STUDY of FOLDED REFLECTOR MULTIBEAM ANTENNA with DIELECTRIC RODS as PRIMARY SOURCE

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Abstract— **Based on a folded reflectarray antenna, a three-beam antenna is investigated using dielectric rods as primary feed placed in open-ended waveguides for obtaining an optimal illumination on the reflector. The performances for a dielectric rod and a combination of three rods are investigated using Ansoft HFSS software. In a first step, dielectric rods have been manufactured and measured at 77 GHz. In a second step, they are used as primary feed of the reflectarray. The corresponding shift of the phase centre caused by the rods has been estimated in simulation and accounted for in the antenna arrangement. The radiation pattern measurements show a gain improvement of 2dB.**

Index Terms— **Dielectric rods, folded reflector, reflector antenna feeds.**

I. INTRODUCTION

Millimeter wave radars system e.g. for automotive or helicopter obstacle detection require antennas with sharp beams, on one hand, and with potentialities for beam scanning on the other hand. A classical solution is the use of a mechanical scanning as described in [1]. It can be replaced, to some extend, with multibeam antennas such as in [2]: a multiple feed is used as feeding source of a lens the profile of which has been calculated for appropriate phase compensation. The multibeam performance is achieved by source switching. The same result can be obtained by replacing the lens with a printed reflector. For this purpose, a three-beam antenna has been developed at the University of Ulm for the Daimler-Chrysler automotive radar. It consists of folded reflectors [3] [4] with circular open-ended waveguides as primary sources.

Dielectric Rod Waveguides (DRW) made of materials with low dielectric permittivity (Teflon, polyethylene etc.) which provide a good matching of the DRW with a metal waveguide have been successfully employed as antennas [5]. In [6], the dielectric rod antennas of rectangular cross section have been used as optimized feed elements for focal plane arrays. The objective of this work is to improve the performance of the primary sources by inserting dielectric rods in the waveguides. This makes it possible to adjust the feed diagram for optimal illumination of the reflector and to enhance the gain for the different radiation patterns.

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II. MULTIBEAM FOLDED REFLECTOR ANTENNA

The folded reflector is composed of an array of printed patches, which constitutes the main reflector, and of a polarizing slot array, which behaves like a secondary reflector (Fig. 1) [4]. The slot array is adjusted in such a manner that the radiation of the primary source is entirely reflected towards the main reflector. The latter compensates for the delays of propagation, as in conventional reflectarrays, but also turns the initial polarization by 90°, so that the wave can pass through the grid and is focused at infinity. In order to get the required 90° rotation of the polarization, the rectangular patches must be disposed 45° tilted with respect to the incident field. Then they are designed to maintain a phase difference of 180° between the phase angles of the two reflected field components defined along the axes which are parallel to the patches sides and in the same time they have to satisfy the classical phase compensation for focusing the beam. More details can be found in [4,7].

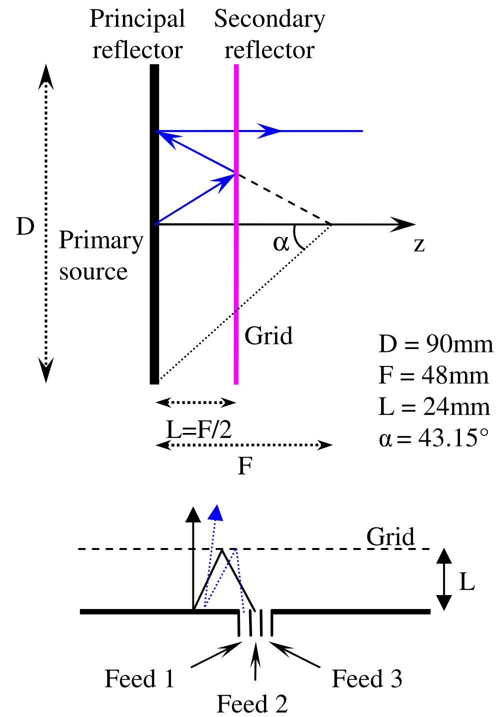


Fig. 1. Structure of the folded reflector antenna

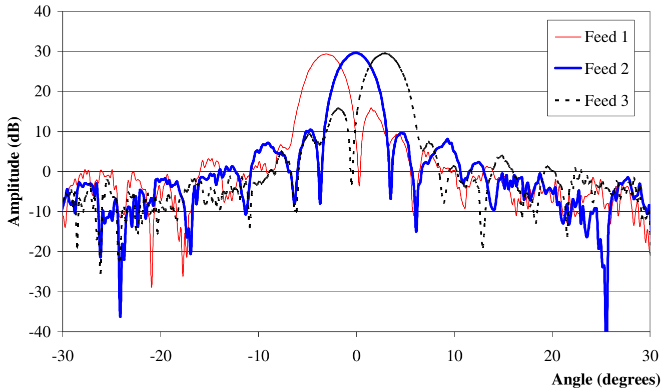


Fig. 2. Multibeam radiation pattern with 3 open-ended circular waveguides $L = 24$mm, $f_0 = 77$GHz

The folded reflector is used for a multibeam radiation pattern obtained by switching the primary feeds as shown in the Fig. 2.

III. Improving the Primary Source

This reflector antenna is illuminated with open-ended circular waveguides. According to the focal length to diameter ratio, the illumination angle 2α is of the order of 90°. This results in an amplitude taper of -5dB. In order to improve the total efficiency of the antenna, the aim is to lower this level to -10 dB for realizing a better compromise between the taper and the spillover efficiencies. In the following part, the value of 2α equal to 90° corresponding to a -10 dB illumination taper, is targeted for the new primary source.

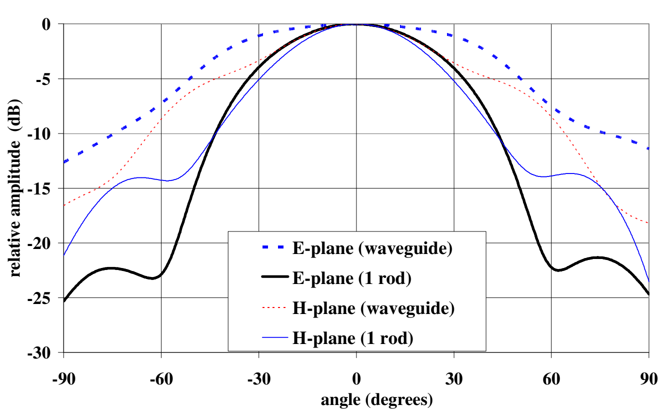


Fig. 3. Simulation of the radiation diagrams of an isolated rod and open waveguide, f = 77 GHz

The investigated solution for reducing the actual amplitude taper consists in inserting dielectric rods [5] in the waveguide feeds. The directivity of the rod can be improved by giving a conical shape to the rod preventing backward propagation by reducing internal reflections. In addition, it provides a uniform field distribution that also enhances the antenna directivity. According to the above considerations, the geometrical parameters H, 2R and $2R_0$ are the critical parameters of the dielectric rod antenna design. Since $2R_0$ is given by the open-ended waveguide, the rod performances are optimized with H and 2R.

The chosen material is rexolite ($\varepsilon_r = 2.53$) due to its low loss dielectric properties. The illumination level is adjusted by means of simulations by varying the geometrical parameters of the rods. The simulations are carried out using Ansoft-HFSS software [8]. Furthermore, once the sources are designed, they are directly inserted in the existing folded reflector. This implies that the rods dimensions have to fit with the actual reflector geometry. In particular, the value of H has to be small enough for space purpose, and because the rod length will cause a phase center shift that has to be kept as small as possible.

First of all, an isolated rod is calculated. The radius of the rod, R, is the most effective parameter for sharpening the radiated beam. The target is achieved for the value 2R equal to 0.6mm. Fig. 3 shows the corresponding radiation diagrams in the E- and H- planes, the open-ended waveguide radiation patterns are plotted for comparisons.

The study is then extended to the total primary source arrangement including the three rods. The best solution, shown in Fig. 4, is based on the use of three separate rods where a 2 mm section of dielectric is added to stabilize the rods inside the waveguides.

In the final antenna setup, the three sources will be switched. Therefore only one source will be active at the same time. In order to make the corresponding simulations, we also set one source active while the other ones are not exited. As expected, the proximity of the sources creates a direct coupling that can be partially reduced by adjusting the height of the external rods. Optimal dimensions are reported in Fig. 4. Corresponding radiation diagram simulations are shown in Fig. 5. The objective in terms of taper illumination is achieved in the E-plane. The beamwidth is wider in the H-plane where the 3 dielectric rods are aligned.

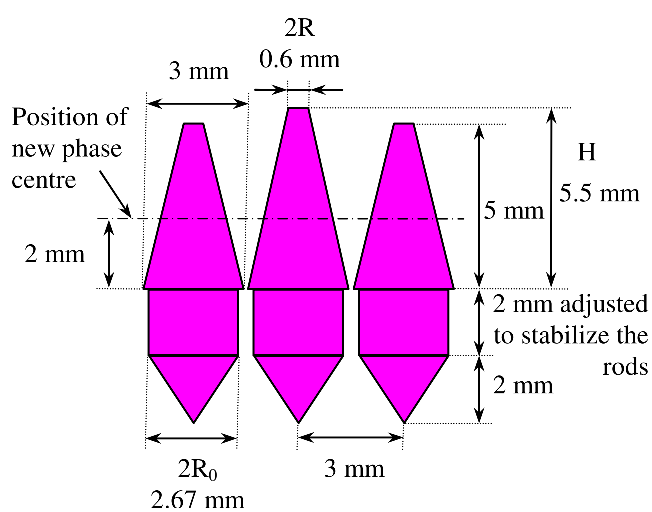
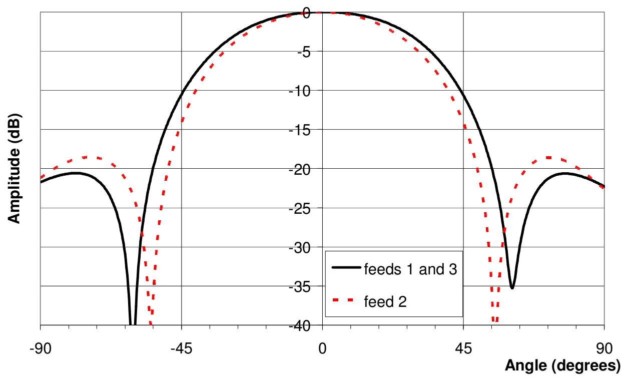
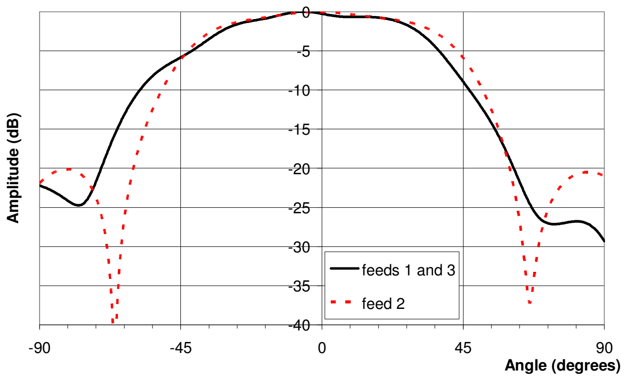


Fig. 4. Geometry of the manufactured dielectric rods

Finally, the dielectric rods are manufactured with the dimensions as indicated in Fig. 4. Fig. 6 depicts the final antenna and the disposition of the rods in the reflector.



(a) E-plane



(b) H-plane

Fig. 5. Simulated radiation pattern of the primary source with 3 dielectric rods .

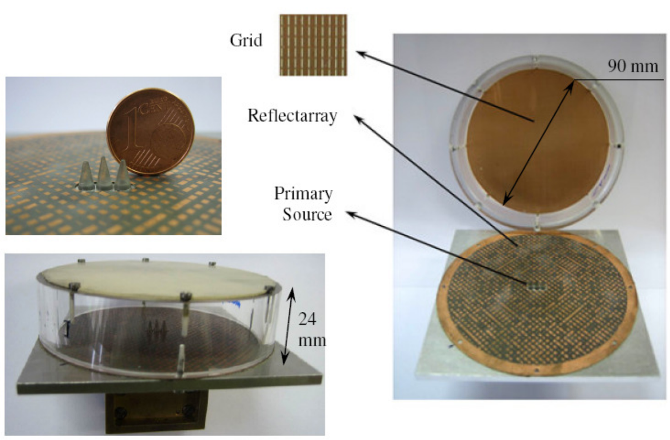


Fig. 6. Folded reflector structure with three dielectric rods

IV. Antenna Measurements

Measurements of the primary source are firstly carried out in the anechoic chamber at the LEAT.

Fig. 7 shows the comparisons between simulations and measurements. A good agreement is obtained with a slightly narrower lobe with measurements that could be due to manufacturing tolerances. The measurements of the whole antenna are carried out in the anechoic chamber of the University of Ulm under the same conditions as the measurements shown in Fig. 2. Therefore, the comparison between the maximum amplitude levels of the radiation patterns of Fig. 2 (without rods) and Fig. 8 (with rods) gives the gain difference due to the rods. It can be seen that it is almost 2 dB. In addition, the gain of the reflect array including dielectric rods has been measured over frequency (Fig. 9) for the central excitation (feed 2). The 3dB gain bandwidth comprised 71.4 and 79.9 GHz which is by far sufficient for automotive applications.

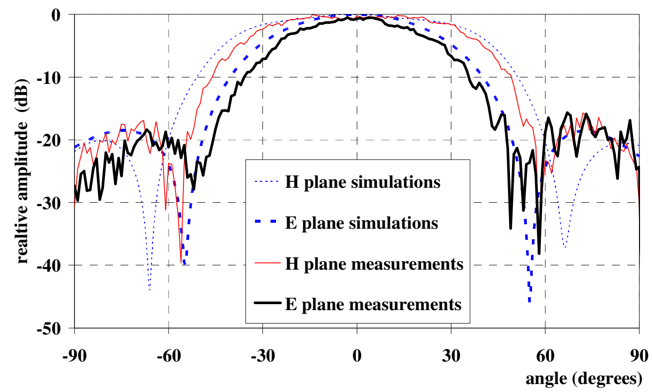


Fig. 7. Radiation pattern of the primary source with 3 dielectric rods

We have also examined several distances between the substrates (reflectarray and polarized grid). Best performances are obtained at 25 mm with the rods on contrary to 24 mm without the rods. The rods shift the phase centre forwards compared to the open waveguides. To compensate for this approximately, the distance between the two reflectors has to be increased by half of the phase center shift.

Simulations on a single rod were carried out using the France Telecom software SRSRD [9] in order to study the phase center shift. This software is specially dedicated to axisymmetric radiating structures. These calculations show that the phase centre of the rod shifts 2 mm forward compared to an open waveguide (Fig. 4). This confirms the corrected distance between the two reflectors found experimentally.

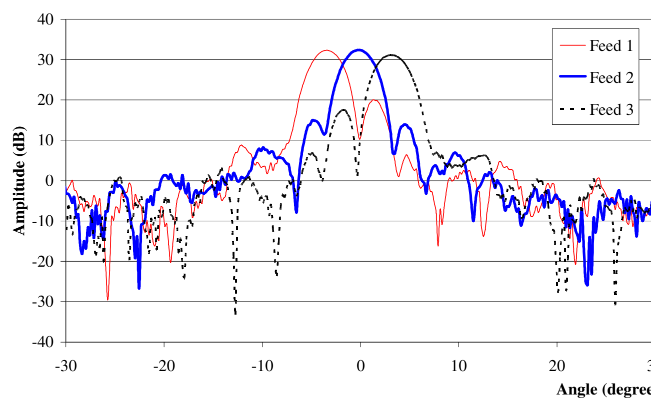


Fig. 8. Multibeam radiation patterns with the dielectric rods in the open circular guides, L = 25mm, f_0= 77GHz

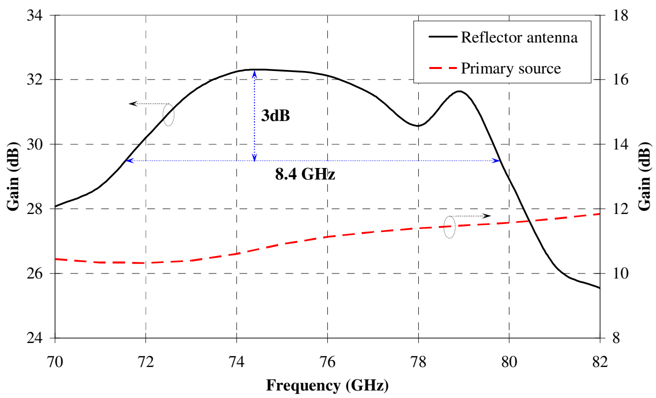


Fig. 9. Measured gain over frequency

V. CONCLUSION

An improvement by inserting dielectric rods in primary sources of folded reflectors is shown in a multi-beam configuration. An increase of 2 dB of the gain is obtained by using the dielectric rods. It has been shown also that the phase centre shift due to the dielectric rods has to be taken into account. In the investigated configuration, the rods were inserted in an existing reflector configuration just correcting for the distance between the reflectors, but performance could probably be further improved by redesigning a reflector according to the new phase center location.

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