Using CORPS-BFN to feed Multibeam antenna systems

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INTRODUCTION

Every day more applications appear in which more simultaneous beams are required: Reconfigurable antennas, MIMO, Smart antennas, etc.

The ideal behaviour for the antennas of these systems could be to generate and launch all the beams from the unique aperture of the system, trying to optimize everything in a single step: maximizing the aperture efficiency for each of the beams (uniform field distribution), having a large number of beams with a minimum antenna size (100% overlapping of the radiating effective areas of the beams), scanning electronically all the beams independently (affecting seriously the complexity of the feeding system), etc.

It could be quite difficult to obtain all these features with a unique antenna system, in the same way that each application requires a specific antenna depending of the particular requirements; we should do the same trying to improve one or two relevant aspects of the antenna system for each particular application.

In this sense, the introduction of the CORPS-BFN (Coherently Radiating Periodic Structures – Beam Forming Network) concept in the design of the multibeam antenna systems could help to improve some of the previous aspects. For instance, the effective overlapping between two orthogonal beams, as well as the possibility to control independently the scan of different beams from a reduced set of input ports, could be the most interesting improvements of using CORPS-BFN in Multibeam antenna systems.

The CORPS-BFN combines the necessary feeding network with the control system, being a layered system that combines power dividers and combiners in such a way that a stop band filter, defined by the periodic structure, will be defined horizontally (at the level of each of the layers), and, at the same time, having a good matching between layers.

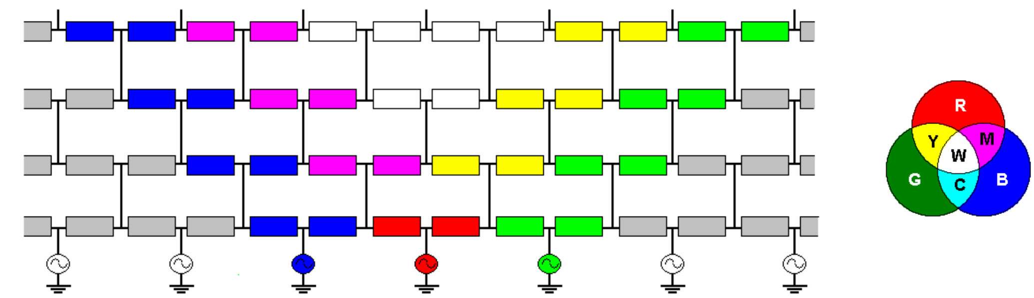

Fig. 1 Ideal signal spreading inside a CORPS-BFN structure, from the orthogonal and independent sources (down) to the output ports (top). The different colours follow the addition law of the three basic colours: Blue, Red and Green.

In these feeding networks the information of different beams is smartly spread inside the structure (Fig. 1), following a fixed function self-defined by the structure used. In other words, the signal introduced to each input port will be driven through the structure to a set of output-ports, the closer ones to the input port, generating a Gaussian taper at the output port plane.

These could be quite interesting, particularly, in multibeam systems which some focusing system (lens or reflector system) is included. The more impressive example of multibeam system is the human eye, as it has been shown in previous conferences by the authors [1].

In the conventional systems, each beam is usually defined by a horn antenna or detector. It is clear that it is physically impossible to place two horns or detectors exactly at the same point. In fact the separation between two horns is defined by its aperture size, limiting seriously the angular resolution of the whole system. We learn from the human eye to overlap the different radiating effective areas, being possible high directive beams very close to each other.

It is clear that the human eye is not using the whole retina surface to receive all the simultaneous beams, but it is also clear that for a fixed number of beams, the total area needed by the human eye is much smaller since the strong overlapping of the radiating areas. In other words, the human eye takes profit of sharing radiators or detectors among different beams.

This is particularly the kind of systems we want to analyze in this paper, those using several orthogonal beams simultaneously. Normally, the problem is solved with a multi-feed reflector system, based on a set of horns at the focal plane illuminating a unique reflector system.

These systems could be seen as a small part of the human eye, and could be improved increasing the similarity with the real human eye behaviour, especially regarding angular resolution, that could be translated in a strong reduction of the transversal dimensions of the feeding array at the focal plane.

By replacing the horn antennas by an array of smaller antennas, controlling these array with a CORPS-BFN, the number of input ports could be maintained despite the higher number of radiating elements; as well as the directivity of each of the individual beams, since the signal of each input port is spread thanks to the CORPS-BFN to a set of radiating elements that ideally could cover the same radiating effective area that the aperture of a horn antenna.

The main advantage of this solution is the physical distance between two neighbouring beams: working with horn antennas, the minimum distance is fixed by the diameter of the horn aperture, and with a CORPS-BFN combined with smaller radiating elements, the spatial step is the physical size of a single radiator, much smaller than the effective radiation area of one beam.

By introducing the concept of CORPS-BFN to the feeding system, all the beams could be closer to the focal point of the optical system, so, the global distortion could be improved significantly.

PRACTICAL EXAMPLE

We are going to compare the behavior of a CORPS-BFN feeding an array of small antennas with the equivalent based on horn antennas.

The Horn antenna array configuration is as shown in fig. 2, as a multibeam scenario, each antenna is radiating a different signal, therefore, we are going to analyze in detail an individual horn antenna. Consider a horn antenna with maximum directivity equal to 20 dB and with side lobe level of -30 dB. There exist many studies about this kind of antennas, and in the same way, many possible configurations and shapes. The Choked-Gaussian corrugated horn antennas [2] are a good choice to achieve the requirements exposed before. So, based in curves shown in Fig. 3 a corrugated horn antenna with 20 dB Directivity and side lobe level of -30 dB has an aperture diameter of approximately 5 λ (including the outer metallization) and a total length of 5.5 λ.

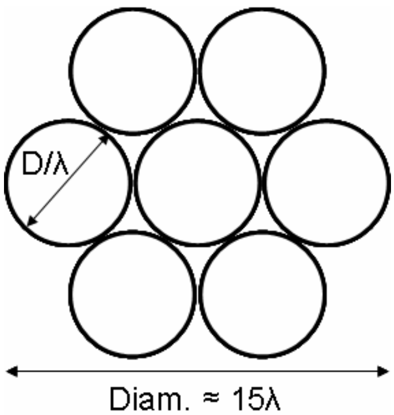

Fig.2 Horn Antenna Array

The total Horn antenna Array configuration is composed by 7 antennas circularly arranged. The circular configuration is proposed due to physical limitations of rigged antennas and the space baste in between them.

Ideally, working with perfectly uniform field distribution, the diameter of the circular aperture generating 20dB is 3.2λ, but if we want to define the side-lobes below 30 dB, a bigger diameter will be needed. In any case, considering the optimum solution of uniform field distribution, the whole composition of 7 ideal horns will be embedded in a circle of aprox. 9.6λ diameter.

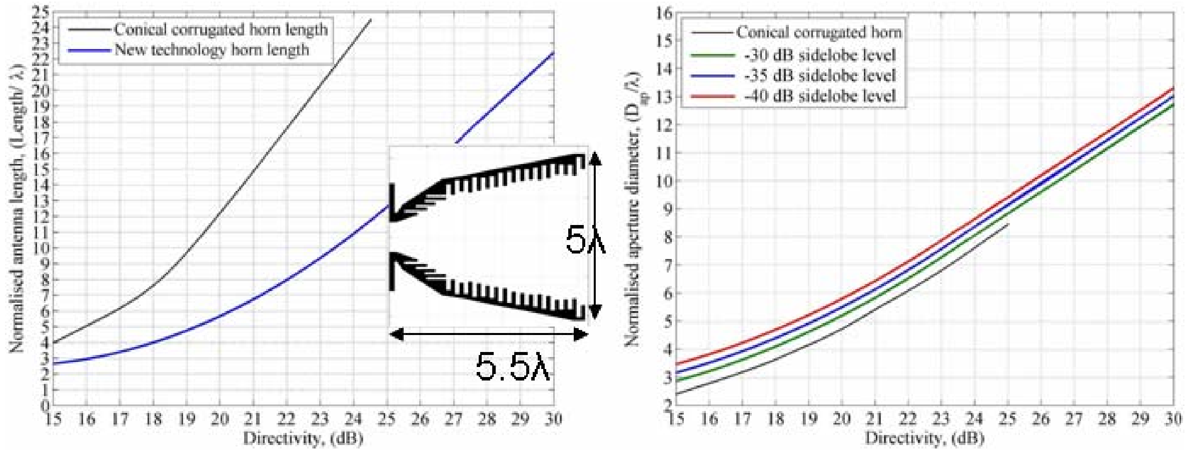

Fig. 3. Design curves for Corrugated Horn Antenna and Horn Antenna with specific dimensions to have 20 dB of Directivity and -30 dB of Side lobe Level.

We will compare the two configurations listed above with an array of smaller antennas fed by a CORPS-BFN, so, the amplitudes at antenna level have Gaussian shape [3]. In order to define comparable systems (similar beam directivity), we select a planar circular array of 9 elements diameter separated λ/2 to generate each of the beams.

Fig. 4 shows the Array Factor of a planar circular of diameter 9 elements, separated λ/2. From the fig. 4 we could have a estimated directivity of this CORPS-BFN antenna array, about 20 dB, being the side lobe level almost -30 dB.

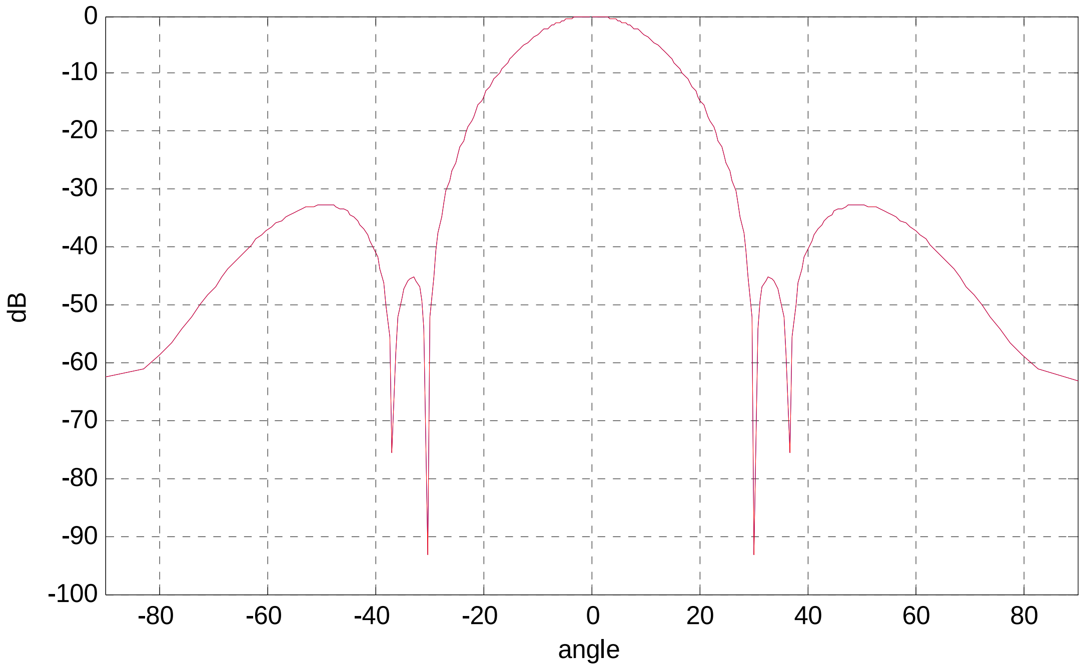

Fig. 4 Array factor Pattern of a circular array of 9 elements in diameter.

Taking into count the especial behavior characteristic of a BFN based on CORPS concepts [3] we can define a circular array of diameter 13 elements as show in fig. 5 and based on this array define sub-areas of circles of 9 elements diameter overlapped each with others that can radiate independent beams at same time. In fig 5 is show how is defined each sub-area, in total from this specific configuration we can obtain 9 different beams, separating the different radiating areas in two elements (one wavelength).

The total Area of CORPS-BFN antenna array is a circle of diameter 6λ. Compared with the total area necessary to allocate 7 Chocked-Gaussian horn antennas (circle of 15 λ diameter) or with optimum uniform field horns (circle of 9.6λ diameter). We are achieving a significant reduction in the total area, improving the angular resolution of the system, since we are maintaining the directivity of the beams, getting closer the beams.

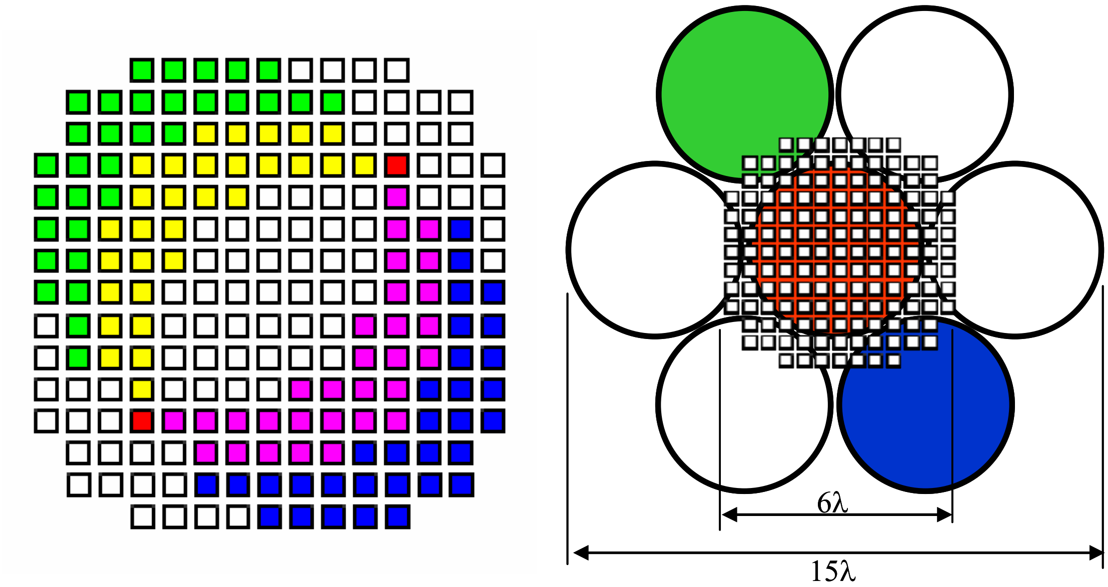

Fig. 5. Planar Circular Array of 13 elements diameter. In figure is show three of nine possible beams.

CONCLUSIONS

In this paper, a simple example of application of the CORPS-BFN concept has been presented.

A multibeam antenna system is seen as a small part of the human eye, and therefore, improving the similarity of the whole system with the human eye, the main features of the system could be also improved.

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