DESIGN AND MANUFACTURING OF MILLIMETER-WAVE LENSES IN SUBSTRATE INTEGRATED WAVEGUIDE

ESF Activity: New Frontiers in Millimetre / Sub-Millimetre Waves Integrated Dielectric Focusing Systems (NewFocus)
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Summary

1. Purpose of the visit
2. Description of the work carried out during the visit
3. Description of the main results obtained
4. Future collaboration with host institution (if applicable)

1. Purpose of the visit

The aim of this exchange visit has been to develop and experimentally verify a new class of millimeter-wave lenses in substrate integrated waveguide (SIW) technology, by using the facilities available at the QuB ECIT's laboratories.

Fig. 1 View of the ECIT building in Belfast.

Over the past two years, the proposer and host have jointly developed a design methodology that allows focusing of electromagnetic energy radiated by a leaky wave lens (LWL) at a desired near-field focal point. The concept requires capability to independently control the pointing angle and leakage rate of leaky waves and was initially demonstrated in bulk technology. When compared to conventional focusing subsystems based on curved metallic reflectors, shaped refractive dielectric bodies, phased arrays or reflectarrays, the proposed lenses present opportunities for compact, planar, easy-fed, and low-cost devices. Moreover, leaky-wave lenses (LWL) show the ability to frequency scan the focal point, thus providing enhanced capabilities with many exciting potential applications in security and medical imaging systems, hyperthermia, wireless sensors, wireless power-transfer systems, non-radiative wireless communication, non-contact high-speed interconnects, or enhanced RFID readers.

The key concept in the proposed SIW topology, which is represented in Fig. 2, is that one of the rows of metallic posts is sparse so that energy can penetrate through it, thus acting like a partially reflective surface (PRS). Crucially, the transparency can be controlled by varying the separation of the vias (parameter P in Fig. 2). The other row of dense posts behaves as a perfect electric conductor (PEC) wall, and it does not allow the leakage of energy as in conventional non-radiative SIW circuits. The energy that leaks through the PRS is radiated at the truncation of the upper metallic plate of the dielectric-filled parallel-plate waveguide, providing the same radiation mechanism and field distribution than the well-known microstrip LWA operating in its first higher order mode (see scheme in Fig. 2b).

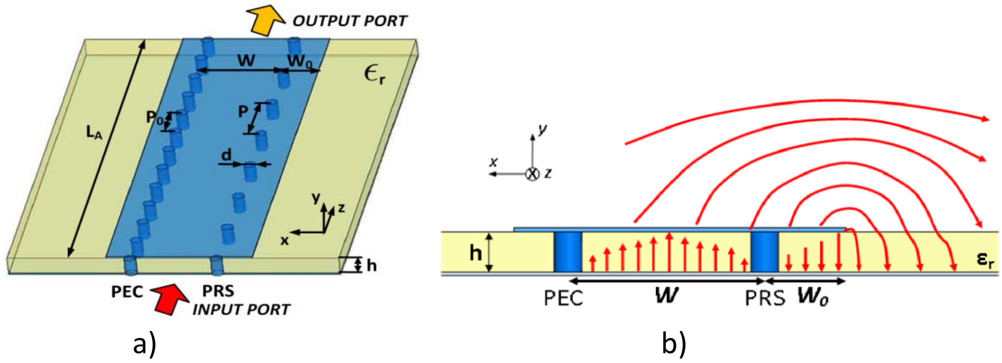

Fig. 2 Different views of the SIW LWA: a) Three dimensional view and main geometrical parameters. b) Electric field lines at the cross section of the antenna (E-plane).

2. Description of the work carried out during the visit

The main tasks carried out during this exchange visit have been the design, manufacturing and measurement of several prototypes of leaky-wave antennas in SIW technology operating at the frequency of 15 GHz. The antennas have been built in a commercial substrate Rogers RT/duroid 5880 by using milling technology. In addition, standard SMA to microstrip connectors were soldered in order to have an easy feeding of the antennas (see Fig. 3).

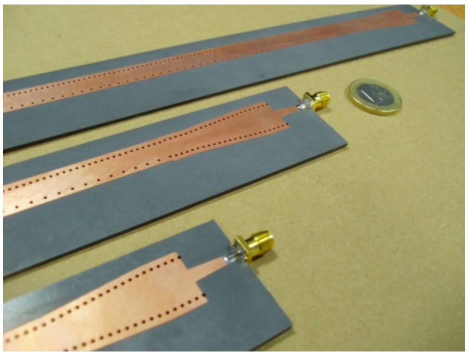

Fig. 3 Detailed view of the feeding of the LWA.

The first period of the stay has been focused in the design and manufacturing of several prototypes in SIW technology. Particularly, the designs manufactured have been the following:

- Broadbeam antenna radiating from 10 to 50 degrees
- Broadbeam antenna with a radiation null
- Broadbeam antenna with two radiation nulls

By demonstrating the capability to tailor the radiation pattern of the antenna while keeping a high radiation efficiency. Fig. 4 shows a picture of the manufactured prototypes in SIW technology.

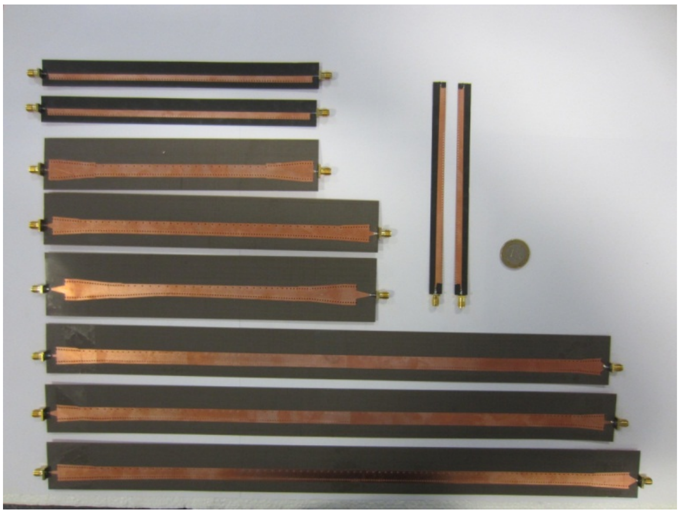

Fig. 4 Photography of the prototypes manufactured and measured in the QuB ECIT.

Once the prototypes were manufactured, a measurement campaign was carried out during the final part of the stay, in order to validate the electrical performances of the designed antennas, using ECIT's anechoic chamber (see Fig. 5). Particularly, input matching and radiation pattern measurements have been measured and a very good agreement between theoretical and experimental performances has been found, as it will be shown in the next section. In this way, the ability to easily tune the radiation pattern by modifying the antenna printed-circuit dimensions has been demonstrated.

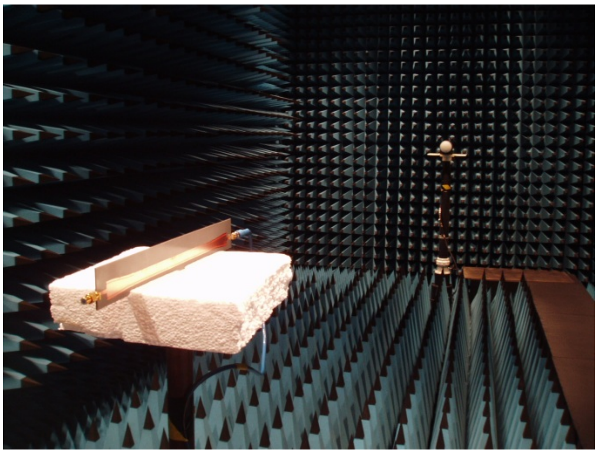

Fig. 5 Configuration of the measurements inside of the anechoic chamber.

3. Description of the main results obtained

In this section the main results obtained as consequence of the work carried out during this exchange visit, are described. In order to show the capability to control the radiation performances along the antenna length, several nonconventional radiation patterns have been synthesized.

The first example has been an antenna designed to obtain a broadbeam radiation pattern in the angular region [10^o, 50^o], while assuring high rejection out from this prescribed angular region. The broadbeam synthesis can be obtained from a diverging near field phase pattern and a uniform amplitude illumination function. However, in order to obtain a better matching with the feeding source and thus less diffraction at the borders of the LWA, a quasi-uniform illumination has been synthesized for the case of an antenna with L_A = 400mm = 20 λ_0. Fig. 6 shows the measured and simulated radiation patterns for the proposed antenna.

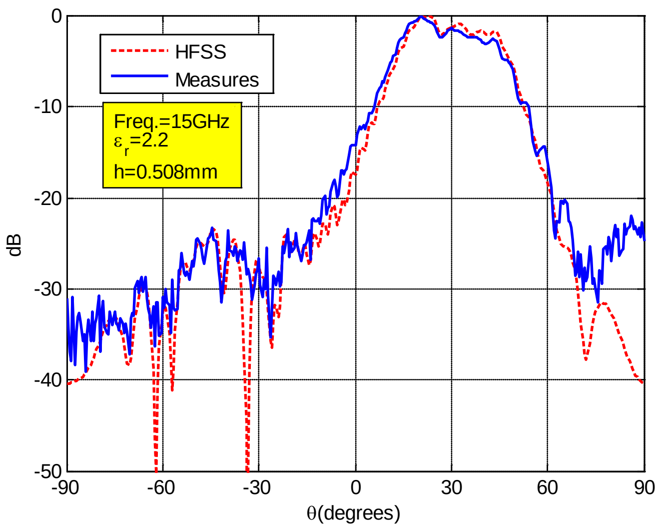

Fig. 6 Configuration of the measurements inside of the anechoic chamber.

The second example corresponds to an antenna with a broadbeam radiation pattern, which synthesizes a wide and sharp radiation null in the angular region [0^o, 10^o], as it is illustrated in Fig. 7. In order to obtain this radiation null non canonical variations of the leaky-mode complex wavenumber are required along the antenna length. These variations are produced by applying an iterative fast Fourier transform (FFT) technique, which was proposed for the efficient synthesis of large array antennas, and can be applied due to the similarity between continuous LWAs and discrete array for the synthesis of tailored LWA radiation patterns.

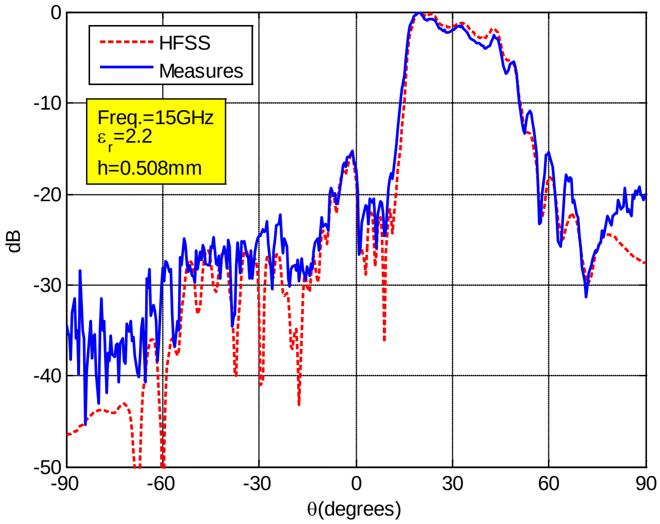

Fig. 7 Configuration of the measurements inside of the anechoic chamber.

The third example shows an antenna with a broadbeam radiation null which synthesizes two radiation nulls in the angular regions [0°, 15°] and [45°, 60°]. The design process to obtain such as radiation pattern, is similar to the one used for the antenna with the radiation pattern with one radiation null. However, for this case the results obtained show how a very selective antenna can be designed, by properly varying the leaky mode along the antenna. In Fig. 8, it is compared the simulated and measured radiation patterns for the designed antenna.

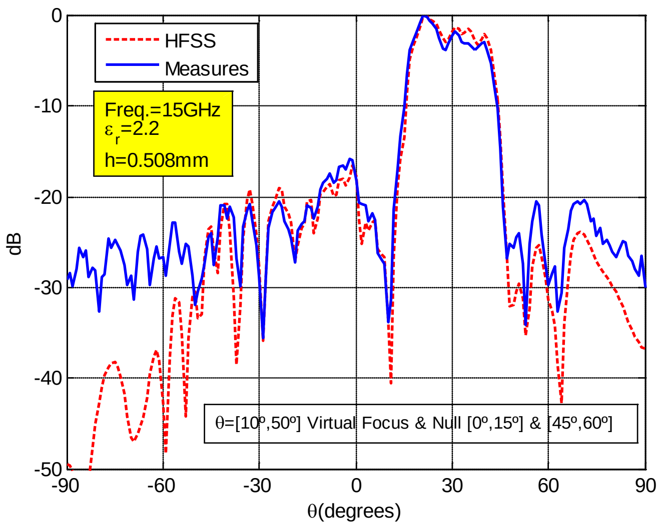

Fig. 8 Configuration of the measurements inside of the anechoic chamber.

4. Future collaboration with host institution (if applicable)

The work developed during this stay, will allow to continue with several common projects between the Universidad Politécnica de Cartagena (UPCT) and Queen's University of Belfast (QuB). Moreover, these successful experimental results will be combined with theoretical data and the proposed design methodology, to submit a paper to an international journal in the field of Antenna Engineering. Also, future work on enhanced designs will be proposed as a result of this collaborative work between UPCT and QUB-ECIT.