BROADBAND PLANAR ANTENNA WITH LOW SIDE LOBES LEVELS CAPABILITIES AND HIGH CROSS-POLARISATION REJECTION FOR DBS RECEPTION

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Abstract - **This contribution describes a novel microstrip array antenna for DBS reception. Specific features are low side lobes levels as well as high cross-polarisation rejection. For the former purpose, a specific arrangement of the antenna elements along the elevation axis is used, enabling a tapering of the array characteristics in the azimuth direction. Based on a virtual symmetry, appropriate broadband feeding networks are designed, eliminating phase errors. Moreover, the two feeding networks, each corresponding to a polarisation state, are separated by a ground plane, which leads to a very good decoupling between the ports.**

I. INTRODUCTION

Conventional passive array antennas are often uniform and composed of equally spaced single antenna elements. In the case of DBS reception, the array has to fulfil, on the one hand, the characteristics provided by a single element (bandwidth, polarisation, cross-polarisation), and on the other hand, additional requirements related to its radiation pattern. These supplementary features include the level of the side lobes of which the first one is the most determinant and the 3 dB-beamwidth. For a conventional uniform array, the first side lobe level amounts to $-13.5\,\text{dB}$, which is too high for an appropriate DBS reception. Indeed, a maximum level of $-20\,\text{dB}$ is required. Such level is necessary at angles corresponding to areas where interfering satellites are located. The goal is then to suppress undesired signals and disturbances. Moreover, the 3 dB-beamwidth of the array antenna must be narrow enough in order to permit an appropriate selection of the desired satellite. The recommended value in Europe is about 3.5°.

Further requirements for DBS reception in Europe are a dual linear polarisation, a relative bandwidth of 17.5% (from 10.70 GHz to 12.75 GHz) and a port isolation as well as a cross-polar component less than $-20\,\text{dB}$.

This contribution concentrates on the development and design of a novel array antenna providing all the characteristics cited previously. The single element utilised has the multilayer configuration presented in [1]. In the desired bandwidth, measurement results point out side lobe levels less than $-20\,\text{dB}$ in all directions. Moreover, due to the specific positioning of the feeding network layers, a port isolation better than $-40\,\text{dB}$ is attained.

II. ANTENNA STRUCTURE

An array antenna can be steered by varying the excitation [2]

$$I_{nm} = \hat{I}_{nm} e^{j\varphi_{nm}} \qquad (1)$$

of the single antenna elements, where $\hat{I}_{nm}$ is the amplitude excitation and φ_{nm} the phase factor. In particular, the amplitude is associated with the grating lobes, meaning that an array antenna reaches a given side lobe level depending on the amplitudes weighting the single elements.

In order to understand the new concept used to reduce the grating lobes, it is important to consider, as starting point, an equally spaced linear array where N elements are disposed along the x-axis as shown in Fig. 1. The phase factor is identical for all elements and is taken for simplification to be null.

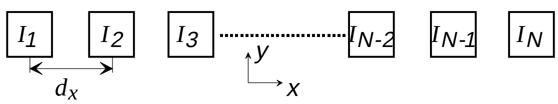

Fig. 1. Linear equally spaced and tapered array

A uniform distribution of the amplitudes yields high side lobes levels whereas a continuos taper from the centre of the array toward the edges leads to low side

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lobes levels [3]. Therefore, the previous linear array is extended to an array where the elements in the centre possess the highest amplitude. Moreover, in order to generate a symmetrical radiation pattern, the weighting factor of the first element is identical to the weighting factor of the $(N)^{th}$ element; the weighting factor of the second element is identical to that of the $(N\text{-}1)^{th}$ element.

Transforming now the described linear array into a planar one is achieved by replacing each single antenna element by a subarray. Each subarray is composed of a given number of identical subelements. This number is associated with the desired weighting of the equivalent element in the linear array of Fig. 1. As a consequence, a planar array is obtained consisting of *N* subarrays in azimuth as shown in Fig. 2.

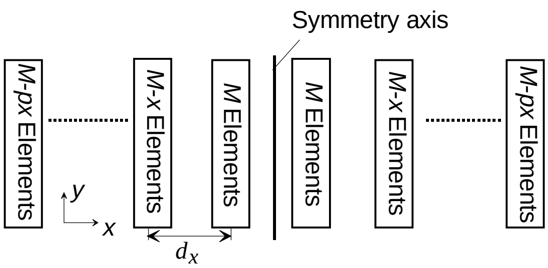

Fig. 2. Planar array with low side lobes levels capabilities

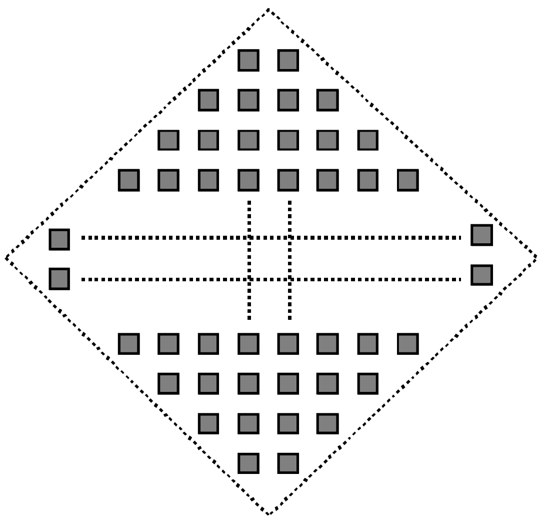

Fig. 3. Developed planar array with low side lobes levels capabilities

Finally, the planar array obtained has a rhomboidal form illustrated, exemplary, in Fig. 3, where each grey square represents a single antenna element.

If the planar array is rotated 90°, the array structure is unchanged and the spacing between the elements in the azimuth and the elevation are interchanged. The novel planar array is consequently suitable for a dual polarisation and the second state of polarisation is obtained by considering the array in the orthogonal direction.

III. Feeding Technique

For a conventional array, the majority of networks are symmetrical and are therefore not complicated to realise. However, it becomes difficult to design a feeding network for a "non" square or "non" rectangular array antenna without phase errors arising and consequently without the distortion of the radiation pattern. Moreover, maintaining a large bandwidth is required. Therefore, a novel feeding network was conceptualised for the newly developed planar antenna.

A virtual symmetry is used is used as illustrated in Fig. 4. The goal of this step is to connect all antenna elements with the alimentation point, located in the centre of the array antenna, via feeding lines having identical lengths. In this way, phase errors are omitted and side lobes preserve their low levels discussed previously.

The whole antenna is divided into four equal parts. Each part is enlarged virtually for the generation of a subarray containing the same number of elements in the azimuth and the elevation. The resulting virtual subarray is also divided into four equal parts. Then, a symmetrical parallel feeding network is designed for the actual existing parts and for the virtual parts. The feeding network has the form shown on the right side of Fig. 4. Only the continued lines belong to it. The virtual elements which edges are dashed in the figure are replaced by appropriate weights on the correspondent dividers. The aim in this case is to share out all available power on all existing antenna elements.

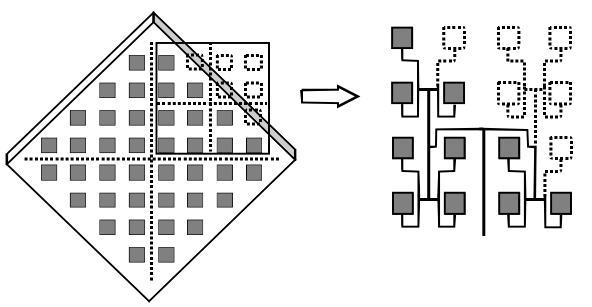

Fig. 4. Realisation principle of the novel feeding network

Because of the rhomboidal form of the planar antenna, place problems occur for some lines running over the place at disposal. That implies that it is not always possible to design a part of the network simply like that of Fig. 4. Thus, in order to preserve the desired lengths of the lines, the latter are redirected and run through another way until reaching an allowed area.

It is important to note that the feeding network used is parallel and introduces additional resonances in order to achieve the demanded broad bandwidth. Moreover, the resulting structure contains bends and discontinuities arranged in an anti-symmetrical configuration, leading to an improvement of the cross-polarisation.

The novel planar array includes single elements in multilayer technology described in [1]. That implies that both feeding networks, each corresponding to a linear polarisation state, feed the patch via a crossed slot cut in a ground plane. The latter is positioned between the two layers containing the feeding networks which do not, consequently, interact with each other. Thus, the port isolation and the cross-polarisation rejection are improved.

IV. Measurement Results

In order to achieve the required 30 dB gain for DBS reception, a dual polarised array antenna with 572 elements was realised. A relative bandwidth of 22.7% was achieved at both ports whereas a bandwidth of 17.5% is required. The measured port isolation, illustrated in Fig. 5, is better than –47 dB and fulfils the requirement of a maximum of -20 dB.

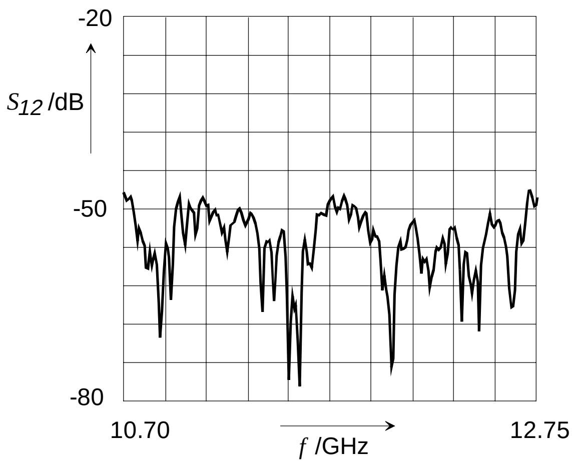

Fig. 5. Measured port isolation

Fig. 6 shows the measured E-plane radiation pattern of the antenna at the upper port. For illustration, the middle frequency $f = 11.725$ GHz is given. The co-polar component points in the main direction (about 0°), and the cross-polar component is very low overall and is much better than the required -20 dB, complying with the measured port isolation.

The side lobes levels are, as expected, less than -20 dB in all areas. The most determinant side lobe level, namely the first one, is illustrated versus frequency in Fig. 7. It varies between -26.6 dB and -20 dB in the desired frequency band, fulfilling the requirement of a maximum of -20 dB.

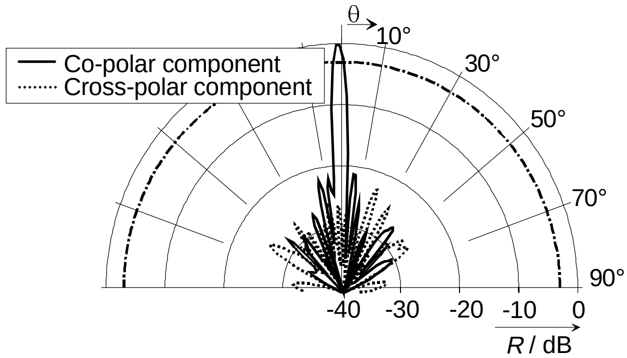

Fig.6. Measured E-plane radiation pattern, f=11.725 GHz

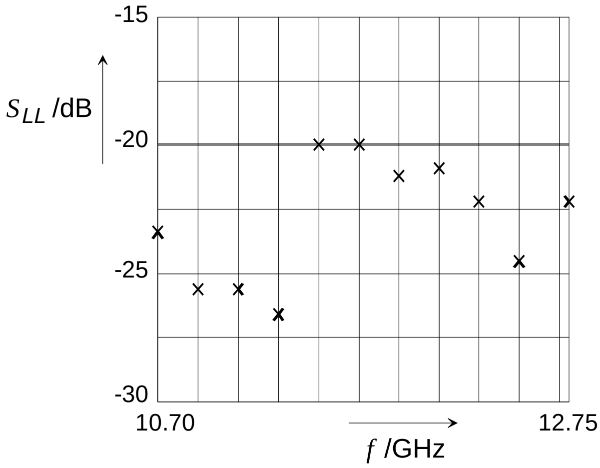

Fig. 7. Measured first side lobe level versus frequency

The 3 dB-beamwidth was also measured over the whole desired frequency band and has values situated between 2.4° and 3.2°.

V. CONCLUSIONS

The design of a novel planar array antenna for DBS reception in Europe was presented. A specific aspect of the novel planar antenna is a shaping of the radiation pattern without the recourse to any active components and consequently without any external amplitude tapering. Thus, a specific arrangement of the antenna elements provides side lobes levels lower than $-20\ \text{dB}$. A broadband feeding network allows the elimination of phase errors as well as the obtaining of a large relative bandwidth of 22.7%. The location of the two feeding networks on different layers separated by a ground plane yields a very good port isolation of less than $-47\ \text{dB}$. A high cross-polarisation rejection is consequently also attained.

All investigations were performed for dual linear polarisation. However, all design principles can be easily transposed to circular states of polarisation. In this case, the disposition of the single elements remains unchanged whereas the polarisation of a single radiator becomes circular.

ACKNOWLEDGEMENT

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REFERENCES

[1] Bekraoui L., “Low Cost Broadband Microstrip Antenna for Satellite-TV Reception”, *Proceedings of the IEEE International Antennas and Propagation Symposium*, pp. 916-919, Orlando, FL, 1999.

[2] Stuzman W. L. and Thiele G. A., *Antenna Theory and Design*, John Wiley & Sons, New York, 1998.

[3] Balanis C. A., *Antenna Theory: Analysis and Design*, John Wiley & Sons, New York, 1997.