LOW WEIGHT ANTENNA
ON
EBG SUBSTRATE FOR GALILEO TERMINALS

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ABSTRACT

Satellite navigation systems are nowadays irreplaceable for traffic control and localisation. The first generation systems, GPS (Global Positioning System), was developed by the U.S. department of Defence, and is now partly accessible to all users. Since the introduction of GPS, different developments of second-generation systems are on going, of which the GALILEO project is one of the most promising.

Antennas for user terminals in these navigation systems must comply with very challenging requirements, as multipath interference would cause intolerable errors. Therefore, the antennas of such terminals must show good circular polarisation properties over a wide operating angle, and high phase stability in order to achieve sufficient accuracy.

Until now, choke rings, manufactured out of solid metal, were used in order to suppress the multipath interference and enhance the circular polarisation properties. However, these structures are expensive and cumbersome. The use of EBG materials could solve this problem much more conveniently, as they can be constructed from standard substrate materials, with light weight and at low cost, by etching a well defined configuration of EBG cells onto the top layer of the substrate containing the planar antenna. The EBG substrate helps suppress surface waves within a certain frequency region, by acting as a kind of band-pass filter.

Here, the EBG structures for the antenna front-end for high-precision GALILEO applications will be investigated, to show the potential of EBG technology in combination with planar antenna technology for the frequency range around 1.17 GHz.

INTRODUCTION

The final goal of the project outlined here is to develop a low weight, high precision GPS antenna with circular polarisation. High precision implies a high phase stability which is a special feature within this work. EBG technology will be used, in order to reduce the cost and the weight of the antenna.

The standard solution in such cases is the use of choke structures, made out of solid metal, surrounding the antenna, as depicted in Fig. 1.

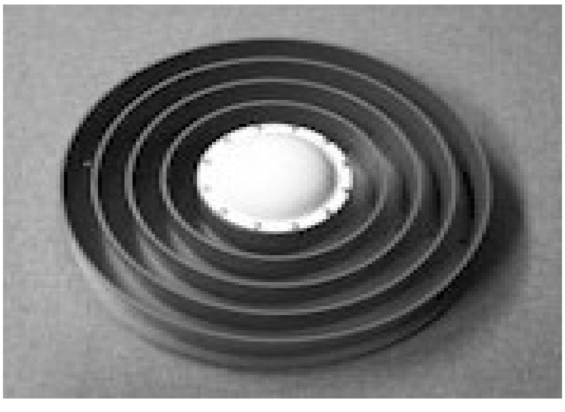

Fig. 1. GPS antenna with choke ring structure

This type of antenna is therefore heavy, bulky and relatively expensive. EBG Technology could offer here an alternative, low-cost, low-weight solution.

The basic design presented here will be based on the specifications for the GALILEO system. It consists of a circularly polarised antenna element surrounded by EBG-cells, as show in Fig. 2. Different EBG cell configurations will be investigated in order to enhance the behaviour of the antenna with respect to polarisation purity and phase stability. For example, grounded printed strips around the patch, or special EBG cells with alternating spatial orientations, will be considered.

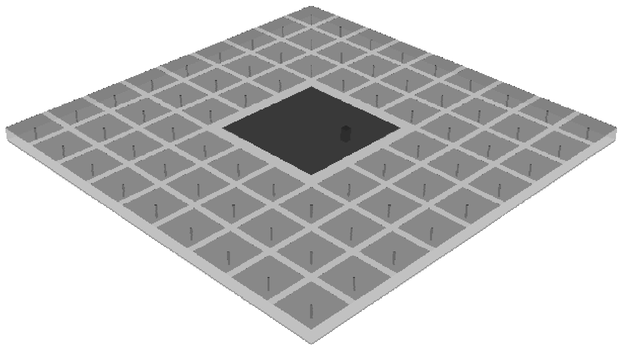

Fig. 2. Patch on generic EBG substrate

A special characteristic that will be taken into account during the design of the EBG-cells will be the influence of the finite size of the ground plane. This aspect is of great importance, as the antenna is expected to be portable, and therefore size will have a major influence on its commercial success.

In a first step, the patch antenna and the EBG structure will be conceived and measured separately . The structures will be tuned according to the measurement results, and thereafter integrated onto one substrate. The same measurement and tuning procedure will then be repeated. The final outcome of the project will be a prototype of a GPS antenna suited for GALILEO applications.

Due to the fact that the project presented here has just recently started, only an outline of the work to be performed can be given here. First, the simulation model will be discussed and some interesting issues will be explained. Thereafter, the design strategy of the EBG-cells will be introduced. A summary will conclude this paper.

SIMULATION MODEL

The field solver used here will be Empire. This is a full 3D commercial package, based on the FDTD principle [1]. Normally, EGB structures are analysed using Periodic Boundary Conditions (PBC) [2],implying that both the ground plane and the substrate have infinite dimensions. Here, however, a finite size ground plane will be used. So, PBCs are not an option. This will complicate the simulation procedure, as the use of finite size ground plane models require far more CPU memory and simulation time than in case of applying PBCs. Yet, nowadays the available processing power and memory capacity have increased in such a way that this should not longer pose a serious problem. On the other hand, the small size of the antenna element is a key issue within this project.

The EBG structures will therefore be investigated using a plane plane wave excitation to excite a structure with finite substrate and ground plane, as depicted in Fig. 3. It can be observed that the NearField-to-FarField (NF-FF) transformation box is located within the Plane Wave (PW) excitation box, whereas the structure under test is placed within the NF-FF box. The PW box enables the generation of plane waves with different directions of propagation within this box. The NF-FF box enables the transformation of the recorded near field on the 6 faces of this box, according to the Huygens' principle. In this way, plane waves incident on the EBG surface at different angles can be defined. It should be noted here that despite the fact that this model looks rather simple, it is not a trivial matter to arrive at a solid simulation model when considering finite EBG surfaces. Moreover, not only the far field will be considered but also the near field will be included in the analysis, by using a field probe at a certain distance of the structure.

Another option is to place the PW box in the NF-FF box, and to set the fields on the lower (bottom) face of the NF-FF box to zero. This model is currently under investigation and the first simulations yield results that are similar to those of the model described previously.

The simulation model used in this work enables the determination of the reflection phase of the finite EBG surface by comparing the reflected far field values of a model containing the EBG structure with those of a reference object consisting of a finite metal plate placed at the same height as the top of the EBG surface. The results of simulations of test structures look promising at this time, yet some unexpected resonances appear within the bandgap region, related to the finite nature of the ground plane of the EBG. These problems are being investigated at this moment, and it is expected to solve those details in the near future.

In a further stage, it is expected that the antenna combined with the EBG-cells will be investigated not only using the simulation model with PW box as discussed before, in a receive configuration. Also, a more standard simulation model will be employed to check the transmit case, namely by exciting the antenna itself instead of using the PW box as excitation source. Both analyses should of course give similar results.

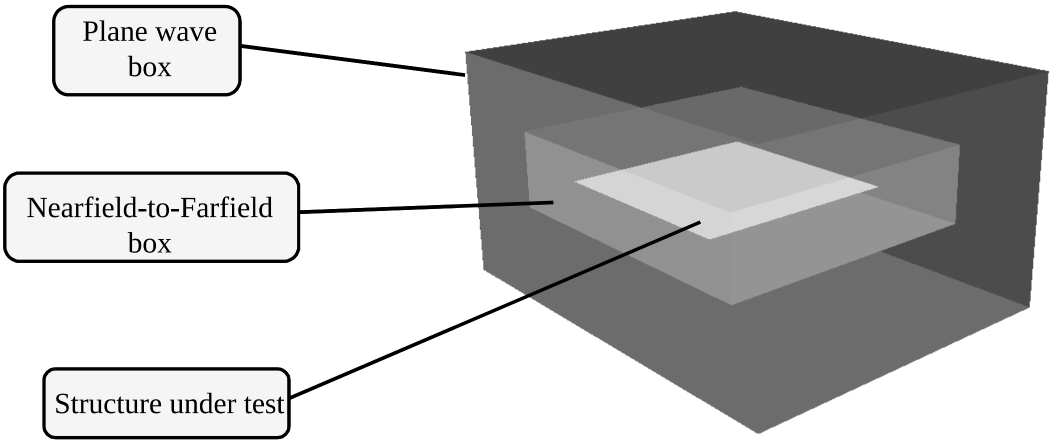

Fig. 3. Simulation model for analysing finite EBG surfaces

EBG STRUCTURES

As mentioned previously, one of the objectives pursued here is to have a small but effective number of layers of EBG-cells surrounding the antenna element. A problem appears then due to the fact that the antenna must be circularly polarised. However, EBG cells can cause problems when considering circular polarisation [3]. Latter aspect will be one of the key issues in the design. The requirements referring to the axial ratio of the Galileo antenna are stringent, and the performance of the antenna should be only marginally influenced by the use of EBG cells.

The following strategy will therefore be adopted. First, the most basic EBG structure, grounded metal patches with mushroom shape, will be analysed with respect to its polarisation behaviour. Using the results of these investigations, several other configurations will be modelled and simulated. The FDTD model as presented in the previous section will be applied here.

The EBG cells focussed on within this project will be based on grounded metal patches with slots (Fig. 4) that give them a spiral shape [2]. It is planned to use such spiral cells, with alternating spatial orientations (left-hand and right hand spirals), to enhance the circular polarisation properties of the EBG substrate. A first draft of the design is depicted in Fig. 4. Besides this type of EBG-cells, other linear EBG configurations [4] will be included in the analysis. A first approach in this direction could be to surround the antenna element with conducting printed strips, to obtain a structure similar to the traditional choke rings.

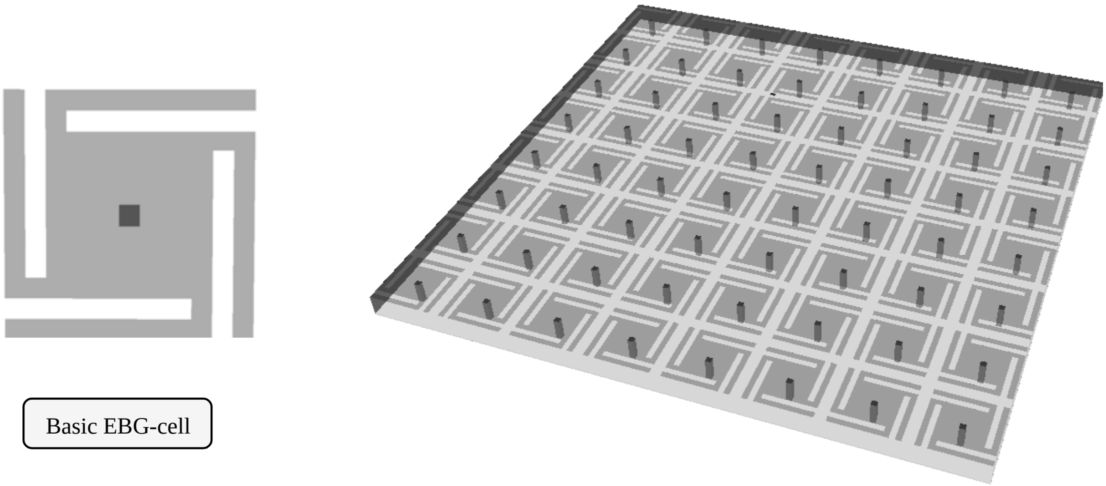

Fig. 4. EBG structures to be analysed

All the above mentioned concepts will be investigated using finite size ground planes. In order to decrease the total dimensions of antenna and the EBG cells another aspect will be examined, namely a non-uniform size of EBG cells. A spatial arrangement of EBG cells of different sizes will be modelled and compared to standard uniform sized EBG cells.

SUMMARY

This paper described a first outline of a project, which aims at developing a low weight, high precision GPS antenna front-end for the GALILEO navigation system using EBG structures. The focus within this project will be on the influence of the finite size of the substrate and the ground plane, and the effect of the EBG structures on the circular polarisation. A first prototype is expected to be realised in the second half of 2004.

REFERENCES

[1] *EMPIRE User and Reference Manual*, IMST GmbH, 2003.

[2] F. Yang and Y. Rahmat-Samii, 'Reflection Phase Characterisation of the EBG Ground Plane for Low Profile Wire Antenna Applications', *IEEE Trans. on A&P*, Vol. 51, NO. 10, PP. 2691-2703, October 2003

[3] J.M. Baracco, P. de Maagt, 'Radiating Element on a photonic bandgap structure for phased array applications', *JINA*, Nice, 12-14 November, 2002

[4] [P.S. Kildal and S. Maci, 'Short-Course: Theory and Applications of PBG structures used as Artificial Magnetic Conductors and Soft and Hard Surfaces', *International Conference on Electromagnetics in Advanced Applications*, September 12, 2003