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ECCM AUXILIARY ANTENNA SYSTEM FOR A MULTIBEAM SAR ARRAY*

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A SAR (Synthetic Aperture Radar) antenna typically consists of a large planar array to obtain a directive pattern with low side lobe level. A multibeam SAR system requires a set of secondary beams, implementing some additional features. To protect the SAR operation from possible jammers ECCM (Electronic Counter-Countermeasure) capabilities can be implemented requiring an auxiliary beam which cover the portion of main pattern to be protected. A possible architecture of this secondary antenna system is here presented by using a set of radiating elements combined together to obtain the ECCM channel. To minimize the feeding network complexity and to maximize the system reliability, the ECCM antenna is a cluster of circular corrugated horns, eventually realized as a single-block unit.

Keywords: Synthetic aperture radar; multibeam antenna; secondary antenna system; horn cluster; electromagnetic compatibility techniques.

1. Introduction

Synthetic aperture radar antennas typically consist of large planar arrays with a high gain and narrow beamwidth electronically steerable main beam. In the last few years multibeam SAR systems have been developed, which, besides the main receiving channel, are equipped with a set of receiving sub-channels providing advanced features and additional capabilities.[1,2] Among these ECCM techniques allow one to assure radar operation also in the presence of possible, intentional or not, electromagnetic interferences.[3,5]

The side lobes cancellation, which is here considered, is an example of an ECCM technique. Radar jamming can occur either through the main lobe or, if the jammer is strong enough, also from side lobe directions. This latter is more challenging since it may affect the radar when the main lobe points in a wide range of directions. To

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cancel the interference, an omnidirectional auxiliary receiving channel is used to provide a comparison signal. By comparing the signal strength as received by both the omnidirectional and the directional main channel, signals can be identified that are not coming from the direction of the main beam, allowing to isolate and ignore these signals.

To assure side lobes cancellation, the ECCM channel has to satisfy specific requirements both in terms of main beam width and side lobe levels. In particular, for each portion of the main pattern, where cancellation should operate, the ECCM antenna gain must be higher than that of the antenna to be protected.

This result can be obtained without additional antennas by exploiting a suitable sub-array synthesizing the desired radiation pattern. This solution has the advantage to minimize the number of additional radiating elements, but, on the other hand, it is very challenging to accurately control the position of the pattern nulls and, in general, this solution implies a large increase of the feeding network complexity.

As an alternative, we can realize a secondary nearly-omnidirectional antenna system covering the principal array pattern in those regions where the ECCM technique should operate. This second approach has the disadvantage to involve additional radiating elements, but it minimizes the feeding network of the SAR antenna, without degrading effects on its electromagnetic performances.

The aim of this contribution is not to compare the two solution approaches, because our study starts from a given optimized SAR antenna, for which additional ECCM capabilities are required with minor impact both on electromagnetic performances and on the structure of the principal array. Therefore, in our case, the choice of a secondary ECCM antenna system is mandatory.

As shown in next section, the ECCM auxiliary antenna makes use of a cluster of radiating elements each one serving a particular angular region where side lobes cancellation should be performed.

2. ECCM Antenna Architecture

The SAR antenna for which additional ECCM capabilities are required consists of a planar rectangular array, operating in X-band (10 GHz), with 240 along-track and 64 across-track radiating elements. The distance between array elements is 0.028 m in along-track direction and 0.0218 m in across-track direction. For the sake of simplicity all elements have been considered isotropic radiators and a -25 dB Taylor feeding has been assumed to control the side lobe level.

The radiation pattern of the SAR antenna is shown in Fig. 1 on the $\phi = 0^\circ$ (along-track direction), the $\phi = 90^\circ$ (across-track direction) and the $\phi = 45^\circ$ planes. The antenna gain is 46 dBi.

In the proposed auxilary antenna architecture the ECCM signal is obtained by the in-phase combination of nine sub-channels, each one associated with a single antenna consisting of a circular corrugated horn operating at 10 GHz, in the hypothesis that electromagnetic coupling effects can be neglected.[6] The horn cluster

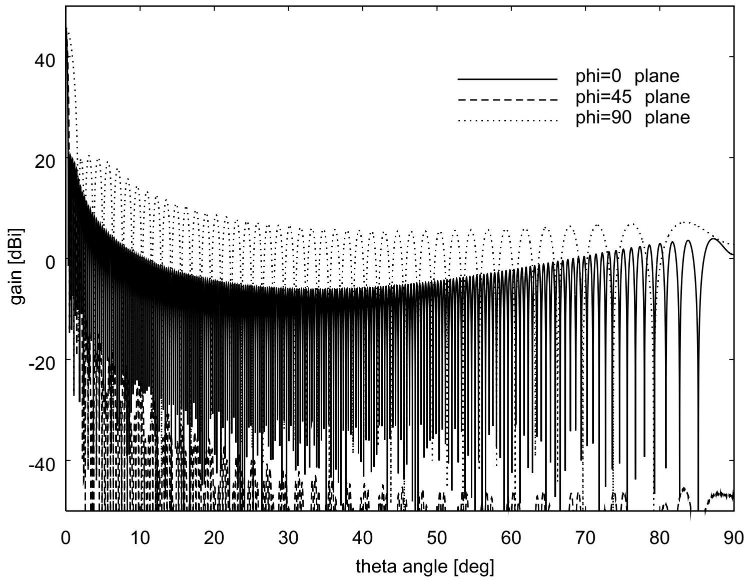
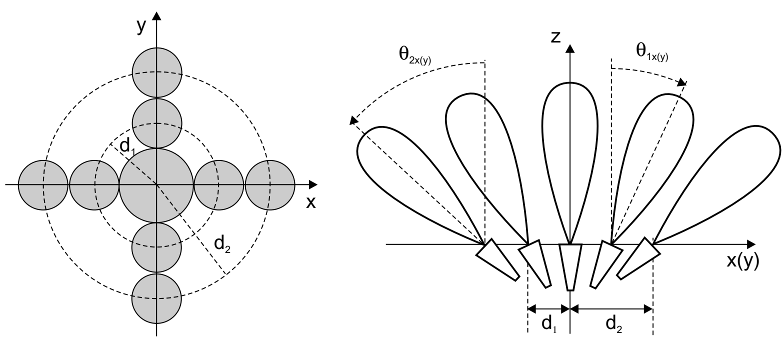


Fig. 1. SAR principal array pattern on the $\phi = 0°$ (along-track direction), the $\phi = 90°$ (across-track direction) and the $\phi = 45°$ planes; a -25 dB Taylor feeding has been considered.



(a) (b)

Fig. 2. ECCM cluster geometry: (a) layout of the horn apertures on the xy plane with $d_1 = 120$ mm and $d_2 = 220$ mm; (b) pointing direction of each horn with $\theta_{1x} = 30°, \theta_{2x} = 60°, \theta_{1y} = 40°$ and $\theta_{2y} = 80°$.

elements differ from each other for the pointing direction, such as each antenna covers a particular angular region of the space. Figure 2(a) shows the geometry and layout of the horn apertures on the xy plane, being $d_1 = 120$ mm and $d_2 = 220$ mm. The central horn, which has a 4.5 cm aperture radius and a 25 dBi gain, has been chosen more directive than others to efficiently protect the first side lobes region. On the other hand, the peripheral horns can be chosen less directive because they are devoted to the protection of the far side lobes: they are identical to each other with an aperture radius of 3.6 cm and a gain of 16 dBi. Figure 2(b) shows the pointing direction of each horn, which have been chosen as $\theta_{1x} = 30^\circ, \theta_{2x} = 60^\circ, \theta_{1y} = 40^\circ$ and $\theta_{2y} = 80^\circ$, to correctly protect the principal array pattern in the side lobe region.

3. Numerical Results

Numerical simulations have been carried out by means of an efficient and accurate hybrid MM-MoM (Mode Matching-Method of Moments) based numerical code, for the synthesis of each circular corrugated horn, and a commercial PO (Physical Optics) based numerical tool to perform the electromagnetic in-phase combination of the nine ECCM sub-channels. Figure 3 shows the geometrical profile and the electromagnetic performances of the central horn, while in Fig. 4 the same data for the horn used as element of the peripheral cluster are reported.

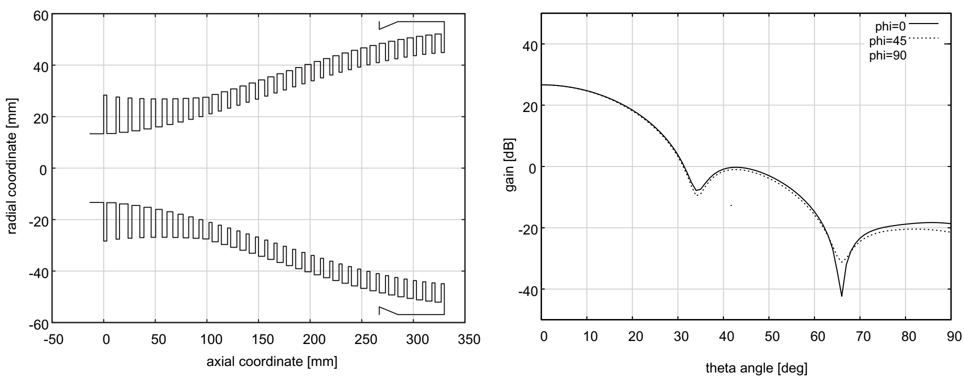


Fig. 3. Geometrical profile (left) and principal planes radiation patterns (right) of the central circular corrugated horn.

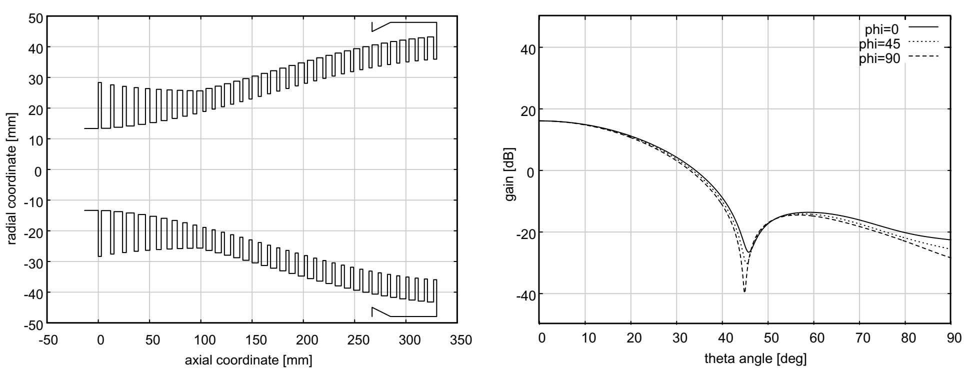


Fig. 4. Geometrical profile (left) and principal planes radiation patterns (right) of the circular corrugated horn used as element of the peripheral cluster.

In Figs. 5–7, radiation patterns of the principal array and of the ECCM channel on $\phi = 0°$ (SAR along-track direction), $\phi = 45°$ and $\phi = 90°$ (SAR across-track direction) planes are reported, respectively, showing that the gain of the ECCM antenna is higher than that of the principal array as requested.

Since the ECCM synthesized pattern is very sensitive to d_1 and d_2 parameters and to the pointing direction of each horn of the cluster, to assure that these parameters do not vary during SAR operation, the cluster should be realized as a mono-block structure, which would result much more reliable even in the presence of thermo-mechanical stresses as in the case of space applications.

From the feeding network point of view, the proposed architecture requires a 9:1 combiner, but no change is due to the principal array Beam-Forming Network (BFN).

For the sake of clarity, it is worth noting that the 15,360 radiating elements of the principal array are grouped in 1280 modules of 12 elements, which in turn are grouped in 40 tiles of 32 modules. The tiles are grouped in five electrical panels, each one comprising eight tiles. The resulting BFN architecture is shown in Fig. 8.

The antenna (higher) level BFN distributes the signal to the five panels; the switch matrix at this level serves to multibeam functionalities, providing five different radar channels for multimode operation. The panel (intermediate) level BFN distributes the signal to the eight tiles of each panel, whereas the tile (lower) level BFN serves the 32 modules of each tile.

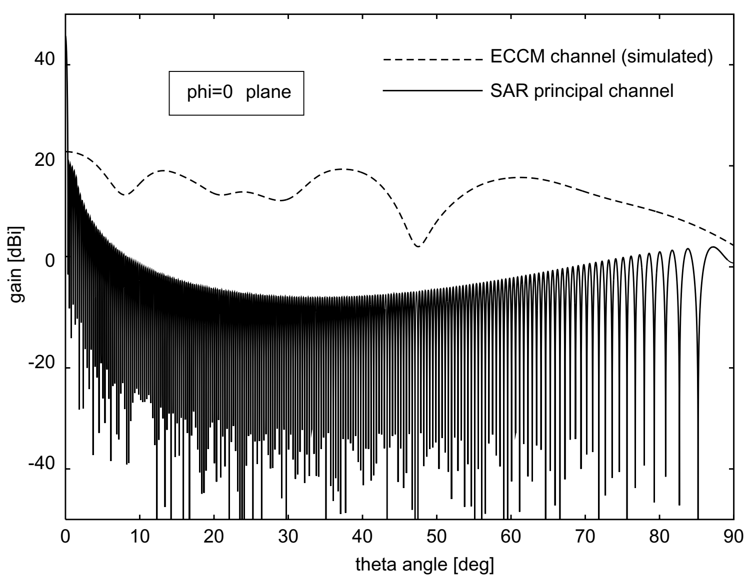


Fig. 5. Radiation patterns of the principal SAR antenna and of the quasi-omnidirectional ECCM channel on the $\phi = 0°$ (along-track direction) plane.

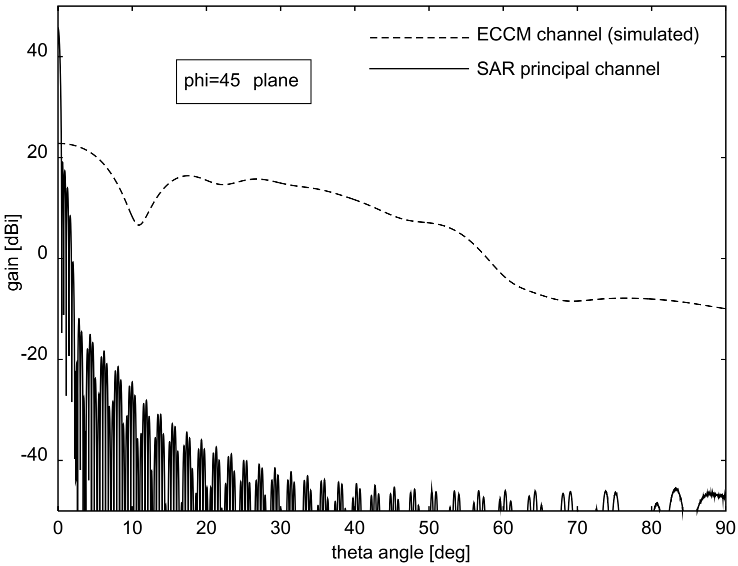


Fig. 6. Radiation patterns of the principal SAR antenna and of the quasi-omnidirectional ECCM channel on the $\phi = 45^\circ$ plane.

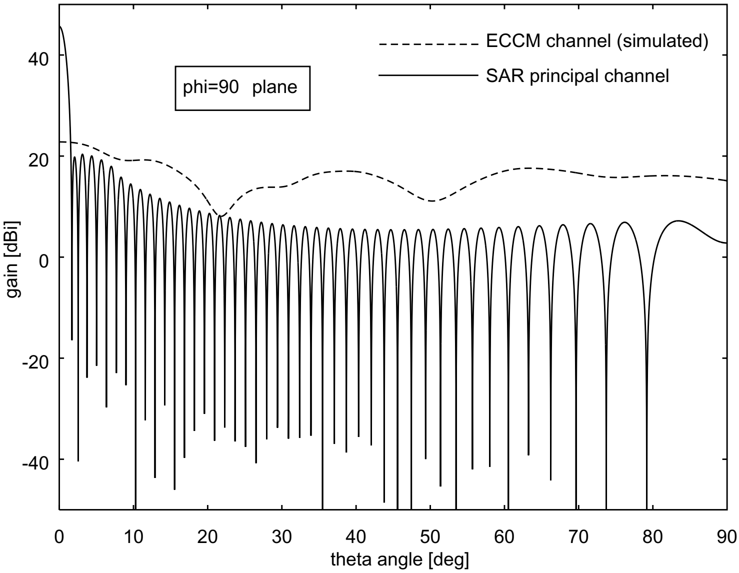


Fig. 7. Radiation patterns of the principal SAR antenna and of the quasi-omnidirectional ECCM channel on the $\phi = 90^\circ$ (across-track direction) plane.

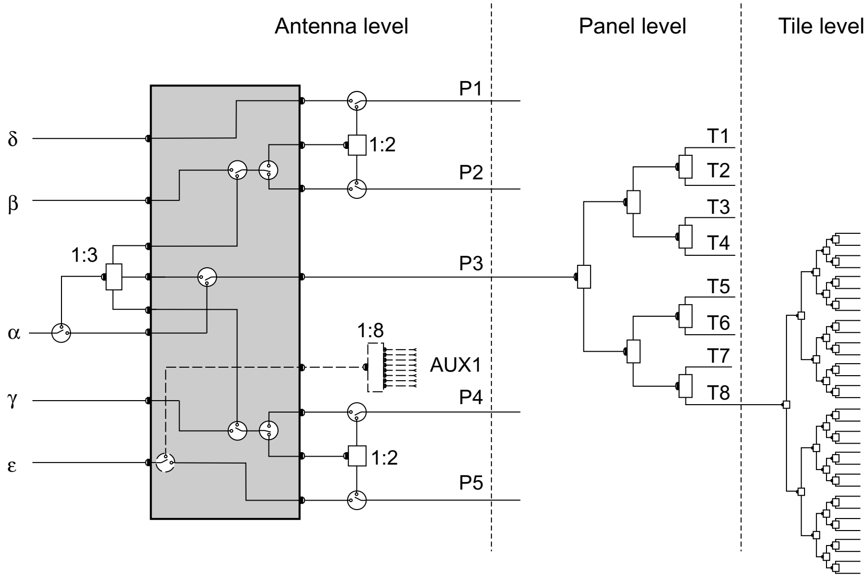


Fig. 8. Architecture of the SAR antenna beam forming network, with the switch matrix at antenna level providing multibeam functionalities; the dashed part of the BFN is relevant to the elements devoted to the auxiliary ECCM channel.

In Fig. 8, the dashed part of the antenna level BFN is relevant to the additional elements devoted to the auxiliary ECCM antenna: it is evident that if we realized the auxiliary antenna as a sub-array of the principal array it would be necessary to introduce modifications at the intermediate or lower level BFN, which would be more critical.

4. Conclusion

A possible architecture for a secondary antenna system, aimed to side lobes interference cancellation in a SAR multibeam structure, has been presented. The ECCM antenna consists of a cluster of nine circular corrugated horns, which have been chosen for their pattern symmetry, polarization purity, high robustness and reliability, especially required for space applications. The proposed architecture has the advantage to minimize feeding network complexity, because it does not require modifications to the principal array beam-forming network. The above configuration can assure quasi-omnidirectional pattern at a sufficiently high gain level, avoiding pattern nulls, which might compromise interference cancellation. Numerical results have been presented to show the electromagnetic performance of the proposed solution.

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