Research Networking Programmes

Short Visit Grant ☒ or Exchange Visit Grant ☐

(please tick the relevant box)

Scientific Report

The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online within one month of the event. It will be published on the ESF website.

Proposal Title: NEW STEERABLE FOCUSING SYSTEMS BASED ON RECONFIGURABLE METASURFACES

Application Reference N°: 6563

1) Purpose of the visit

The present project arises in the framework of a joint research activity between the University of Siena (UniSi) and the University of Rennes 1 (UR1) on the design of a steerable focusing system based on reconfigurable metasurfaces (MTS).
The objective of the short visit has been to bring at the final step the work, described in the follow, carried out remotely by UniSi and UR1.

The novel concept of pattern control by MTS is likely to offer a very effective alternative to existing solutions (e.g. phased arrays, mechanically-controlled antennas, etc.) with the potential of reducing complexity and cost. The equivalent surface impedance of the MTS is properly shaped so as to generate a desired aperture field distribution, thus, enhancing the radiation characteristics of the feeding structure. At millimeter and sub-millimeter wavelengths, the technological aspects play an important rules in designing highly directive antennas, especially when additional lossy beam forming networks are considered for steering the antenna main beam. Recent developments (see Minatti G., Caminita F., Casaletti M., Maci, S., "Spiral Leaky-Wave Antennas Based on Modulated Surface Impedance," IEEE Transactions on Antennas and Propagation, vol.59, no.12, pp.4436-4444, Dec. 2011) have shown the possibility to design high efficiency MTS antennas using a very simple feed arrangement.
While a quite considerable effort has been devoted to the design of fixed beam antennas, very few studies have been dedicated to beam steering MTS antennas. The general objective of this project is to develop a new type of MTS antenna able to change its

pointing angle by changing the local value of the surface impedance, responsible of the radiation phenomenon. The investigate solutions are composed by a lower MTS and by an upper dielectric layer separated by an air gap. The MTS is designed to have a pencil beam in a certain direction. By varying the distance between the MTS and the dielectric layer, it has been verified that it's possible to change the pointing angle of such structure for an acceptable angular range. The research activity done by UniSi and UR1 has been divided in two parallel main tasks. The task of UR1 has concerned the investigation of some feed architectures, suitable to be integrated with the MTS. Integrated focusing systems using pillbox parabolic systems have been chosen. Instead, UniSi was responsible for developing an ad-hoc simulation code, so as to faster analyze the behavior of the MTS, followed by a study of several MTS's typologies able to be reconfigured.

The proposed focusing system is designed for Satcom application in the Ku band.
The pillbox parabolic focusing structure, designed by UR1, is shown in Figure 1. As reported in the figure, the proposed feed architecture shows an acceptable matching behavior in the entire bandwidth and good pattern performances.
In figure 2 has been reported the reconfigurable MTS. The chosen configuration is composed by sinusoidally variable depth corrugation and a movable dielectric slab on top. By varying the distance of the slab from the corrugation has been possible to change the pointing angle as shown in Fig. 2b). In the same figure has been reported the matching behavior for various air-gap distances.

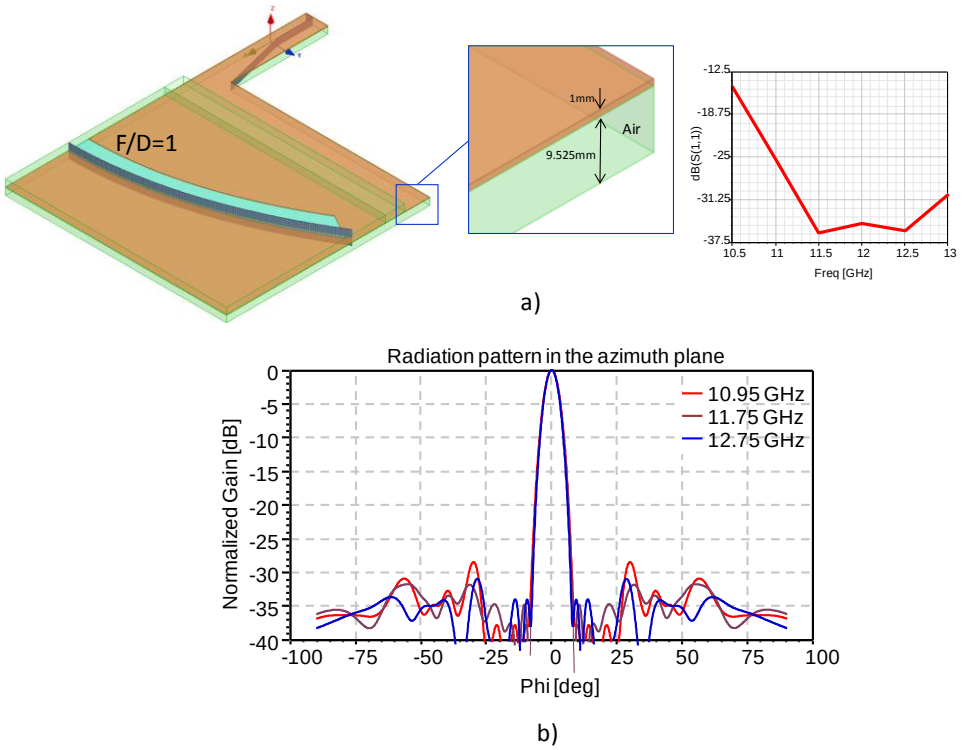

Figure 1 Pillbox parabolic focusing systems: a) designed architecture and relative reflection coefficient for the input port, b) normalized radiation pattern in the azimuth plane.

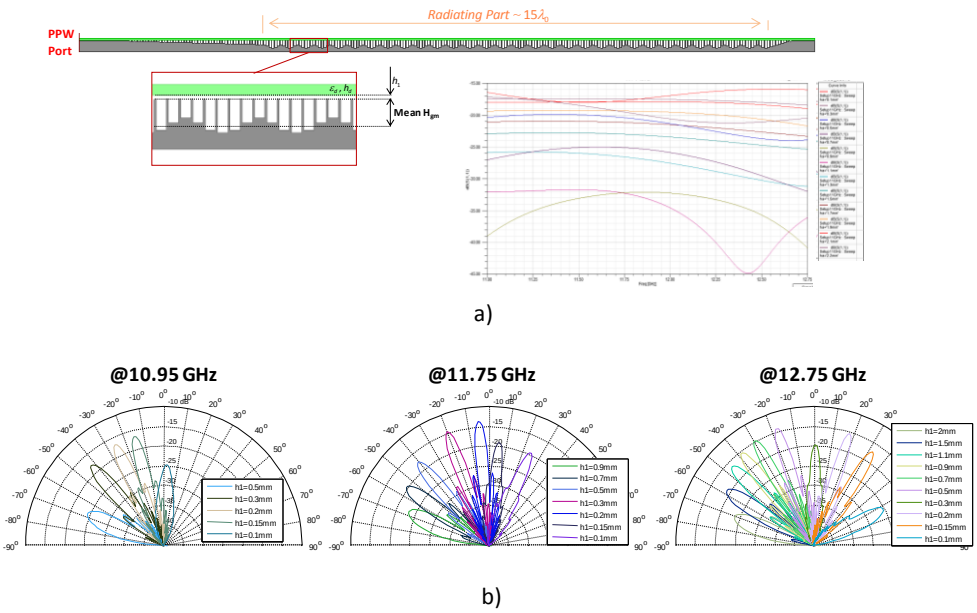

Figure 2 Reconfigurable MTS: a) designed structure with the relative matching behavior for various air-gap distances, b) Radiation Patterns in elevation plane in function of the air-gap height variation.

2) Description of the work carried out during the visit

The work carried out during the visit has been focused on the final definition of the antenna layout for the realization of a proof-of-concept demonstrator and can be summarized by the following steps:

1) review the work carried out by UR1 for the feeding structure and the work done by UNISI for the reconfigurable MTS, in order to verify in details some critical aspects relative to the integration of the two structures.
   Two crucial aspects are found:
   a. the design of the transition between the upper parallel plate waveguide (PPW) of the pillbox focusing system and the fixed PPW of the reconfigurable MTS (Fig. 3b).
   b. the design of the contactless transition between the fixed PPW and movable part of the MTS(Fig. 3b).
2) simulation of the whole focusing system (Fig. 3a) and initial optimization. After the design of the two transitions, it has been done a full-wave simulation of the entire structure using the commercial software Ansys HFSS.

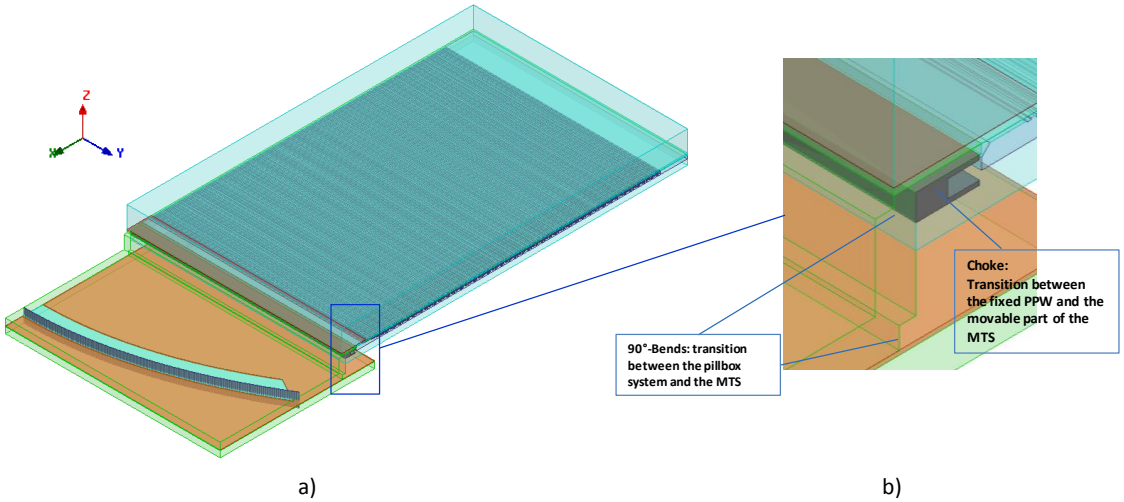

Figure 3 Designed steerable focusing system: a) proposed final configuration, b) transition between the feed system and the reconfigurable MTS

3) Description of the main results obtained

The simulation performed for the entire structure are reported in Figure 4, where is shown the matching performance and the radiation pattern by varying the air-gap distance. While the designed parts of the structure (i.e. Pillbox feeding system, MTS and the two transition between them), simulated alone, work with good performances, from the results reported in fig. 4 it seems that the integration imply a degradation of the cumulative behavior. This results lead to further investigation and optimization of the proposed focusing system.

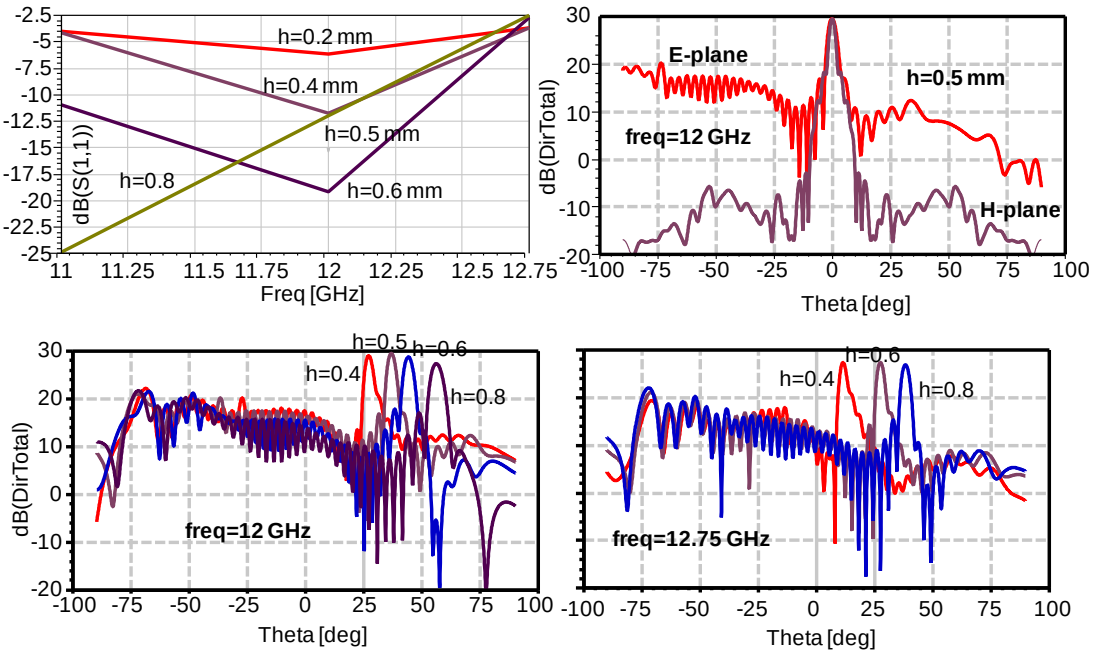

Figure 4 Reflection coefficient and radiation pattern for the final configuration of the antenna system.

4) Future collaboration with the host institution (if applicable)

Collaboration with UR1 will prosecute to obtain better performances of the proposed focusing system architecture so as to obtain the final definition of the antenna layout for prototyping.

5) Projected publications/articles resulting or to result from the grant (ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)

6) Other comments (if any)