Application of Genetic Algorithms to the Manufacturing of Large Planar Array Antennas on Radar Applications

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Abstract— **A genetic algorithm (GA) is presented to obtain the best arrangement for the linear arrays (previously measured) used for the construction of a large planar array for radar applications. The designed algorithm allows the selection of the frequency and the pointing, furthermore the given weight of the different parameters of the radiation pattern (SLL, directivity…). Finally, some results are showed.**

I. INTRODUCTION

Nowadays, phased array antennas are used on many applications. This is mainly due to their capacity to change their radiation pattern, allowing even several patterns at the same time. These properties make them especially useful for radar applications.

Spanish company Indra has developed in the last years a complete new family of air surveillance radars, called *Lanza*. These radars work on L band and present as antenna a large planar array composed of a set of linear arrays vertically tiled, with separate feeding distributions in both main planes. The azimuth scan is performed mechanically, whereas the elevation scan is made electronically.

Considering the independent feeding distribution for both plane directions, each one of the linear arrays that shapes the planar antenna is tested to confirm the design specification fulfilment, and so the parameters of the azimuthal cut of the radiation pattern can be easily estimated. To test them, a linear antenna measurement system [1] is used.

Although all the linear arrays which are part of the planar array pass several quality tests in order to verify its specification, they are not completely equal. Actually, they present small variations due to the tolerance of the material electromagnetic features used for their fabrication.

These small differences can slightly affect some radiation properties depending on the placement order over the complete antenna plane. As there are separate feeding distributions, the vertical cut of the radiation pattern will be much more affected than the horizontal one. In this paper a method to take advantage of this matter is presented, improving particular antenna parameters for the vertical cut. The method is based on genetic algorithms (GA) and allows choosing which parameters are optimized, considering all the frequency band and different vertical pointings. Examples of the results are presented.

II. CONTEXT

As it is well known, the radiation pattern of the radar antenna has an influence on the complete system capabilities. For example, gain is related to the range and side lobe level (SLL) affects to the level of the false alarm rate and jamming.

During the antenna design process all these parameters are optimized according to the radar requirements. However, the commented slight differences among the linear arrays introduce small variations that can be used to perform a fine optimization of some parameters of the vertical cut of the far field radiation pattern.

The starting point of the optimization process is the measurement of each linear array performed at the linear measurement system. This system consists of a 12m semi-anechoic box (see figure 1). The antenna under test radiates the field placed inside the box. To acquire that field (in amplitude and phase) all over the frequency band, a probe moves along a linear slide, stopping in front of each array element. Then, the acquired field is processed using FFT techniques, to obtain the far field radiation pattern for the array plane. After that, a post processing is implemented to obtain the radiation pattern main parameters.

Once the linear arrays characterization has been carried out, and taking into account that the physical distance between them as well as the frequency band are fixed, the placement order of the rows is the last variable to consider over the radiation pattern estimation. Thus, depending on the placement order, parameters of the vertical cut of the radiation pattern, such as directivity, SLL, pointing or beamwidth, will slightly vary. Consequently, it is possible to optimize one or several of these parameters just choosing the appropriate placement order.

Fig 1 Linear Measurement System For Large Array Antennas

III. OPTIMIZATION METHOD

An optimization program based on genetic algorithms (GA) has been developed to obtain the best tiling order of the rows according to some optimization objectives. The reason to choose GA is its capability to optimize a multiple variable function (as occurs in this application) without taking derivatives to obtain the next step of the optimization [3]. So, it is possible to select which parameters are going to be optimized just only fixing their weight over the complete optimization process.

Moreover, the developed GA is so flexible that allows expanding the optimization over the entire frequency band and over different pointings.

IV. RESULTS

Choosing the weights it is possible to optimize only the Tx or Rx parameters. For example, table 1 and figures 2 and 3 show results obtained considering only Tx and table 2 and figures 4 and 5 only taking into account Rx channel. Both of them use a simulated planar antenna composed of 32 real rows, which were previously measured. Uniform feeding vertical distribution was considered in transmission, and Taylor 35 was fixed for reception. The GA will also consider the quantification information of the attenuators and phased shifters used for beamforming. Eleven frequencies and five pointings were selected for the optimization. The different parameters to optimize (SLL, directivity, pointing and beamwidth) were weighted in the same percentage (25% each one).

Table 1 Results obtained choosing the Tx parameters

	Mean of 100 random orders		**GA Order**	
	Tx	**Rx**	**Tx**	**Rx**
Directivity	15.7	14.5	15.7	14.4
SLL	-13.1	-32.4	-13.7	-34.1
Pointing Error	0.01	0.01	0.01	0.01
Beamwidth at 3 dB	2.79	4.02	2.80	4.06

Table 2 Results obtained choosing the Rx parameters

	Mean of 100 random orders		**GA Order**	
	Tx	**Rx**	**Tx**	**Rx**
Directivity	15.7	14.5	15.7	14.5
SLL	-13.1	-32.4	-13.3	-35.8
Pointing Error	0.01	0.01	0.01	0.01
Beamwidth at 3 dB	2.79	4.02	2.80	4.05

Finally, it is possible to obtain a solution considering Tx as well as Rx (see figures 6 and 7).

Table 3 Results obtained choosing Tx and Rx parameters

	Mean of 100 random orders		**GA Order**	
	Tx	**Rx**	**Tx**	**Rx**
Directivity	15.7	14.5	15.7	14.4
SLL	-13.1	-32.4	-13.5	-35.9
Pointing Error	0.01	0.01	0.01	0.01
Beamwidth at 3 dB	2.79	4.02	2.80	4.05

The results obtained (see table 1-3) show that the radiation pattern given by the GA placement order presents an improvement of 3.5 dB on the reception SLL against the mean of 100 random placements (when it is selected this parameter), whereas in transmission the improvement is about 0.5 dB. The rest of the radiation pattern characteristics are not significantly affected.

V. CONCLUSION

The small variations on the linear arrays that form the large planar antennas produce small changes on the final vertical radiation pattern, just due to their placement order. An optimization program based on GA has been developed to take advantage of this, choosing the best distribution in order to optimize different parameters. The developed method is really flexible, allowing optimizing SLL, directivity, beamwidth and pointing as well in transmission as in reception. Also, is possible to select the frequency and pointing domain and give different importance to the parameters to be optimized.

Results over an ideal antenna with real measurements of its 32 rows have been presented, showing a remarkable improvement of the SLL in reception (3.5 dB) and even in transmission (0.5dB) without significant changes on the directivity.

References

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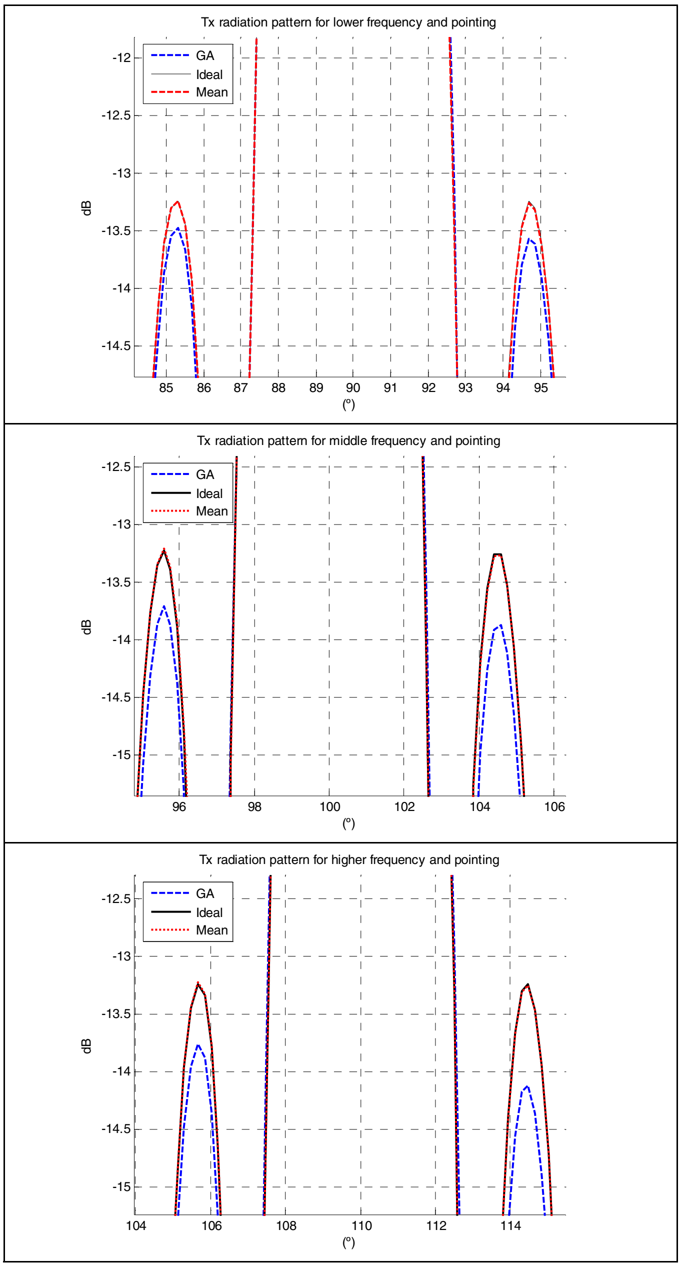

Fig 2 Comparison of the Tx array factor optimizing only the Tx radiation pattern characteristics

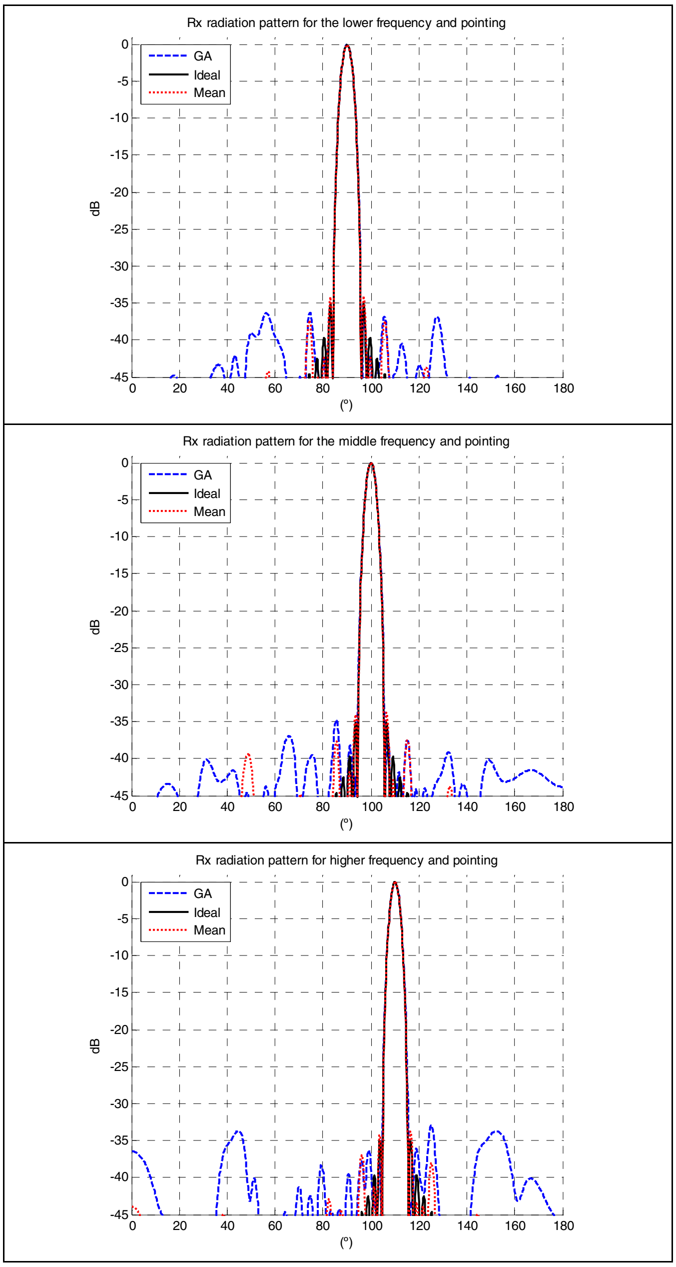

Fig 3 Comparison of the Rx array factor optimizing only the Tx radiation pattern characteristics

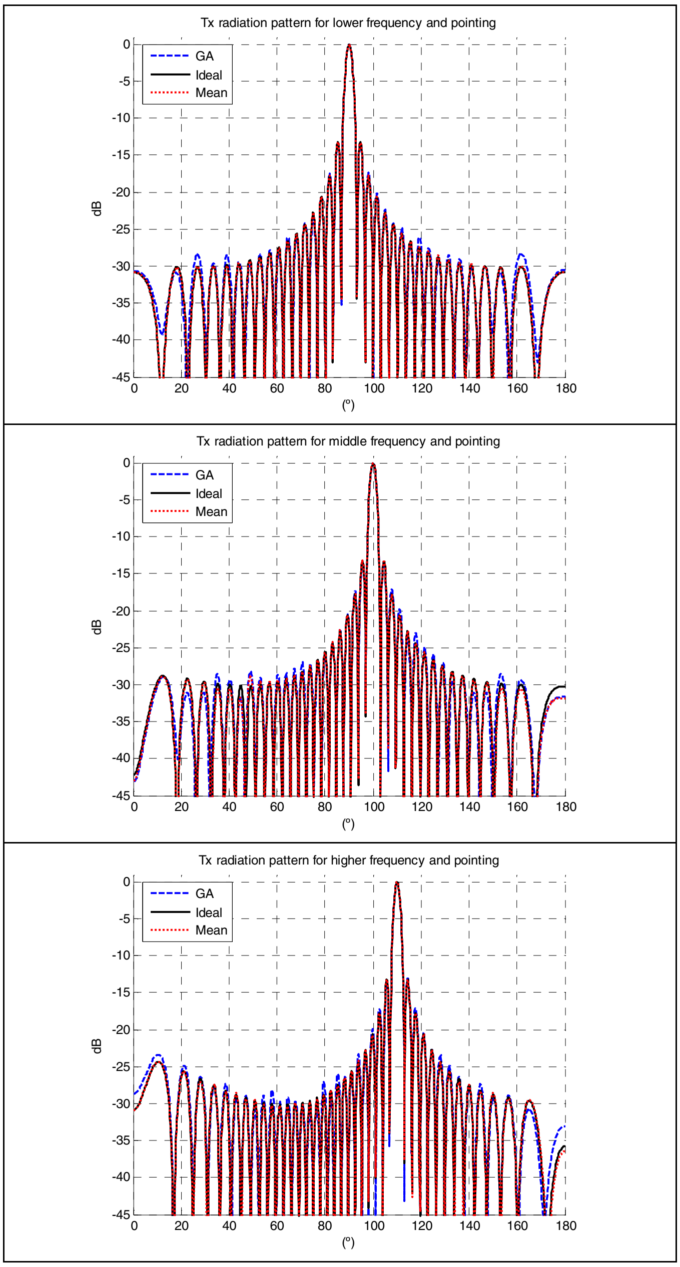

Fig 4 Comparison of the Tx array factor optimizing only the Rx radiation pattern characteristics

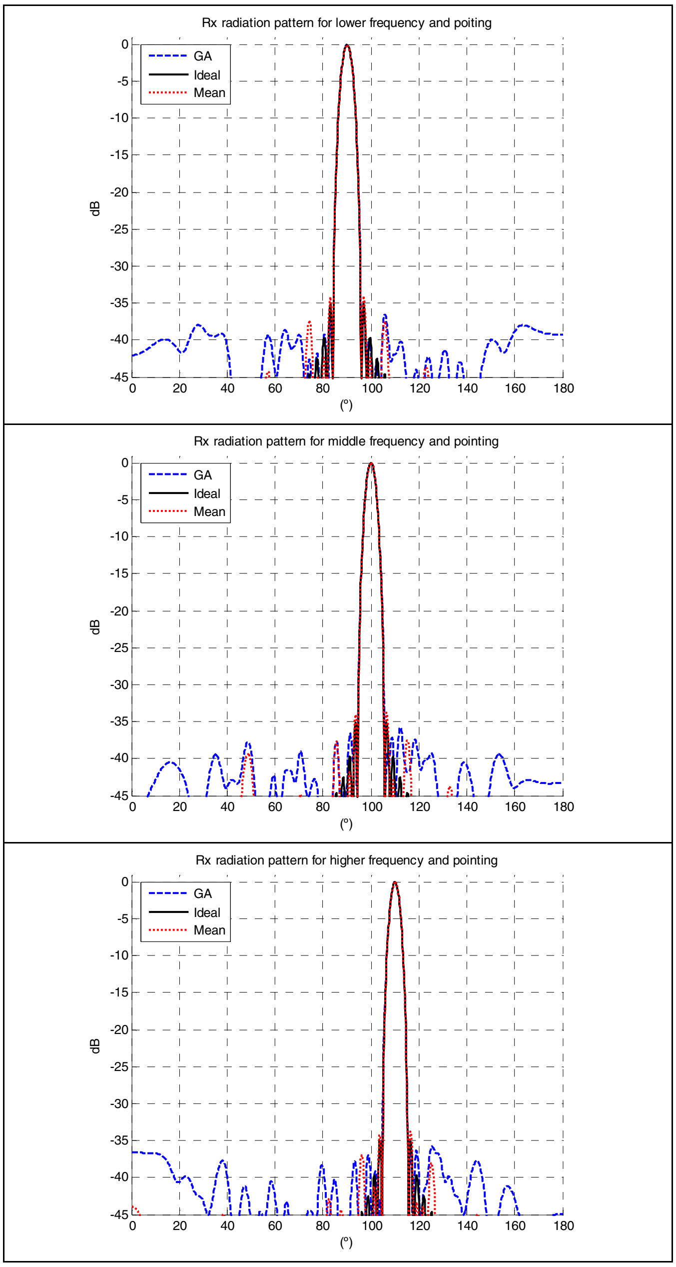

Fig 5 Comparison of the Rx array factor optimizing only the Rx radiation pattern characteristics

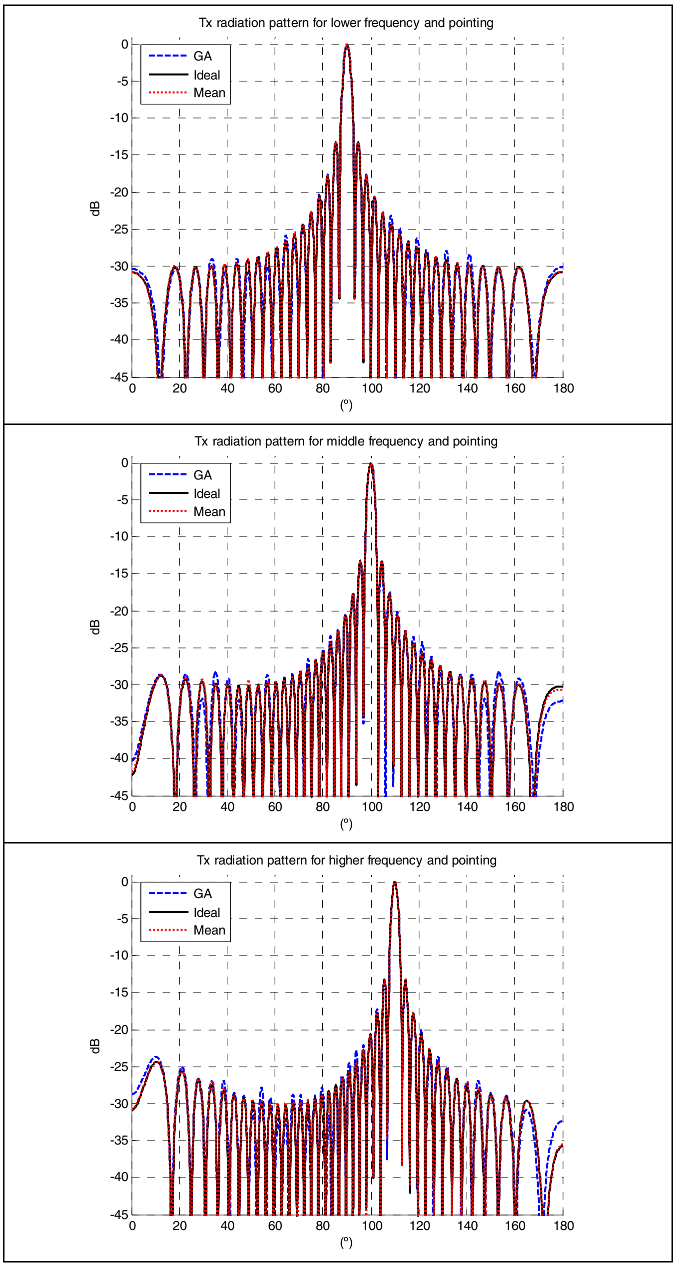

Fig 6 Comparison of the Tx array factor optimizing Tx and Rx radiation pattern characteristics

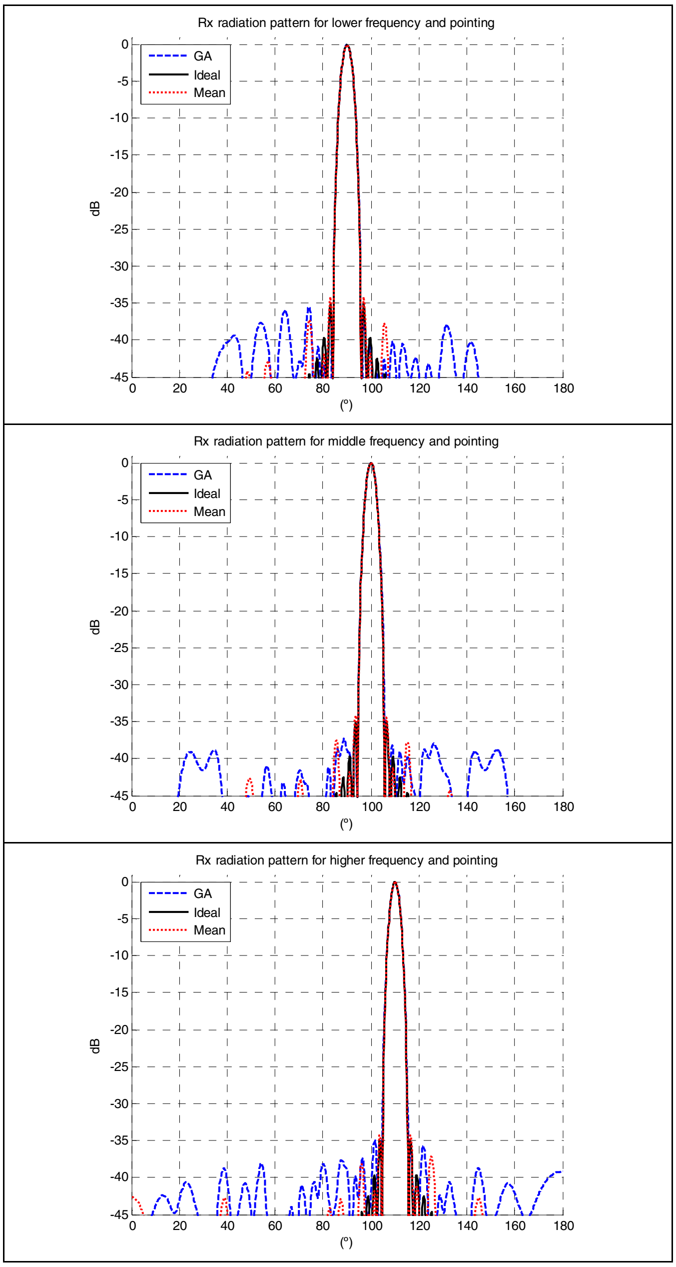

Fig 7 Comparison of the Rx array factor optimizing Tx and Rx radiation pattern characteristics