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Polarized Scanning Possibilities of a Conformal Wideband Array

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1. Introduction

The feasibility of using an airship as a host platform for an antenna array used in reception is under study. This kind of platform offers great potential, as its hull provides a large surface. Thus good performances could be expected for applications like radar and telecommunications, at lower cost than satellites. Nevertheless, the inflatable nature of the airship, as well as its non planar shape leads to major conception issues. First, the array must be conformed and follows the ellipsoidal shape of the hull causing severe degradation in the radiation pattern. Then, low weight, low profile conditions must be respected. Therefore, the use of a ground plane, commonly considered for antenna arrays [1], will be avoided and we assume that the equipment must lie outside the hull. Finally, the array has to be wideband and must be fully polarized.

The choice of the element array has to take into account all these considerations and fulfill the performance requirements. For all these reasons, the Archimedean spiral has been chosen since it is a good candidate for wideband application and because it can be arranged on low profile array. It can radiate above frequency corresponding to $\lambda \leq \pi D$, with D the diameter of the spiral. With the scanning condition $2D \leq \lambda$, we can consequently expect good functioning between 400 and 600 MHz. In this paper we will consider only one frequency (600 MHz) to simplify the study, but all the results could be applied at any frequency of the band. We will first describe the configuration of the array on the plateform and give an insight on the assumptions made. Then, the scanning possibilities of the array will be explored according to the polarization characteristics, in order to obtain the best performances.

2. Array description

2.1 Platform and antenna description

The airship is filled with helium and its hull is made of a very thin dielectric layer of few millimetres. In consequence, we assume that the antennas do not interact with the platform. The feeding and data link issues are not considered in this paper. The spiral antenna is the element of the considered array. This antenna has broad band radiation, normal to the elevation plane $\varphi = 90°$, containing the spiral (see Fig. 1). The electric field radiated is left handed circularly polarized (LHCP) on one side of the antenna and right handed circularly polarized (RHCP) on the other side. Furthermore, the level of cross polarization is quite low. The array elements will be arranged on half of the airship hull, in a 1D conformal array having a half ellipsoidal shape (see Fig. 2). The ellipse has a major axis of 30 m and a minor axis of 10 m. All elements are oriented to radiate the RHC polarization outward the ellipse and are half wavelength spaced. Thus 134 elements are considered with element 1 at angle $\varphi = 0°$ and element 134 at angle $\varphi = 180°$. The purpose is to scan in every direction of the azimuthal plane φ, at $\theta = 0°$. Because of the conformal configuration, all antenna elements have their own orientation, thus their own radiation characteristic. Furthermore the radius of curvature of the conformal array is changing according to its position on the ellipse.

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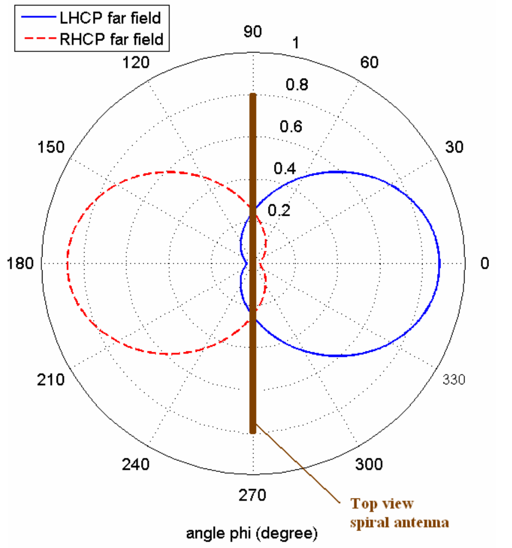


Figure 1: Top view of a spiral antenna, with its RHC and LHC polarized radiation characteristic.

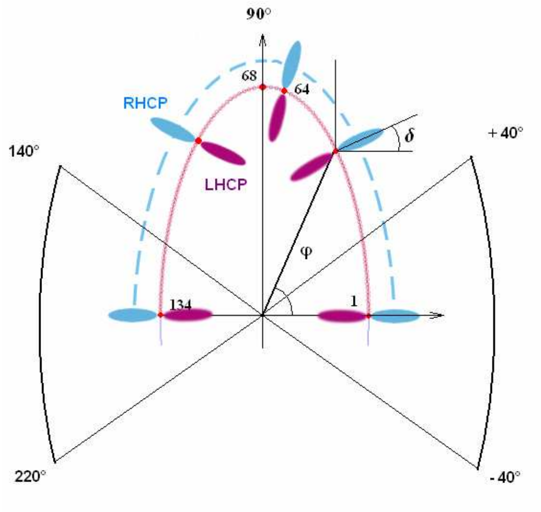


Figure 2: Conformal array of 134 spiral antenna elements arranged on a half ellipse. RHCP radiation is oriented outward as depicted.

2.2 Coupling between array elements

For this array configuration, we differentiate two types of coupling. The first is the coupling of each antenna element with its neighbors (i.e. elements n+1 and n-1 of Fig. 2). It has been shown in [2] that the most important coupling was due to the next element presence. Then, for this kind of antenna, the coupling results are low enough to be neglected thereafter, and comparison with full wave method has validated this approximation.

Then, the lack of ground plane leads to a second type of coupling that concern the elements positioned on the opposite side of the airship (i.e. element 1 and 134 of Fig. 2). Modeling of two spiral antennas distant of 5m and 1m (i.e. 10 λ and 2 λ at 600MHz respectively) has shown that this coupling was also low enough to be neglected. This can be explained considering the nature of the polarization radiated by the spiral antenna (see Fig. 3). Each element radiates RHCP electric field outward the hull and LHCP field inward, while receiving RHCP field inward. That means that each element is faced to an orthogonally polarized element. So, if the spirals are positioned with the same face outward, as it is in the previously proposed configuration, this source of coupling is minimized.

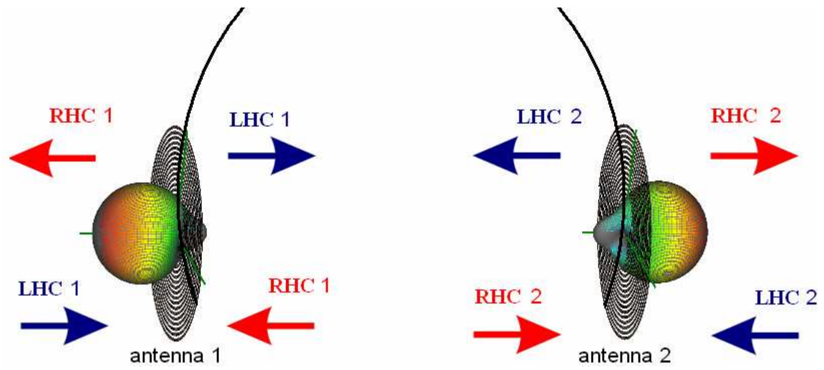


Figure 3: Coupling between elements on opposite side of the airship. Each element radiates RHCP electric field outward and LHCP field inward, while receiving RHCP field inward.

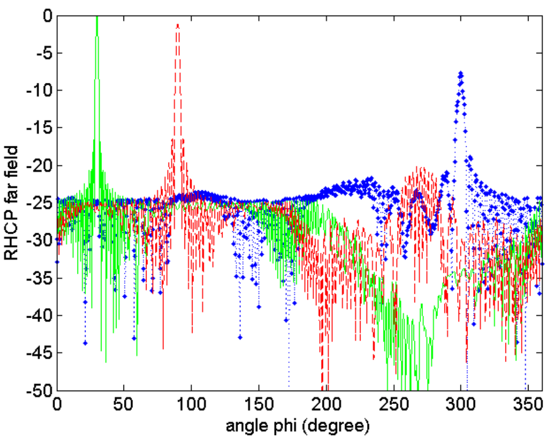
A full wave modeling tool based on the Method of Moment (MoM) has been used for the spiral antenna modeling. However, the considered array has too many elements and is too time-consuming to be modeled by MoM. Hence, an approximated method that takes into account the vectorial nature of the radiated field has been developed [2]. The radiation characteristic of the array is obtained by means of the vectorial sum of each element radiation characteristic, rotated according to the orientation of the element. Consequently, this method has been used to obtain the following results.

3. Radiation pattern synthesis

3.1 Scanning performances

Let's consider the previous array configuration given in Fig. 2. The spiral antenna radiates simultaneously RHC and LHC polarizations in opposite directions as depicted in Fig. 1. This property will be used to scan in every direction for both polarizations. Thus, for angles $\varphi \in [-90, 90°]$, corresponding to the right side of the airship, the RHCP scanning will be achieved by the elements placed on the right side of the airship (1 to 67). LHCP scanning will be achieved by the elements placed on the left side of the airship (68 to 134). It has to be noticed that the radiations from spirals placed on one side of the airship do not interact with the elements of the other side because they are perpendicularly polarized, as explained in Fig. 3. Using the symmetry of the configuration, we obtain the two types of polarization at any direction.

In order to evaluate the ability of the considered array to scan in every direction, a radiation pattern synthesis method for conformal array is used to focus the main beam. We apply the Alternating Projection (AP) [3] to synthesize a power pattern in order to find the complex excitation coefficients of the 134 elements. The radiation pattern synthesis is performed for each polarization LHC and RHC successively, at any direction. Each computation gives a set of excitations that gives also indications about the position of the elements used to focus the beam. Fig. 4 shows three examples: $\varphi = 20°$, the main lobe is obtained by the elements positioned on the two sides of airship (see Fig. 2) poorly curved and exhibit low side lobe level and good directivity. The case of $\varphi = 90°$ is obtained successfully for the RHCP because the spirals are turned with their RHCP face outward. Finally, the case of $\varphi = 300°$ corresponds to a limit case for the RHCP because the main beam is steered at more than the 60°. However 60° direction is achieved correctly by the internal face of the top left corner radiating LHCP. Because of the lack of elements on the other half ellipse, the two directions 90° and 300° are two extreme cases and can be obtained by only one type of polarization.



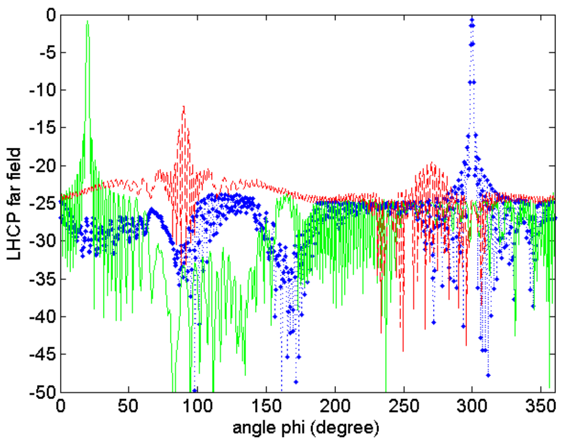


Figure 4: Radiation pattern optimized for the RHCP (left) and LHCP (right) component of the electric far field main lobe at 20°, 90° and 300°. AP algorithm is used with a -25 dB side lobe level and 8° main lobe width desired parameters.

3.2 Cross polarization level

We compare now the level of the co-polar and cross-polar radiated field. It is optimized to have both a co-polarized main lobe in one direction and a low cross polarization. Indeed, the cross polarization is simultaneously radiated because of the double polarization nature of the antenna.

Fig. 5 shows an example where the array radiation pattern is optimized to radiate a LHCP main lobe at 20°. In this case, the cross polarization do not exceed -10 dB. Each element has different orientation and thus different polarization characteristic at a given direction. Thus, Fig. 6 depicts the relative cross polarization level defined as *max(LHCP)-max(RHCP)* when the array is optimized for LHC co-polarization and *max(RHCP)-max(LHCP)* when the array is optimized for RHC co-polarization. The results are obtained with a main polarization reference at 0dB and plotted according to the optimized direction. They show that some directions have a predominant polarization capability. Indeed, for $\varphi \in [0°;40°] \cup [140°;220°] \cup [320°;360]$, (shaded parts in Fig. 6) both RHCP and LHCP with a low level of cross polarization can be obtained. For the directions $\varphi \in [220°;320°]$, corresponding to the outward directions, mostly the RHC polarization can be obtained as shown previously in Fig. 4 for the case $\varphi = 300°$. For $\varphi \in [40°;140°]$, the array has high RHCP cross level and radiates merely RHC polarization. So in the case of only one polarization required, the array would be able to scan over 40°+180°+40°= 260°, and this using only an half ellipse array.

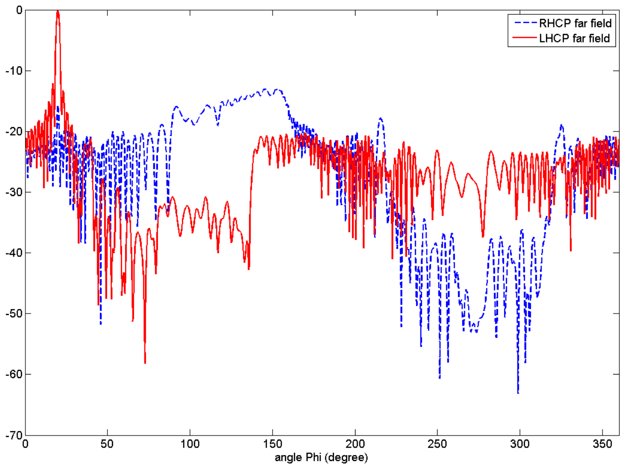


Figure 5: Radiation pattern optimized for LHC co-polarized main lobe at 20° and the simultaneously radiated RHC cross-polarized component of the electric field

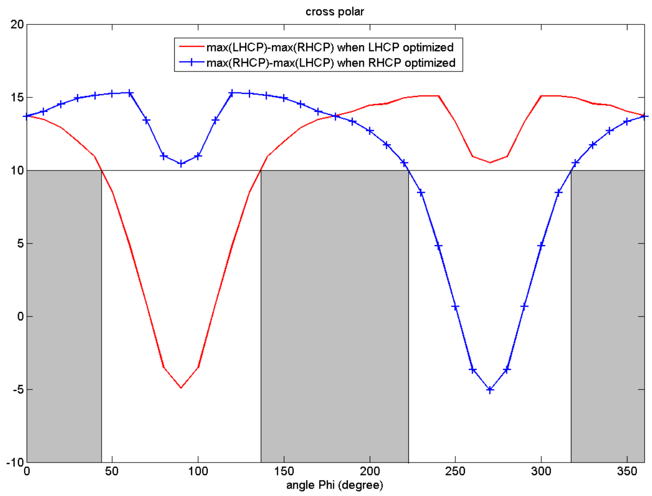


Figure 6: Relative level of co-polarized component max(co-polar)-max(cross-polar), at different angle of direction Phi.

5. Conclusion

A wideband conformal array has been proposed to be mounted on an airship and allows radar and telecommunication applications. The array behaviour and the host platform have been described. The polarization parameter of the array has been especially analyzed in order to exploit its scanning possibilities. The chosen configuration takes advantage of the transparency of the platform as well as the position, orientation and the double polarization nature of the element. Thus, a computation based on a radiation pattern synthesis method has shown that the scanning coverage is partially achieved because of the half ellipse configuration chosen. Full polarization beamforming, with high cross polarization level, as well as single polarization with low cross polarization can be obtained over a 260 ° angle. Finally, a full polarization with low cross level can be achieved for +/- 40 ° scanning on both side of the airship with a minimum number of elements.

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