A Metamaterial Pyramidal Horn Antenna for High Power Applications

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Horn antennas are widely used in high power microwave systems, mainly due to their high power handling properties. Different variations of the traditional horn antenna geometry have been introduced in the past years to improve the radiation characteristics. Some of these techniques are used to alter the boundary conditions on the walls of the horn antennas allowing for the propagation of hybrid modes (hybrid mode horns). As an example, corrugations can be used to create hard and soft horn antennas with reduced side lobes, increased radiation efficiency and low cross polarization levels. Similar to corrugations, metamaterials can be added to horn antennas to generate hybrid modes.

The main objective of this work is to design a metamaterial horn antenna that operates in a hybrid HE11 mode, and to analyze its performance and power handling capability. The suggested structure is based on a traditional pyramidal horn antenna. Planar metamaterial structures are added to both of the E-plane walls of the antenna, which changes the boundary conditions at the surface. By properly choosing the metamaterial design parameters, and thus optimizing its effective surface impedance, an HE11 mode can be generated inside the horn. CST Microwave Studio is used for the antenna design. In the simulations, the E-plane walls of the antenna are coated with a homogeneous and isotropic material, the surface impedance of which can be set to any desired value. With this setup, the E-plane wall surface impedance can be optimized for HE11 mode operation and the sought radiation properties. The optimized antenna model, as well as the relationship between the boundary conditions on the E-plane walls and the radiation characteristics of the antenna, will be presented. Then, a metamaterial structure is designed to have the same surface impedance as the coating material, and is used in the simulation. In addition, the actual planar metamaterial structure will be fabricated and tested with an S-band horn antenna. The simulated and measured results of the optimized antenna will be reported and compared.

The power handling capability of the antenna is mainly limited by air breakdown at its aperture, as well as the possible vacuum breakdown on the metamaterial surface. A magnetron capable of delivering up to 600MW will be used to feed the proposed antenna. The breakdown point can be assessed by changing the vacuum pressure inside the antenna and relating it to the simulated electric field values, or alternatively by tweaking the output power of the magnetron. The power rating of the antenna will then be indicated.