SLOT ARRAY FED BY AN OVERSIZED TEM WAVEGUIDE

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ABSTRACT

We propose a novel slot-array antenna fed by a new guiding structure which forces a quasi-TEM mode within an oversized rectangular waveguide using a hard surface on the bottom face of the waveguide.

In this paper, our objective is the evaluation of the order of magnitude of slot internal mutual coupling, as well as its interaction with the propagating quasi-TEM mode. This study can allow us to use a simplified model to analyse the whole slot array.

Simulation results are shown.

1. INTRODUCTION

The expansion of multimedia applications and wireless communications is causing lack of bandwidth, thus the use of new frequency resources, such as millimeter frequencies, is more and more pressing. Waveguide slot array antennas are becoming a promising solution for communications at these frequencies owing to their capacity to provide low loss and high efficiency. A radial line slot antenna (RLSA) is a kind of the above antennas that consists of a radial parallel plate waveguide. Efficiencies higher than 80% have been achieved for circular polarization by using such RLSAs for DBS applications. However, to achieve linearly polarized RLSAs with high efficiencies is quite a difficult task [1]. Therefore, it is more usual to resort to rectangular waveguides for linear polarization. The first planar arrays made use of monomode waveguides. Later, slot array antennas in oversized rectangular parallel plate waveguides were proposed to simplify the antenna and make it cost-effective for mass applications. Nevertheless, fields in such oversized waveguides are difficult to control in order to achieve a uniform distribution. Some attempts have been made. In [2] a post-wall waveguide array was used, which was excited by a feeding waveguide and a set of openings on it to distribute the fields uniformly. Other ways of feeding have been employed, for example with microstrip patch arrays [3].

In a previous paper [4], the authors proposed a new guiding structure for oversized rectangular waveguides using hard surfaces [5]. The structure is able to force a quasi-TEM mode which is useful for broadband feeding networks. In this paper we use this guiding structure to feed a slot array.

2. GUIDING STRUCTURE

In this section we show some pictures of the guiding structure finally used to make more understandable the objective of this paper.

Fig. 1 depicts an oversized rectangular waveguide with a hard surface at its bottom face for TEM propagation. The hard surface consists of dielectric-filled longitudinal corrugations, which stop transverse currents.

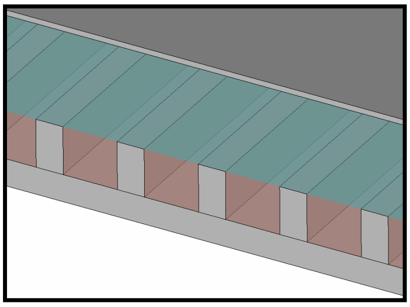

Figure 1. Oversized rectangular waveguide with a hard surface at its bottom face for TEM propagation.

As a consequence, when a uniform excitation is applied, a quasi-TEM propagation is obtained [4]. Fig.2 shows the uniform distribution obtained throughout the hard waveguide.

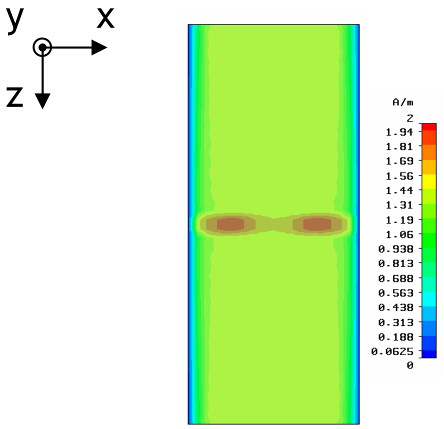

Figure 2. Transverse magnetic field distribution, when a uniform excitation is applied by means of multiple probes at the middle of the guide.

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So, in this paper, we have stressed slot internal mutual coupling, as well as its interaction with the propagating quasi-TEM mode.

3. LINEAR SLOT ARRAY

As a first step we consider a linear array of slots, fed by a single probe, on an oversized rectangular waveguide. In this way we will be able to see the field dispersion due to scattering at the slots.
Fig. 3 shows the magnetic field within the waveguide when a single probe is used. As can be seen, as a result of the presence of a hard surface at the bottom face, the magnetic field, transverse to the propagation direction, remains fairly confined in front of the source.

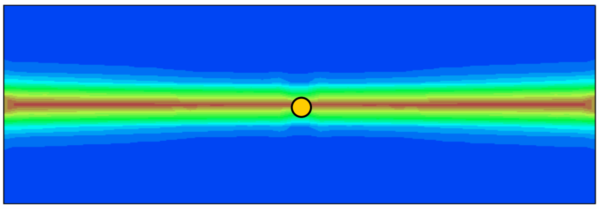


Figure 3. Transverse magnetic field distribution generated by a single probe inside an oversized waveguide with a hard surface at its bottom face.

When an array of non-resonant slots is added to the upper face, what is illustrated in Fig. 4, the magnetic field, transverse to the propagation direction, hardly disperses.

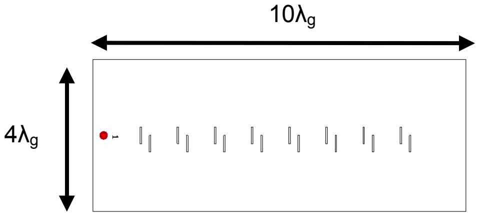
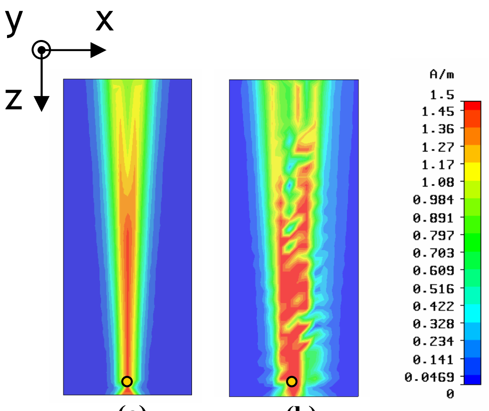


Figure 4. Top view of a linear slot array on the hard waveguide.

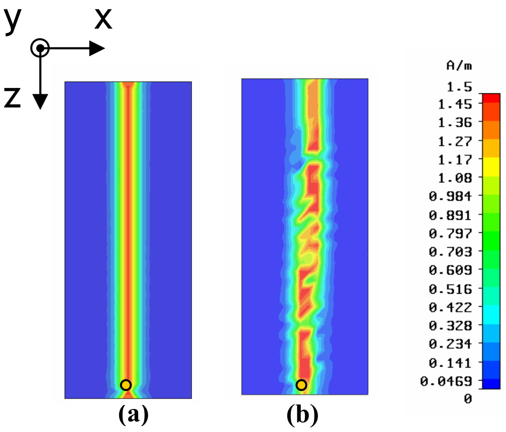
Fig. 5a-5b shows the field within the hard waveguide without and with slots respectively, at the working frequency, 10GHz.

Fig. 6a-6b shows the same results than Fig. 5a-5b, but at 10.25GHz. It is worth noting the confinement of the field is even better at this frequency, what suggests a very well behaviour in frequency.



(a) **(b)**

Figure 5. Transverse magnetic field distribution generated by a single probe inside the hard waveguide at 10GHz: (a) without slots, (b) with slots.



(a) **(b)**

Figure 6. Transverse magnetic field distribution generated by a single probe inside the hard waveguide at 10GHz: (a) without slots, (b) with slots.

In order to show the field dispersion due to scattering at the slots more precisely, the transverse component of electric field has been plotted at a transverse line of the guide at four guide-wavelengths distance from the source in Fig.7. The electric field within the hard waveguide with slots is compared with that one within the hard waveguide without slots. It is clearly observed a slight field dispersion due to scattering at slots.

Fig. 8 represents the transverse component of the magnetic field along a straight line between the source and the end of the guide. A weak stationary wave is observed in the hard waveguide with slots, even though we consider cancelling reflection slots at a quarter of the guide-wavelength from the other ones. However, the average value corresponds with the field in the hard waveguide without slots.

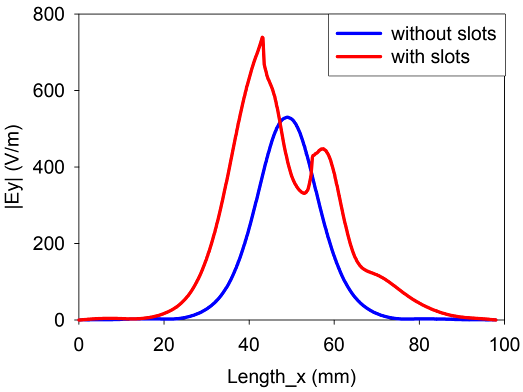


Figure 7. Transverse component of electric field at a transverse line at four guide-wavelengths distance from the source, in the hard waveguide without and with slots.

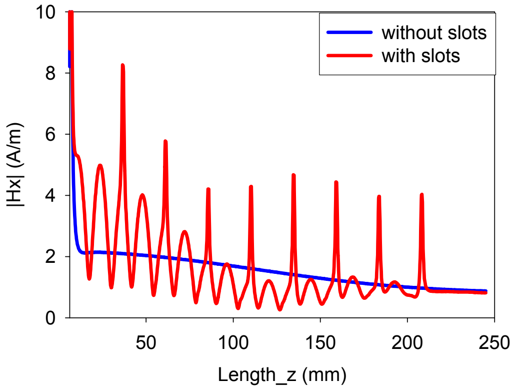


Figure 8. Transverse component of magnetic field along a central longitudinal line, in the hard waveguide without and with slots.

It should be noted that length and position of cancelling slots have not been optimized. Here, our objective is the evaluation of the order of magnitude of slot internal mutual coupling, as well as its interaction with the propagating quasi-TEM mode.

As a consequence of the results shown in previous figures, we can state that internal coupling among slots belonging to different rows is negligible. This is due to the suppression of transverse propagation in the hard waveguide. In conclusion, we have to consider only external coupling between different rows and both external and internal for slots placed in the same row. Therefore, only the self-admitance in presence of a hard surface has to be calculated.

4. LINEAR TRANSVERSE SLOT ARRAY

As a second step we consider a linear transverse array of slots, fed by five equal phase probes separated 0.7 guide-wavelengths, on the same waveguide, as Fig.9 illustrates. In this way we will be able to see how field distribution is preserved after passing the slots.

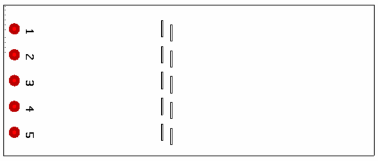
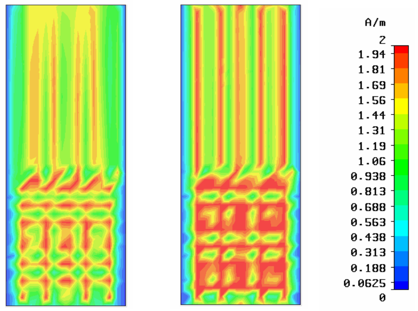


Figure 9. Top view of a linear transverse slot array on the hard waveguide.

Fig. 10a-10b shows the magnetic field distribution within the hard waveguide with the linear transverse slot array of Fig.9, at 10GHz and 10.25 GHz respectively.
We can see field distribution after passing the column of slots is maintained and thus, we can state transverse propagation has also been supressed in presence of slots.
Before the column of slots a stationary wave is observed due to reflections generated by slots. That is due to cancelling slots have not been designed in a suitable way.



(a) **(b)**

Figure 10. Transverse magnetic field distribution generated by five probes inside the hard waveguide with slots of Fig.9: (a) at 10GHz, (b) at 10.25 GHz.

5. PLANAR SLOT ARRAY

In this section we consider a planar array of slots, fed by five probes separated 0.7 guide-wavelengths, on the same waveguide, as Fig.11 illustrates. There is a phase difference of 90º between sources.
In this way we will be able to see if excitation phase is preserved at each column of slots.

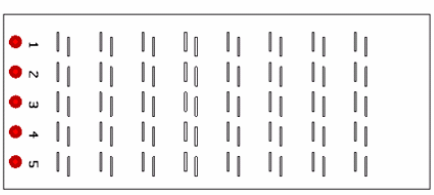
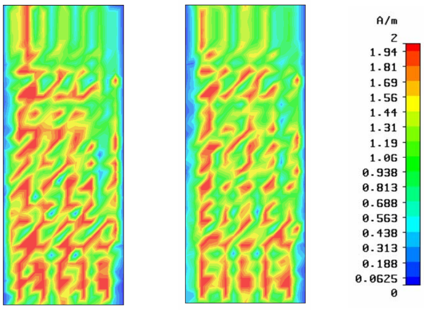


Figure 11. Top view of a planar slot array on the hard waveguide.

Fig. 12a-12b shows the magnetic field distribution within the hard waveguide with the planar slot array of Fig.11, at 10GHz and 10.25 GHz respectively.

As has been said above, a suitable design of cancelling slots is needed. However, fields propagating in longitudinal direction can be appreciated.



(a) **(b)**

Figure 12. Transverse magnetic field distribution generated by five probes inside the hard waveguide with slots of Fig.9: (a) at 10GHz, (b) at 10.25 GHz.

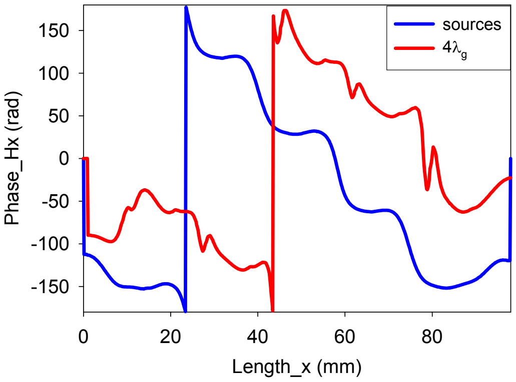


Figure 13. Phase of the transverse magnetic field generated by five probes with a phase difference of 90º inside the hard waveguide with the planar slot array of Fig.11, at four guide-wavelengths distance from the sources compared with that one of the sources, at 10GHz.

Fig.13 shows the phase of the transverse magnetic field generated by five probes with a phase difference of 90º, at the transverse line where the sources are placed, and a parallel line at four guide-wavelenghts distance.

It is observed that phase distribution is preserved. However, the observed difference in x-axe is owing to effective wavelength in presence of slots do not coincide exactly with the guide-wavelength without slots. Thus, if we place the columns of slots in the correct position, the phase of magnetic field on each row of slots will be equal.

So, if length and position of slots are optimized, it is possible to achieve a field distribution with equal amplitude on each slot, and a phase distribution on each column of slots equal to the phase distribution of excitation.

6. CONCLUSIONS

We have proposed a novel slot-array antenna fed by a new guiding structure which forces a quasi-TEM mode within an oversized rectangular waveguide using a hard surface on the bottom face of the waveguide.

A study of the order of magnitude of slot internal mutual coupling and its interaction with the propagating quasi-TEM mode has been realized.

The results show the hard waveguide is robust, as transverse propagation is supressed in presence of slots, and this quality is also preserved if the sources has a phase difference. In such case, we have been able to see phase distribution is maintained.

In conclusion, it has been shown we can control fields within the hard waveguide very much easier than within a standard oversized waveguide, in order to feed a slot array. Moreover, due to internal coupling among slots belonging to different rows has been shown to be negligible, we have to consider only external coupling between different rows of slots and both external and internal for slots placed in the same row. Therefore, only the self-admitance in presence of a hard surface should be calculated. So, we will be able to use a quite simplified model to analyse the whole slot array.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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