Excitation of Antennas by Using Surface Plasmon Technology

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Abstract—Surface waves has been demonstrated to be a good candidate to transmit electromagnetic waves the THz regime. Particularly, it has been proven that surface plasmons, and particularly the named domino plasmons, can be used to create THz circuitry which presents low losses. In addition, these plasmons can be easily laterally confined without mismatch. In this paper, we demonstrate how this technology can be extended to obtain phase delays in waveguides with the inclusion of dielectric slabs in between the corrugated metallic slabs. This proposal can be used to excite arrays of antennas in order to achieve directive radiation patterns with different pointing directions.

I. INTRODUCTION

Surface plasmons are charge-density oscillations which are excited in the surface between two materials. The practical condition to this excitation is that the first of the media needs to present a positive dielectric constant, and the second medium, a negative one (that can be achieved in practice with a metallic ground plane). In these conditions, an evanescent wave or surface wave will be confined close to the metallic surface, having an exponential decay of the intensity of the electromagnetic fields [1], [2]. Although, as mentioned, a dielectric material should be placed over the metallic surface, it has been recently reported by the Physics Community that these surface waves can be also excited in the THz regime when a certain periodic repetition of obstacles or holes are tailoring the metallic ground surface [1], [2]. This phenomenon was already identified in the 50’s by the Engineering Community [3], [4] in the microwave regime.

Following this line of research, some authors in the Physics Community have proposed to use these surface waves (in a domino or metallic corrugated configuration) to transmit efficiently energy in the THz regime [5]-[7]. And they have demonstrated the possibilities of this technology to design circuitry. For instance, in [5], power dividers, directional couplers and waveguide ring resonators have been proposed and its corrected operation reported. According with results presented in [5]-[7], these metallic corrugations can be employed as waveguides which present a low level of losses and that have the ability to confine the electromagnetic fields in the lateral dimension without practically mismatch losses, due to the small variations in the propagation constant of the surface mode with this dimension.

However, although the properties and advantages of these structures as transmission waveguides have been demonstrated, there are only few contributions of antennas for this technology [4], [8], [9]. In this paper, we propose to use dielectric inclusions to produce a phase delay in the named domino surface plasmons. This technique can be employed to feed different radiation elements with different phases, and therefore to modulate the radiation pattern of the complete antenna as it was already done in classical array theory for synthesis of arrays [10].

II. SURFACE PLASMONS OPERATION

As mentioned before, the surface waves excited in a metallic corrugated configuration over a ground plane can be used to transmit energy in the perpendicular direction of these corrugations [5]. In Figure 1, it is illustrated the basic scheme of the proposed waveguide. In the general case, the gaps between the corrugations can be filled with a dielectric material (of value $\varepsilon_r$) which will significantly change the propagation constant of the excited mode. This effect is illustrated in Figure 2 for the following dimensions: $h = 0.2mm$, $d = 0.1mm$, $a = 0.05mm$. When the dielectric constant of this medium increase, the cut-off frequency of the mode is shifted down in frequency as it was previously reported in the known as soft-surface concept [11]-[13]. This implies, that at a certain
frequency, for the same configuration but with a denser material between the corrugations, the propagation constant will be lower which is equivalent to the effect of having a dense material (higher refractive index) as it is illustrated in Figure 3.

![Fig. 2. Propagation constant for the corrugations described in Figure 1 with different dielectric inclusions when dimensions are: $h = 0.2\, \text{mm}$, $d = 0.1\, \text{mm}$, $a = 0.05\, \text{mm}$.](image)

Fig. 2. Propagation constant for the corrugations described in Figure 1 with different dielectric inclusions when dimensions are: $h = 0.2\, \text{mm}$, $d = 0.1\, \text{mm}$, $a = 0.05\, \text{mm}$.

![Fig. 3. Equivalent refractive index for the corrugations described in Figure 1 with different dielectric inclusions when dimensions are: $h = 0.2\, \text{mm}$, $d = 0.1\, \text{mm}$, $a = 0.05\, \text{mm}$.](image)

Fig. 3. Equivalent refractive index for the corrugations described in Figure 1 with different dielectric inclusions when dimensions are: $h = 0.2\, \text{mm}$, $d = 0.1\, \text{mm}$, $a = 0.05\, \text{mm}$.

III. PHASE DELAY FOR THE FEEDING OF ARRAYS

Moreover, as reported in [5], the power transmitted into domino waveguide can be divided in two new waveguides simply splitting the metallic corrugation in two pieces. If these different pieces are filled with different dielectric constants, the propagated waves will have a different delay which can be used to feed the antennas of an array with different phases. This concept is schematically represented in Figure 4 for two cases, a first one with the same dielectric materials, and a second one with different ones. The field distribution, for the particular implementation and dimensions described in the previous sections, is illustrated in Figure 5. In Figure 5 (a) is shown how without phase delay in the branches, the waves follows a constant path creating a parallel wave after the structure, while in the Figure 5 (b) a tilt of the angle is obtained after having different phases at the end of the structure.

![Fig. 4. Illustrative scheme of the division in two pathes of the domino corrugated configuration and the phase delay produced depending on having or not the same dielectric material inclusions.](image)

Fig. 4. Illustrative scheme of the division in two pathes of the domino corrugated configuration and the phase delay produced depending on having or not the same dielectric material inclusions.

![Fig. 5. Electric field distribution after exciting the surface wave (left) having in between the corrugations a) same dielectric inclusions ; b) different dielectric inclusions.](image)

Fig. 5. Electric field distribution after exciting the surface wave (left) having in between the corrugations a) same dielectric inclusions; b) different dielectric inclusions.

IV. CONCLUSIONS

In this paper, it has been demonstrated how the use of dielectric inclusions between a corrugated surface waveguide can produce different phase delays. This technique can be further used to excite antennas with different phases in an array, which could be useful to obtain very directive radiation pattern whose main angle of radiation can be changed.
REFERENCES


