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EBG Enhanced Reflector Feeds for Wide Angle Scanning Applications

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Introduction

Present and next generation telecommunication satellite systems often require multiple beam capability. A simple way to achieve high edge of coverage gain is to use a single aperture and a single feed per beam [1]. In the series of works [2], [3], [4] an approach based on the use of dielectric super-layers to enhance the radiation properties of small apertures to improve the excitation of reflector antenna systems has been proposed. In particular [4] shows the results for a demonstrator used as feed of a dual reflector system, with an increase of edge coverage gain of 1.3 dB over a bandwidth of about 6%. However these performances were demonstrated only for systems characterized by moderate values (0.85) of the F/D (Focal distance to diameter ratios). In this contribution the same strategy based on the use of super-layers is adapted to the design of reflector systems based on larger F/D's which in turn are necessary to achieve small degradation of the performances for the off focus beams.

Pattern Synthesis Based on Leaky Wave Enhancement

In [3], [4] a super-layer configuration, characterized by $h_1=0.5 \lambda_0$; $h=0.25 \lambda_d$ (with λ_d the wavelength in the dielectric) and dielectric constant $\epsilon_r=4.5$ was discussed. There it was demonstrated that the mutual coupling between neighboring elements in an hexagonal lattice configuration was dominated by the first couple of TE/TM leaky waves that were supported by the structure. When the inter-element spacing was such that the mutual coupling between neighboring wave-guides was lower than -30 dB the embedded and the isolated beams would nearly coincide. Wide scanning angles for telecom applications require large inter-element separation and a large F/D for the system to be designed. Following the design strategy discussed in [4], it turns out that these specifications can be met using a unique dielectric super-layer characterized by dielectric constant $\epsilon_r=20.25$. When an array configuration as shown in Fig. 1, based on compact square wave-guides loaded with irises and inter-element period $d=2.4 \lambda_0$ is used the radiation patterns turns out to be rotationally symmetric. The patterns directivity depends on the value of the dielectric constant of the super-layer slab. In order to determine the value for the dielectric constant, a trade-off between the edge of coverage gain and the frequency needs to be performed. For this reason Fig.2 shows the edge of coverage gain for several frequencies for a number of different dielectric slabs, assuming $F/D = 1.7$. It is apparent that larger dielectric lead to higher edge of coverage gains over smaller bandwidth. One should note that the configuration based on two dielectric layers of dielectric constant $\epsilon_r=4.5$ is equivalent to a unique layer of $\epsilon_r=20.25$ at the central operating frequency. However the single slab configuration seems to be associated to larger useful bandwidth and seem to be preferable from an electromagnetic performance point of view, at least in the presence of low loss dielectrics. The mutual coupling between the neighboring wave-guides is assumed not to disturb the radiation pattern of the isolated wave-guides because a reuse scheme x4 will be implemented. This means that the wave-guides closest to the

central one are effectively short circuited either by cross polarized irises or by the frequency filters as discussed also in [4].

Figure 1 – Final design of the prototype waveguide array. The area of each unit cell is significantly larger than the dimension of each waveguide

Consequently, the inter-element period for radiators operating on the same polarization and frequency is effectively $4.8 \lambda_0$. Simulations show that, in the frequency band under consideration, the mutual coupling coefficients among neighboring elements S_{ij} are below -30dB.

Figure 2 – G_{EoC} for different super-layer configurations with different dielectric permittivities and with more than one super-layer. The circular horn feed with infinite taper is taken as reference case. The equivalent F/D of the system is set at 1.71.

The predicted directivity patterns for a dielectric slab characterized by $\epsilon_r=20.25$, in four significant planes, are reported in Fig.3 at the frequency of 9.95 GHz.

Figure 3 – Amplitude of the calculated primary radiation patterns at $f=9.95$ GHz for $\phi = 0^\circ; 30^\circ; 60^\circ; 90^\circ$ of a super-layer configuration with $\epsilon_r=20.25$ compared to same field cuts of the reference case with infinite taper and with the iris loaded compact square wave-guide without super-layer stratification.

They are also compared with the ones that would be achieved by the reference (infinite taper) circular apertures and by iris loaded compact square wave-guide without the super-layer stratification. It is apparent that the leaky wave enhanced pattern are much more directive than the isolated one in both cases and thus, over a small frequency range more suited to feed efficiently a reflector with large F/D. Fig. 4 shows the secondary patterns for different frequencies using a reflector of F/D 1.71. In the Figure the highest useful frequency is 10.05 GHz which corresponds to the first frequency at which the beam isolation (defined as gain at the edge of coverage - the first side lobe level) is lower than 12 dB.

Conclusions and future work

This work is an extension of a series of works on the use of dielectric super-layers to shape the radiation pattern of each feed composing a focal plane imaging array. Using dielectric super-layers, the spill over from the reflectors are reduced without increasing the dimensions of each aperture. These effects are achieved when the inter-element distance between the feeds is large (2.4 wavelengths) which is typical for satellite based multi beam telecommunication applications. The shaping of the pattern is obtained with the excitation of a pair (TE/TM) of leaky waves, that radiate incrementally as they propagate between the ground plane and the super-layer. The super-layer can be realized with single dense dielectric slab ($\epsilon_r=20.25$) a double dielectric slab ($\epsilon_r=4.5$) or an equivalent frequency selective surface. The maximum edge of coverage enhancement, with respect to reference free space configurations, that can be obtained in the different cases is equivalent. However the bandwidth over which the enhancement is maintained depends on how the super-layer is realized. The calculated embedded patterns provide an increase of the edge of coverage gain, with respect to the free space case, of at least 1.5 dB in an operating bandwidth of 3%. During the oral presentation the hardware manufactured to implement the previous concepts, including the filters for the frequency

and reuse scheme, will be shown. Also the measured results will be compared with the simulations.

Figure.4 – Secondary patterns in the band 9.7-10.1, considering a reflector with $F/D = 1.71$. The feed patterns can be used until the upper frequency of 10.05 GHz, where the beam isolation is lower than 12 dB

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