# DESIGN OF A DOUBLE ARRAY LENS

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**ABSTRACT**

The aim of the paper below is to present a particular structure, working as if it were a double array lens (Transmitarray). The structure consists of a patch array in the reception part, a phase delay for each patch and another patch array in the transmission part. The idea in using this device is to place it in front of a particular antenna in order to modify the radiation pattern of the feeding antenna.

The architecture that is being applied implies the use of patches with via feeding. To avoid undesired coupling between the reception and the transmission arrays, ground planes that isolate the reception array, the phase delay and the transmission array are placed. In this paper the phase delay part, the radiation part and the whole structure are analyzed and simulated. Finally, some prototypes for the phase delay structure are presented.

## 1. INTRODUCTION

The objective that is being tried to achieve with this research work is to design and manufacture a complete double lens, using patch arrays in the reception and transmission part. This structure is also commonly known as 'Transmitarray'.

The basics of this kind of structures are easy to understand: an electromagnetic wave with specific front wave properties is received, it is processed in a particular way (change in the radiation pattern, amplification…) and finally the wave is retransmitted. Attending to the components used to process the signal, lenses are classified as active lenses (if external feeding is used in the inner circuitry ) or passive lenses on the contrary. In this paper the attention is centred in the design and manufacture of a passive lens.

The idea with this kind of structures (passives in our case) consist of placing them in front of a particular antenna, in order to obtain two fundamental advantages:

- correction of the phase error of an antenna (for instance, the phase error in a horn antenna due to geometry).
- configuration of a new radiation pattern.

All those effects are obtained modifying the signal (delay) in the inner part of the lens. Efforts have been done in changing the phase error in a particular antenna.

## 2. THE STRUCTURE

The structure, in general, consists of two patch arrays, one receiving signal and the other transmitting it, and a transmission line for each pair of patches (one in the reception part, the other in the transmission one). Notice that as far as the structure is a passive one, signal could be either received or transmitted in any of both arrays. Extending or shortening the transmission line among reception patches and transmission ones let us modify the signal phase delay on our own; therefore it is possible to make corrections in the radiation pattern, as it is seen in Fig. 1.

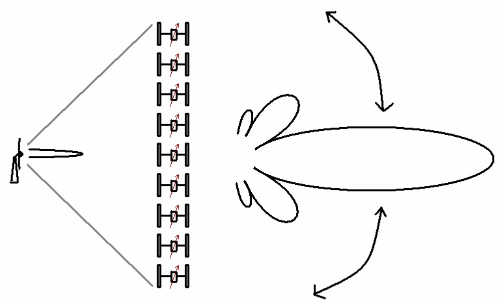

*Figure 1. Double lens operation scheme.*

Even though the proposed scheme (reception array, phase delay and transmission array) seems to be easy, its implementation is quite hard. As conditioning elements that have to be considered from the very beginning, we point:

1- Necessity of a great isolation between the reception and the transmission part. For that reason, the architecture than we are going to consider implies the use of ground planes that isolate the two arrays, and the use of metallic vias to connect patches with transmission lines (for each pair of patches with their corresponding transmission line, placed between the two ground planes).

With these considerations the structure is designed as the one in Fig. 2.

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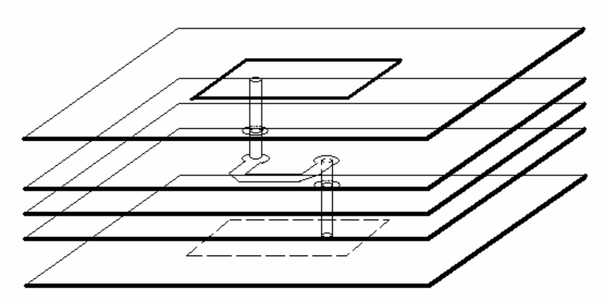


*Figure 2. Simplified lens scheme, with ground planes and metallic vias.*

2- The described structure requires the use of multilayer architecture, with some limitations in some aspects:

- Number of layers that can be afforded (manufacture limitations), therefore the structure is similar to the one in Fig. 3.
- The use of metallic vias is not so easy, as all the possibilities can not be considered because of construction limitations. As it is seen in Fig. 4, that leads to a more and more complicated multilayer structure. In order to simplify the structure, FOAM is used; in that way the problematic part turns to be the layers between ground planes, not the whole multilayer structure.

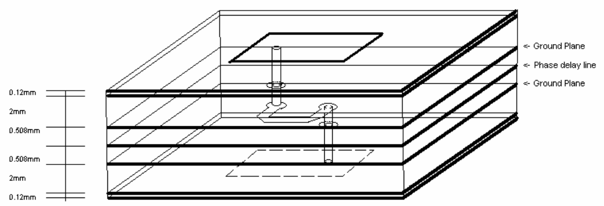



*Figure 3. Lens multilayer distribution*

3- As it has been pointed, transmission lines are placed between the two ground planes. That means Stripline architecture (a 50Ω Stripline is chosen), with metallic vias at the beginning and at the end of the line. In order to avoid the apparition of any undesirable mode, due to these vertical vias inside the layer limited by the two ground planes, metallic walls are going to be placed all around the transmission line (Boxed Stripline). Considering manufacturing problems, the effect of these metallic is going to be replaced by a lot of metallic vias working as if they were a metallic wall. Separation between vias is going to be less than $\lambda_g/10$, as Fig. 4 shows.

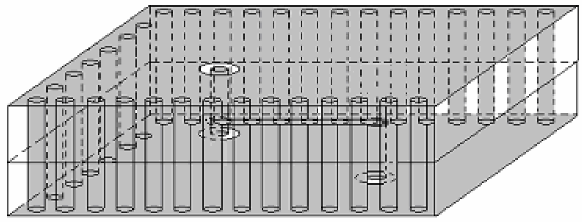


*Figure 4. Details of the surrounding vias to create an electric wall to avoid undesirable modes.*

As it is observed, the structure has turned into a complicated one because of electromagnetic and building up conditionings.

## 3. SIMULATIONS

### 3.1. Whole structure simulation.

Once it is known the limitations in the lens design in a detailed way, and what the structure is going to be, all is ready to start the simulation stage. In our case, Ensemble and CST 5 are going to be used as simulation software, as well as ADS for computing all the results. The working frequency is going to be 12 GHz.

As it has been shown in Fig. 3 the structure is symmetrical. The phase delay is obtained by adding pieces of 50Ω Stripline in the centre of the structure. For than reason it is referable to simulate half a structure, as it is seen in Fig. 5 and 6. If that half structure is adapted to a real impedance (50Ω in this case), the whole structure is going to work in a proper way (the impedance of one half is the complex conjugate of the other).

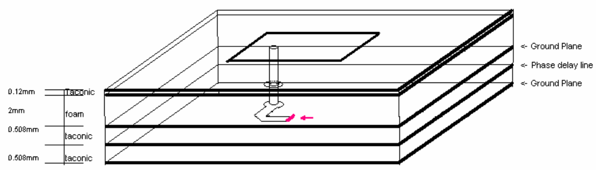



*Figure 5. Simulation scheme for CST 5.*

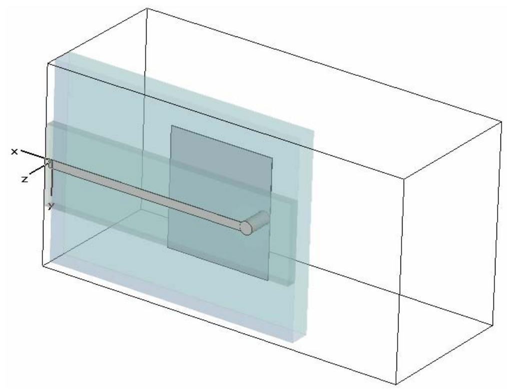



*Figure 6. CST 5 simulation model.*

Fig. 7 and 8 present some simulation results related to reflection and Smith Chart

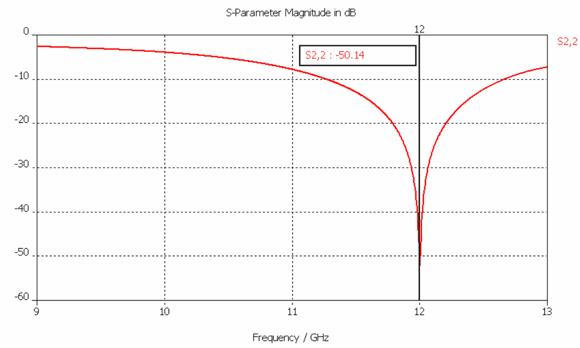



*Figure 7. $S_{11}$ of half a structure.*

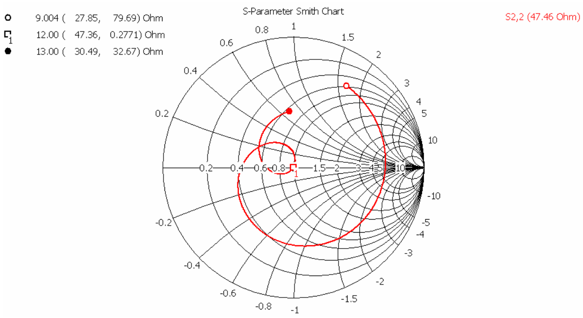



*Figure 8. Smith Chart.*

In the prototypes there are going to be some building tolerances that introduce variations in reflection results and that should be considered in the simulation stage. Among the different aspects that are considered, are selected:

- Line width variation.
- Via to patch transition diameter variation.
- Patch dimension variation
- Patch feeding point variation.
- Via diameter variation.
- Thin air layer over the transmission line.

The simulation results let us conclude that the most important effect is provoked by this thin air layer over the transmission line.

### 3.2. Phase delay part simulation.

Before manufacturing a whole prototype, it is necessary to evaluate the phase delay part (as it is almost the most important part) and to prototype it to validate the structure. The phase delay part is modelled and simulated in CST 5. Instead of the vias it is necessary to model connectors, as it is shown in Fig. 9.

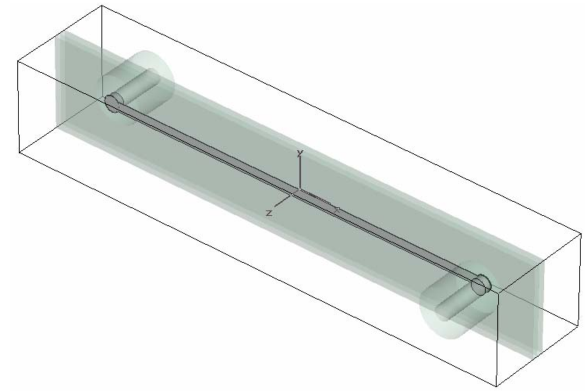


*Figure 9. Phase delay structure model.*

And the results for 50Ω ports are shown in Fig. 10 and 11.

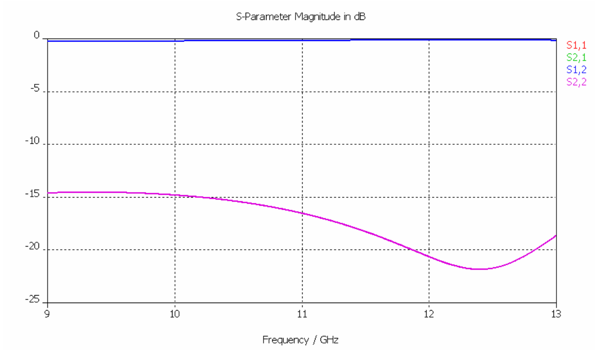



*Figure 10. Reflection results.*

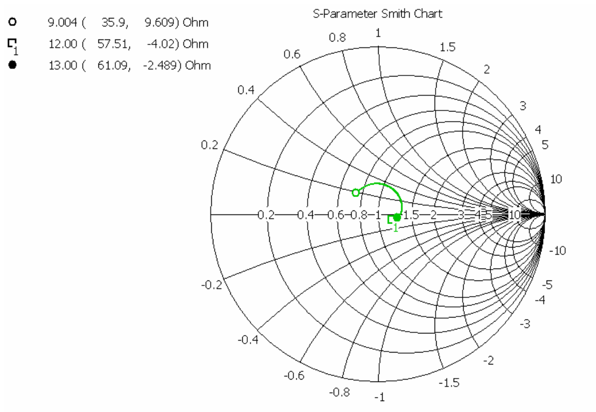



*Figure 11. Smith Chart.*

The port impedance should be changed into the patch one in order to have proper results.

### 3.3. Radiation part simulation

At last, the patch structure has to be simulated. The model is presented in Fig. 12.

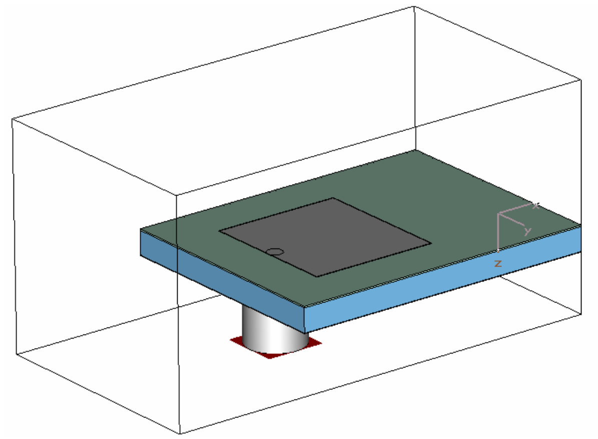


*Figure 12. Patch structure model.*

And the results in Fig. 13 and 14.

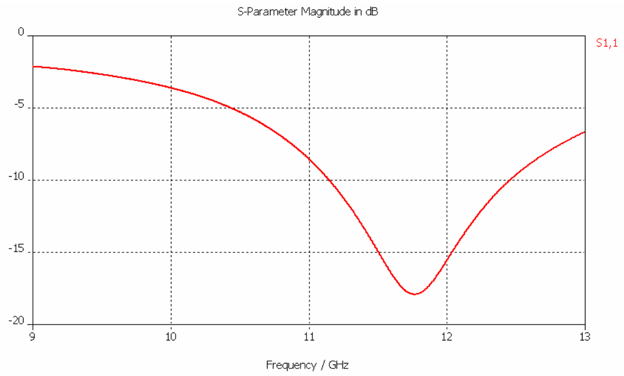


*Figure 13. Reflection results.*

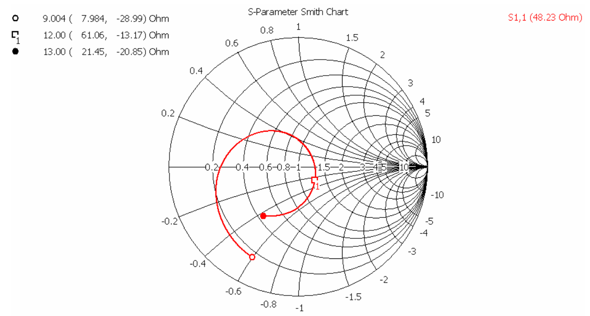


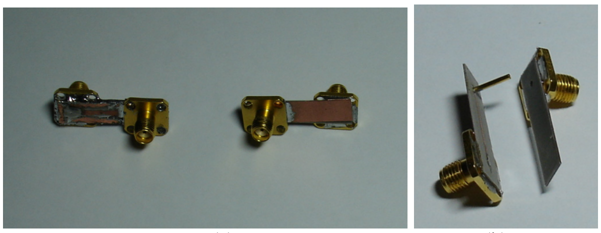
*Figure 14. Smith Chart.*

## 4. PROTOTYPES

When the simulation results are available, prototypes have to be manufactured.

First of all, it is necessary to make and measure the phase delay prototype. In that moment, half a complete patch to patch structure has to be manufactured and measured.

At the moment of writing this paper, only the phase delay prototype (Fig. 15) has been obtained and measured. The rest is under construction.


(a) (b)
*Figure 15. (a) Two identical phase delay prototypes. (b) Detail of one of them.*

And its results (Fig. 16 and 17).

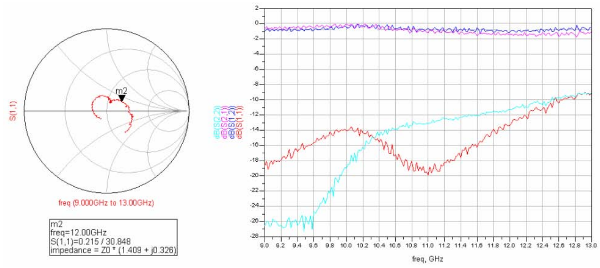


*Figure 16. First prototype results.*

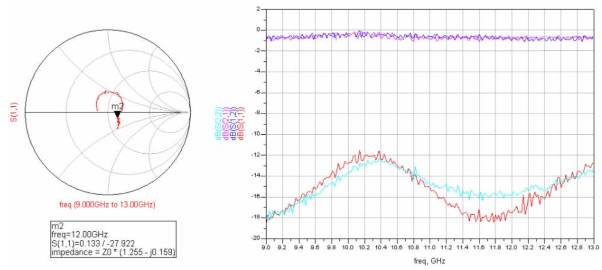


*Figure 17. Second prototype results.*

It is necessary to present a comparison between simulation results and measurements (Fig. 18 and 19), changing the port impedance to the proper one (the same in both cases).

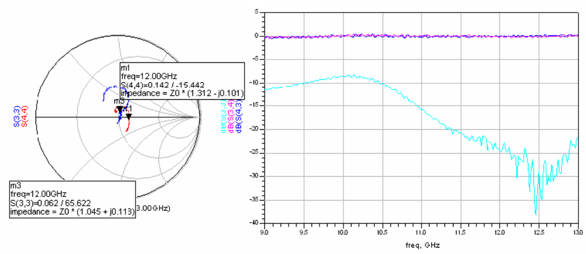


*Figure 18. Second prototype results with port correction.*

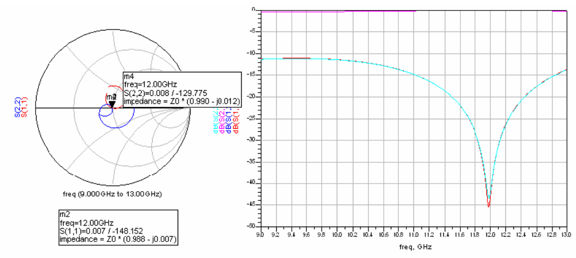



*Figure 19. Simulations with port correction.*

As it is seen, the behaviour is quite similar. More prototype results will be presented in EuCAP2006.

## 5. CONCLUSIONS

In this research work, it has been tried to design and simulate a transmission/reception lens. The most important advantage of this kind of antennas remains in the possibility of modifying the radiation pattern of a given antenna, as well as the reduction of phase errors of this given antenna. In this paper some design criteria, simulation results and prototype measurements have been presented.

More prototype results will be presented in EuCAP2006.

## 6. ACKNOWLEDGEMENTS

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## 7. REFERENCES

[1] E. Fotheringham, S. Rómisch, P. C. Smith, D. Popovic, D. Z. Anderson and Z. Popovic. “A Lens Antenna Array With Adaptative Optical Processing”. *IEEE Transactions on. Antennas and Propagation.*, vol. 50, NO. 5, May. 2002.

[2] Z. Popovic and A. Mortazawi. “Quasi-Optical Transmit/Receive Front End” IEEE *Transactions on microwave Theory and Techniques*, vol. 46, NO. 11, Nov. 1998.

[3] J. Vian and Z. Popovic. “Smart Lens Antenna Arrays” Microwave Symposium Digest, 2001 IEEE

[4] Constantine A. Balanis. “Antenna Theory. Analysis and design”. 2nd edition. John Wiley and Sons,1997.

[5] K.C. Gupta, R. Garg, I. Bahl and P. Barthia. “Microstrip lines and slotlines”. 2nd edition, Artech House, 1996.