A FOLDED 3-LAYER PRINTED REFLECTARRAY WITH SHAPED PATTERN FOR LMDS CENTRAL STATION SECTORED ANTENNA

*J. A. Zornoza [1], R. Leberer [2], M. Moraga [1], J. A. Encinar [1] and W. Menzel [2]

[1] Dept. Electromagnetismo y Teoría de Circuitos, U. Politécnica de Madrid
E.T.S.I. Telecomunicación, Av. Ciudad Universitaria s/n 28040 Madrid, Spain
[2] Department of Microwave Techniques, University of Ulm
Abt. Mikrowellentechnik, Albert-Einstein-Allee 41 D-89081 Ulm, Germany

I. Introduction: Point-to-multipoint fixed radio systems constitute an emerging possibility for the new multimedia channels of communications and future broadcasting applications, which demand broad bandwidth. This kind of broadband wireless systems, known in the literature as Local Multipoint Distribution System (LMDS), include a linearly polarized directive terminal station antenna and a central station sectored antenna. Whereas parabolic reflectors can be used for terminal antennas, the base stations require a shaped radiation pattern which consists of a cosecant squared beam in elevation and a sectorial beam in azimuth. A fan-beam microstrip reflectarray with cosecant squared pattern in elevation has been already demonstrated for radar applications [1]. On the other hand, a folded printed reflectarray with a sectorial beam in azimuth has been demonstrated in [2]. Both references, [1] and [2], achieve the corresponding shaped pattern by using a one-plane synthesis process. Recently, stacked microstrip reflectarrays have been proposed for contoured beam satellite applications [3] since they provide enough bandwidth and are capable of synthesizing the proper three-dimensional (3D) shaped beam by using a suitable phase-only synthesis technique. Bearing in mind both characteristics, multi-layer printed reflectarrays could be thought as suitable antennas for sectored conformal beam antennas. Besides, in order to make a design as robust and compact as possible, an advisable choice would be the use of folded configurations. Folded microstrip reflectarrays have been successfully demonstrated in the last years at microwave frequencies [4]. The aim of this paper deals with the study of a folded multi-layer printed reflectarray with shaped pattern as a result of combining the technologies presented in [3] and [4]. In particular, the design and manufacture of a 3-layer reflectarray is presented as a challenge antenna for sectored LMDS base station.

II. Design and Manufacture: The Fig. 1 shows the geometry of the folded printed reflectarray, with the polarizing grid, the multi-layer microstrip reflectarray and the feed. The designed reflectarray is made up of 749 reflective elements, composed of three stacked rectangular patches arranged in a uniform square grid with 31x31 elements separated 5.85 mm. The antenna dimensions are chosen to achieve the required gain levels (15 dBi) at the application frequency band 24.5-26.5 GHz. The section of the 3-layer configuration is depicted in Fig. 2. The imaginary feed is centered at 10 cm distance from the flat reflector. Hence, the depth of the folded design becomes 5 cm. The used feed is a conical horn with 16mm-diameter aperture and 6.5 mm length. The choice of the feed is constrained to the taper illumination required in the edge of the reflectarray. An 8 dB taper illumination at reflectarray´s edge is chosen. Lower taper means too high spill-over losses, and higher taper requires more directivity, that is, larger feed antenna. The polarizing grid is formed by a strip grating

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sandwiched between 2 substrate layers: 0.508mm-thick Duroid5870 and Duroid5880 of thickness 3.18 mm (total thickness is close to half a wavelength in the substrate). This configuration gives return losses lower than –22 dB in the whole band. The polarizing grid is in far field condition with respect to the feed.

In order to carry out the synthesis and design process, the equivalent non-folded reflectarray (defined by the imaginary feed) is used since no software tool is able to simulate the radiation pattern of the whole folded antenna in a reasonable period of time.

A design method previously applied to very large contoured beam reflectarrays [3], is conveniently modified to be successfully used for the reflectarray under study. In the synthesis process, the separate nature of the required pattern specifications (templates in thin line of Fig. 5) is exploited initially to facilitate the synthesis of the desired shaped pattern. Thus, two independent phase-only syntheses correspond to a 6º-tilt cosecant squared pattern in the plane v=0 and a 90º-sector beam in the cut u=sin(6º) are carried out by means of an approximate analytical technique explained in [5]. As a result, two linear phase distribution are achieved. Taking as starting point the combination of both synthesized linear phase distribution, a full synthesis based on the alternating projection method [3] is accomplished to achieve a final phase distribution for the 3D desired shaped pattern. In this way, local minima are avoided and a suitable final phase distribution of the reflected field over the flat reflector surface is synthesized. The q factor of the cosine feed model used in the synthesis process is set to 3.5 to match as close as possible with the real radiation pattern of the conical feed horn used in the design.

The nine central elements were eliminated to place the feed horn. The fact that these elements do not contribute to the radiation pattern must be taken into account in the synthesis process, since it has been checked that the simulated radiation pattern is modified by increasing the side lobe levels behind the cosecant beam and by distorting the shaped pattern in elevation at the same time. That effect is computed setting them one by one with null excitation in the synthesis process which starts from the non-blockage phase distribution previously synthesized. After the whole phase-only synthesis process the synthesized pattern approximates quite well the desired specifications although the blockage effect produces slight distortion in the final simulations and undesired holes appears (see Fig. 5a).

For the folded reflector antenna as described here, the patch axes of the array are tilted by 45° with respect to the incident electric field. The dimensions of the patches are optimized in such a way that a phase difference of 180° is kept between the reflection phase angles of the two field components parallel to the axes, leading to a twisting of the polarization by 90° [4]. Therefore, the synthesized shaped reflected field is twisted and can pass through the polarizing structure in front of the antenna.

III. Results and Discussion: A picture of the manufactured folded reflectarray is presented in Fig. 3. The required 5-cm separation between the reflectarray and the polarizing grid is achieved by means of eight small nylon posts 5mm-thick. Fig. 4 shows a 3D measured pattern at 25 GHz referred to direction cosines u and v. A comparison between gain simulations and measurements for the main cut planes is shown in Fig. 5a and Fig. 5b; respectively the tilted cosecant squared beam (plane v=0) and the sectored beam (plane u=sin(6º)). A good agreement between the simulated and measured gain patterns is observed. Nevertheless, the measured pattern presents sidelobe levels higher than it would be expected and a sectored beam narrower than the simulations. Several compelling reason can justify the slight mismatching. On the one hand, the real scattering effects produced in the feed horn are unpredictable and not possible to be simulated even with a full wave simulation tool. On the other hand, the analysis of the central elements close to the feed horn is not accurate enough since the approximation of local periodicity used in the design process [3] is not fulfilled any more. The amplitude field on central elements is large and therefore, its inaccurate analysis can produce some distortion in the radiation pattern. The elevation pattern has been measured at several frequency along the band and the results show worse matching with the simulations at extreme frequencies of the band.

IV. Conclusion: In this paper, the design, manufacture and measurement of a folded 3-layer microstrip reflectarray with shaped beam has been presented. The accomplished design practically meets given specifications for a LMDS base station antenna. Those specifications are defined as a 6º-tilt cosecant squared beam in elevation and a 90º-sector beam in azimuth. The measurements are close to the expected simulations at central frequency. Further improvements must be done in order to reduce the sidelobe level out of the shaped beam and to improve the shaped pattern in the whole band.

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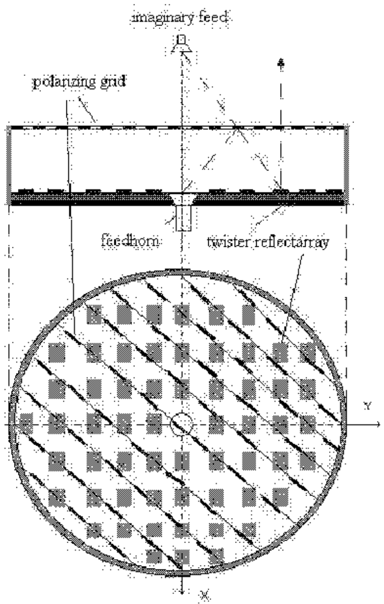


Fig. 1. Geometry of a folded microstrip reflectarray. Section and zenithal view.

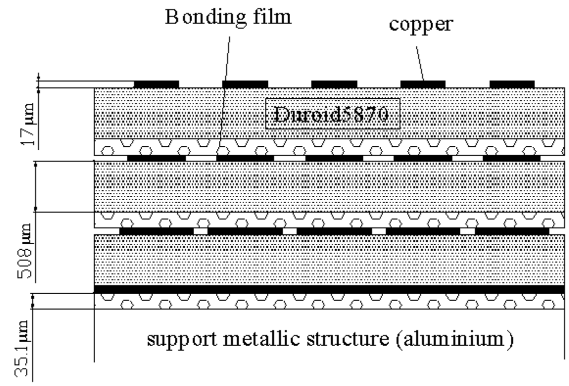


Fig. 2. Cross-sectional view of the 3-layer structure used for the implemented reflectarray.

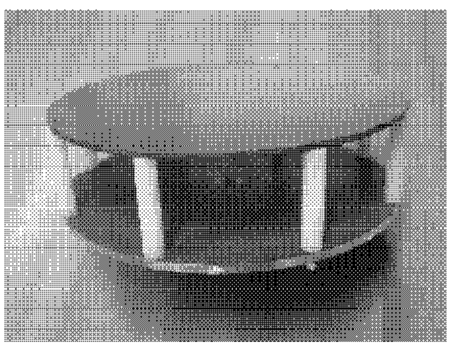


Fig. 3. Picture of the manufactured folded 3-layer reflectarray with shaped pattern.

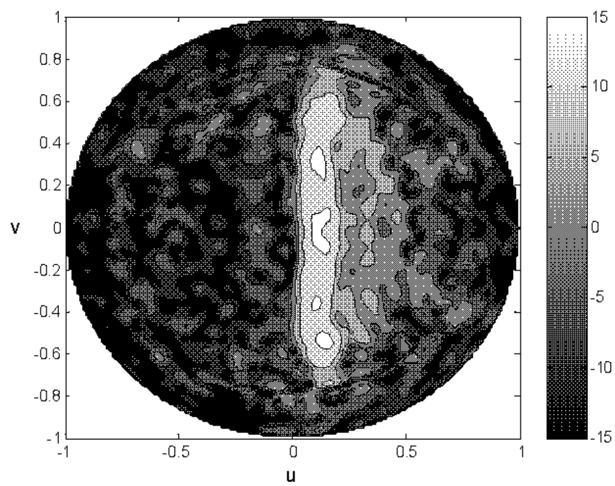
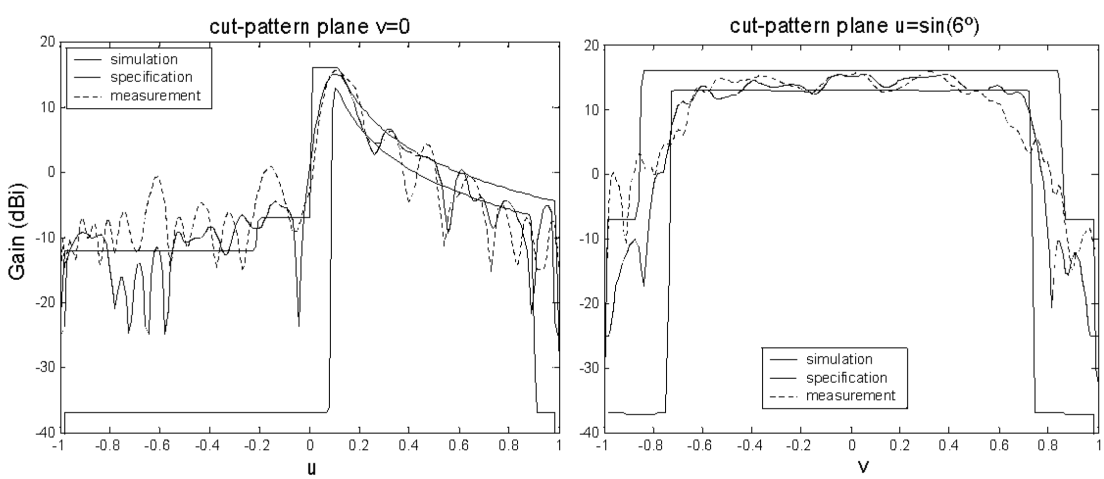


Fig. 4. 3D measured gain radiation pattern at 25 GHz.



(a) (b)

Fig. 5. Comparison of measurements, simulations and specifications at 25 GHz. (a) Elevation plane pattern v=0; (b) Azimuth plane pattern u=sin(6º).