ON THE DESIGN AND OPTIMIZATION OF THE ARRAY ELEMENTS IN THE GEO ATMOSPHERIC SOUNDER INSTRUMENT: A NEW DESIGN PROCEDURE

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1. INTRODUCTION

The GEO Atmospheric Sounder instrument will be a multifrequency radiometer in a geostationary orbit devoted to very short term meteorological forecasting ('nowcasting') having a ground resolution corresponding to 30 Km cell dimensions. This requirement implies, in turn, a instrument diameter in the order of 1.5 thousands wavelengths which enforces formidable challenges to the instrument designers. In order to save costs while guaranteeing the needed performances, a number of unconventional hardware solutions is going to be adopted [2]. In particular, the actual instrument will be an array made up by several receivers (an overall number of 140÷150) located along three directions (arms) at a 120° angular distance each from the other, and wherein the other relevant information is gathered by a rotation of the structure [2]. The fact that the scenario under observation has a scale of time much larger than the one corresponding to antenna rotation actually allows to deal with a kind of 'synthetic' array antenna. In this abstract we will introduce a new procedure for synthesizing the array above.

2. DESIGN CONSTRAINTS

Design constraints include geometry constraints, calibration requirements and requirements on the final radiation pattern.

The geometry constraints include the fact that the array, constituted by roughly 150 elements, should have a Y shape with the 3 arms exactly at 120° degrees relative each other, and the maximum length of each of the three arms of the array should be 700 λ (being λ the wavelength in free space) at most. Moreover, one element should be placed at the centre of the 'Y', and the minimum distance between elements (corresponding to the size of the individual array elements) must be larger than 3.5 λ.

In order to better understand the calibration requirements, it is useful to define the baselines as those vectors joining two generic elements of the array, the co-array as a virtual array with locations corresponding to the baselines, and the 'redundancy region' as that region wherein all baselines used for calibration purposes lie. Notably, in order to enable calibration all elements in the array must be such to generate at least one baseline belonging to the redundancy region (which is herein a circle of radius 26 λ), with the further constraint that such a baseline must have at least one redundancy (i.e., it is generated more than once when considering all the possible couples of receivers).

In the final radiation pattern, which is herein related to the Fourier transform of the rotated co-array, the half power beamwidth should be equal to $8.3*10^{-4}$ radians, as this is the angle corresponding to the required resolution cell on Earth (30 km) as seen from a geostationary satellite. Outside the main beam region, from $sin(\theta)=10^{-3}$ until $sin(\theta)=0.4$ the sidelobe level (SLL) should be lower than -25 dB with respect to the maximum. The requirement on SLL is obviously due to the need of rejecting signals coming from outside the resolution cell at hand, while no signal can really come from outside $sin(\theta)=0.4$, as these directions are outside the cone defined from the satellite to the Earth. Finally, 99% of the energy included in the pattern until $sin(\theta)=0.4$ should be within the main beam region defined by $sin(\theta)<10^{-3}$. This requirement is similar in spirit to the one above. In fact, for $sin(\theta)> 0.4$ there are not constraints on the pattern, which comes again from the parameters of the satellite-Earth cone.

3. A NEW DESIGN PROCEDURE

While in the initial stages of the lay-out design a trial and error procedure had been used to synthesize a small scale version of the instrument (i.e., a demonstrator), in [1] some strategies have been presented for the design which ameliorate the performances of the lay-outs already available for the demonstrator. On the other side, all the presented results keep quite far from the desired behavior inasmuch the requirements on energy are concerned. Also, a much larger number of antennas will have to be located in the final instrument, so that a more effective and more systematic way to proceed is needed with respect to the one adopted in [1].

In particular, while some of the desired characteristics of the array have been managed up to now with the external help of the designer (in particular inasmuch the calibration constraints are concerned), an effective design tool should be able:

- to take into account in an automatic fashion (i.e., to enforce in an automatic fashion) all the given calibration constraints;
- to exploit all the available knowledge about the problem;
- to enforce in a clever and effective fashion the desired behavior of the final pattern in such a way that both the requirements on the pattern behavior and on the relative energy contents are fulfilled.

In so doing, advantage could be taken from the so called ‘density taper procedures’ [3].

After a number of different reasonings and trials, the following general structure has been individuated as the most effective for the design tools.

First, by using the available skills on the synthesis of circularly symmetric aperture fields [4], synthesize one or more patterns fulfilling the given constraints on the final co-array. These patterns, and the corresponding aperture fields, will serve as a guide and as a reference in the subsequent steps. In such a step, attention has to be paid in choosing a reference pattern such to optimize performances in terms of the energy content of the main lobe as compared to the remaining energy.

Second, by using the aperture distribution defined in the first step as a reference into well known ‘density taper’ techniques [3], determine a number of candidate locations for the initial array.

Third, by using as a starting guess both the reference pattern and the locations individuated in the first and in the second respectively, minimize a cost functional enforcing the desired behavior of the final pattern.

Such a strategy is summarized under the flow-chart shown in Fig. 1, and it has been implemented by using the techniques proposed in [3,4] and enforcing calibration constraints in a new automated and effective fashion.

By applying the proposed strategy to the design of an alternative demonstrator (which is a 1:10 scaled instrument) a considerable improvement of performances in terms of SLL has been achieved by means of an uniform weighting of the element amplitudes. Notwithstanding a lower number of antennas is used, the achieved lay-out (see fig. 2.a) favorably compares with the pre-existing demonstrators [2]. Such a circumstance can be deduced from fig. 2.b, wherein the cyan and the blue lines represents the patterns radiated by the pre-existing layout and the actual demonstrator respectively, while the red and magenta lines represent the final pattern constraints. Notably, the main beam contains roughly 80% of the overall energy contained up to the region $sin(\theta)$=0.4 (previous solutions were limited to a 40% percentage), while the raise of the signal-to-noise ratio usually induced by non-uniform weightings is avoided.

More examples on both the demonstrator and the final instrument will be shown at the Conference.

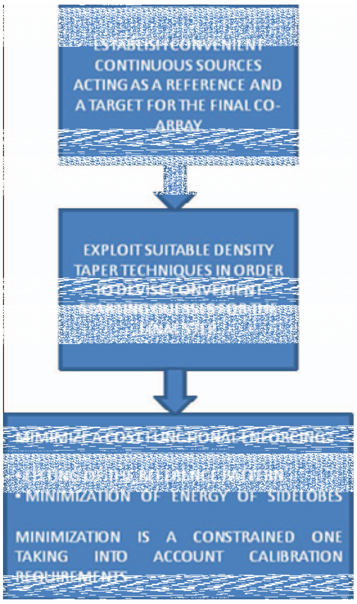

Fig. 1 : General structure of the design tools.

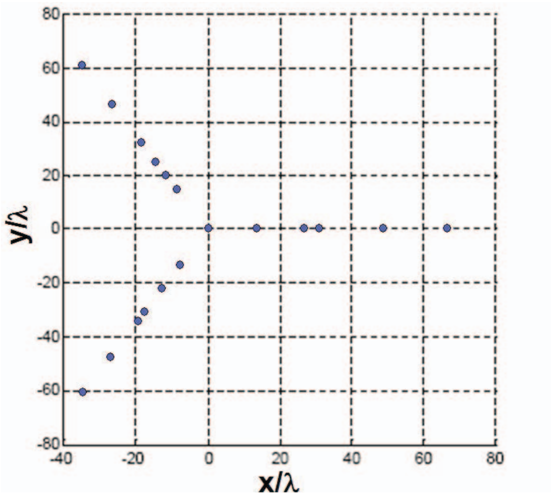

Fig. 2.a: Layout of the demonstrator.

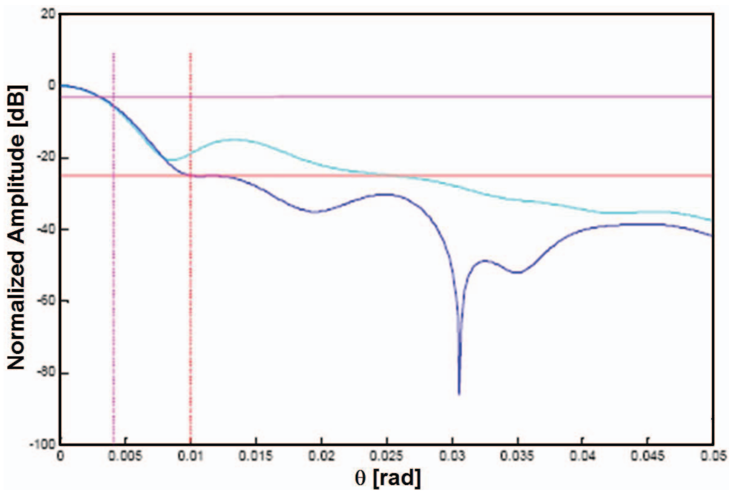

Fig. 2.b: Patterns corresponding to the pre-existing layout (cyan line) and to the actual demonstrator (blue line).

4. REFERENCES

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