well as gain and directivity values are offered.**

I. Introduction

A transmitarray lens is a novel structure whose function consists of changing a propagating wave into another with particular new features (spherical to plane wave translation, new steering direction, etc.).

A. Transmitarray Theory

The basics of this sort of structures are easy to be understood: an electromagnetic wave with specific wave front properties is received, processed in a particular way (change in the radiation pattern, amplification, etc.) and finally signal is retransmitted and a new wave front is generated [1, 2], as sketched in fig. 1.

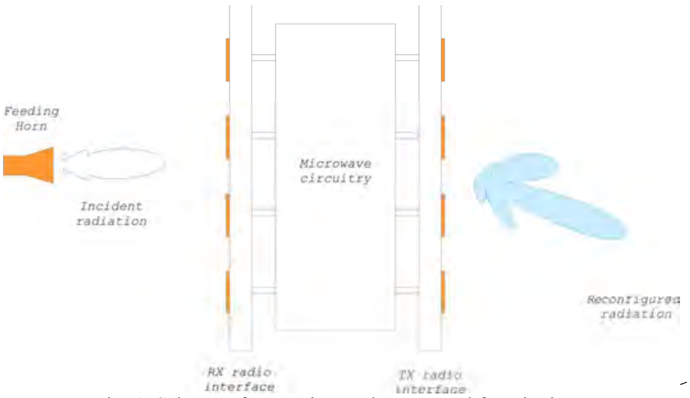


Fig. 1 Scheme of transmitarray lens general functioning.

A spherical pattern reaches the RX radio interface. As the interface is plane and the incident wave received has a spherical distribution, a non negligible phase shift is obtained to each radiation sample because of the different path length from the feeding horn to each cell. This can be solved with spherical to plane wave error correction, as in [2]. The main value in this device consists of placing it in front of a particular antenna, in order to obtain two main advantages:

- Phase error correction due to spherical-type wave front coming from the feeding antenna.
- New radiation pattern configuration, modifying the phase response of each forming transmitarray cell.

The lens structure offered in this paper is constructed with microwave subsystems designed to work at 12 GHz. These subsystems are two radio interfaces and microwave circuitry which connects them. In this way, one radio interface (RX) works as back end while the other one (TX) acts as front end. The RX interface is illuminated with a feeding horn whose phase centre is placed at 120 mm from the interface.

B. Subsystems Implementation

The radio interfaces are bidimensional arrays. Both TX and RX arrays have the same hierarchical structure. The radio array is constructed with N^2 independent radiating cells forming a NxN radiating cells square with 0'6· λ_0 separation, in terms of wavelength (λ_0). Each radiating element is a broadband multilayer microstrip antenna working at 12 GHz. We can see a scheme of the radio interface in fig. 2.

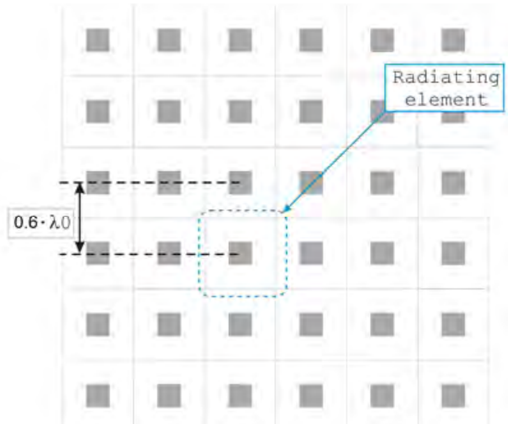


Fig. 1 Parts of the Tx and Rx radio interface

II. STRUCTURE DESIGN

Considering transmitarray structures with planar technology, the most troublesome task is to place the processing interface inside the structure, between both radiating interfaces, because of the space available [3, 4]. To overcome this constrain, perpendicular connection between interfaces is introduced, as fig. 3 offers.

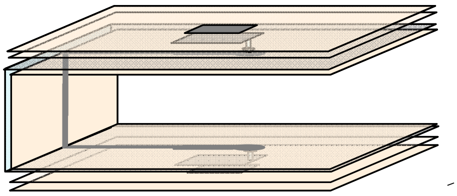


Fig. 3 Scheme of the connection between processing interface and radiating ones.

Globally, the assembly to be performed for the passive lens, for each transmitarray cell, includes the transition device between a coaxial-type feeding at each patch and the microstrip lines, and the perpendicular connection, as it is offered in fig. 4.

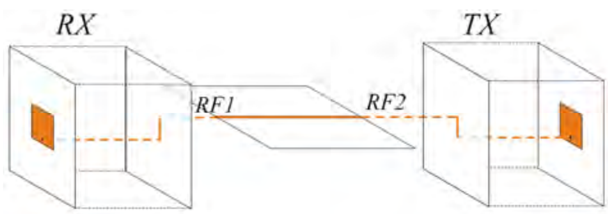


Fig. 4 Assembly model for transmitarray cell.

The patch structure is classified depending on the distance of each patch to the feeding horn, considering the radiation pattern requirements: patches are classified in concentric rings. According to this, the needed phase error correction together with new phase configuration for pattern modification can be introduced at each cell, in terms of lengths in the transmission lines, in the processing interface. The modification in the phase signal at each transmitarray cell is introduced by means of electrical length modification it the transmission microwave devices placed between the RX and the TX interfaces. Doing this, we obtain a homogeneous phase distribution in the radiating cells of the TX interface and a new radiation pattern and plane wave radiation. In this design, a 10 degree tilt is added to one of the main axis of the original radiation pattern.

A. Radiating Interface

The radiating interface is formed by an array of radiating elements. Patches are selected, due to their planar structure, suitable for transmitarray lens devices regarding the selected geometry. In order to increase the bandwidth of the structure, multilayered stacked patch elements over ground plane are applied, rather than simple patch ones, due to their wider working frequency band. Concerning the design stage, CST Microwave Studio is applied. Fig. 5 depicts the layer distribution and materials employed.

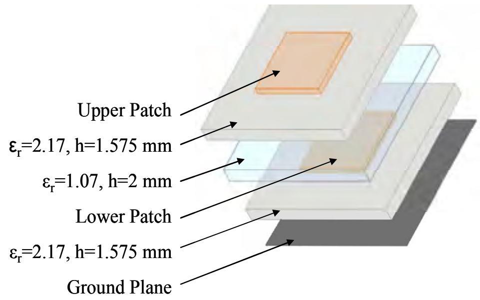


Fig. 5 Model for patch design, in layer scheme.

Fig. 6 shows prototype results along with its design results, for a single stacked patch cell embedded in array.

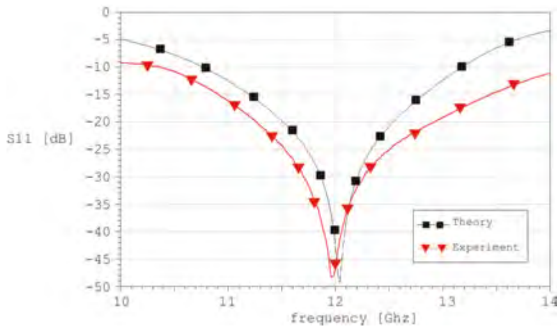
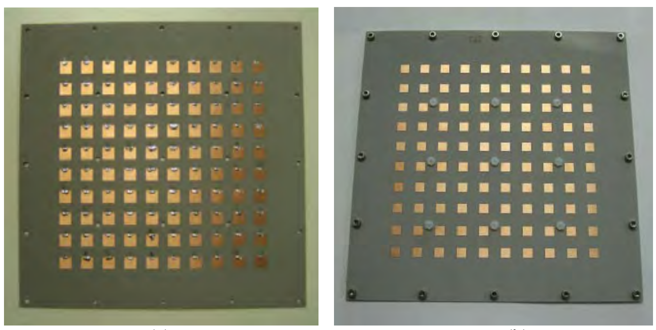


Fig. 6 Stacked patch cell embedded in array: measured and simulated results.

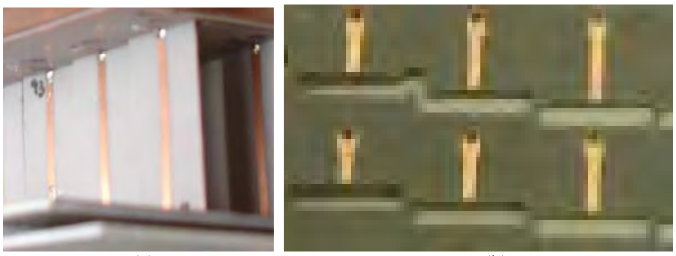
III. TRANSMITARRAY LENS ASSEMBLY

The final complete assembly to be carried out, for each transmitarray cell, includes the transition device between the coaxial-type feeding at each patch and the microstrip lines, and the transition device with perpendicular connection between interfaces, as it was offered in fig. 4. Complete details about the design and prototyping of all the constituting elements are given below, along with the complete assembly of a passive lens. Some details are given in fig. 7, fig. 8 and fig. 9.



(a) (b)

Fig. 7 Transmitarray radiating interface. (a) Lower array layer. (b) Upper layer.



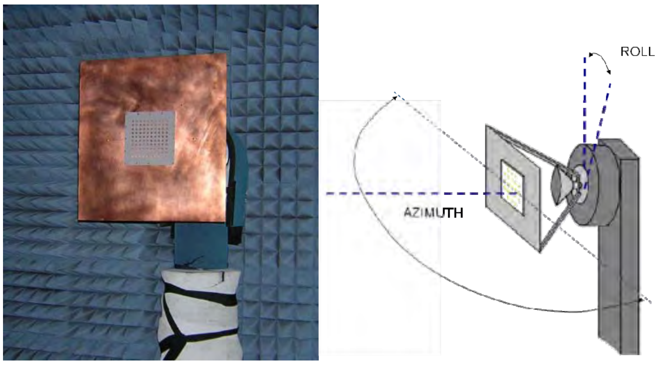
(a) (b)

Fig. 8 Complete assembly (a) Connection detail. (b) Line detail.

Fig. 9 Complete Transmitarray.

IV. Measurement Results

The passive prototype is set up for radiation pattern measurements. As pointed out, the prototype introduces spherical wave correction with steering vector of θ=10º in one of the main axes. In fig. 10 we can observe the mounting scheme for measurements. A tridimensional plot of the full acquisition is shown in fig. 11.



(a) (b)

Fig. 10 Assembly for measurements. (a) Mounted prototype. (b) Measuring scheme.

These measurements are studied in order to determine measured gain results and expected directivity values. Measurements yield 24 dBi in directivity and provide 23 dBi mean value in gain, at 12 GHz.

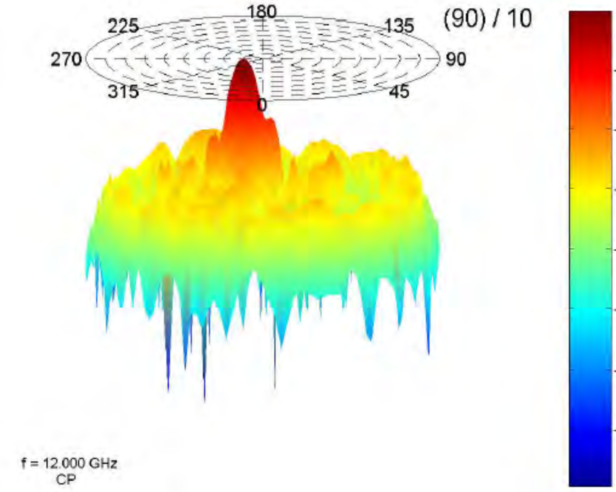


Fig 11 3D Measurement results.

V. Conclusion

A complete passive transmitarray lens device has been shown. Some theoretical background and architecture considerations are given and the proper model is chosen, adapted in order to admit the integration of the processing interface inside the complete lens design. The radiation patterns show very clear main lobes. The measured results of steering configuration agree properly with expected data. Secondary lobes behave as expected. As it is observed the radiation pattern reconfiguration as well as spherical wave correction is achieved with the prototype described.

Acknowledgment

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