Design of Millimeter-Wave Broadband Gradient Index Lens for Gain Enhancement

Research Field
RF, Antenna Design and fabrication.

Description

Communication systems operating at mm-wave and THz frequencies, which are defined in the frequency range 30-300 GHz and 0.1-10 THz respectively, can fulfill the increasing demands for higher data rates, highly spatial resolution in imaging, material characterization, and high localization accuracy due to their huge utilized bandwidth. Besides the spectrum availability, shorter wavelength allows the design of compact and massive antenna arrays. Recently, we have proposed an indoor self-localization system at mm-wave/THz region to achieve high positioning accuracies by using the concept of Reader-RFID tags. In this system, the reader localizes itself by using N-tags positioned at known locations which act as anchors in an indoor area [1]. The link budget of the whole system at THz is studied [2], where it is shown that the main factors limiting the detectability of the tag are the high THz channel path loss and also the low radar cross section (RCS) of the tag. Accordingly, increasing the gain of transmitting and/or receiving antenna at the reader side becomes indispensable. In this regard, engineers generally use two main methods to produce high gain antennas: by combining low gain antennas namely antenna array, which have an amplitude and phase relationship with each other to produce a high gain beam, or increasing the antenna aperture by using reflectors, lens, or reflect array which focus the beam of a low gain antenna. While the antenna array at millimeter-wave frequencies is difficult to realize and needs a bulky feeding network, we prefer to proceed in the design of a lens in combination with a horn antenna which has the advantage over reflectors in the possibility to manufacture with lower tolerances error [3].

Fresnel lens antenna as a highly focusing device is attractive among other shaped lenses due to its flatness, lightness and ease of fabrication [4]. The so-called Fresnel lens plate is composed of a set of rings (called Fresnel zones) which are radially spaced to correctly modify the phase of the incoming wave front so that it is constructively interfere at the focal point. Phase compensation could be realized by using two approaches: etching grooves in a uniform dielectric plate or using rings of multiple dielectric materials (multidielectric zones) without etching [5]. In the second approach, we can benefit from the effective medium theory to design multiple dielectric materials from a single homogenous material by controlling the material porosity which is based on adding air gaps in the homogenous material in different percentage to produce different permittivities [6]. Then, we intend to make use of fused deposition modeling (FDM) technique which is one of the 3D printing technologies to fabricate the resulting lens.
Research Methodology

1. Make a quick survey on the techniques used in enhancing antenna gain and recognize the advantages of utilizing lens antenna, especially at mm-wave/THz.
2. Study the theoretical background of Fresnel lens antenna, the design equation, and the methods used to realize the gradient refractive index.
3. After fixing the design parameters, design and simulate the resulting lens on CST Microwave Studio, then study the effect of parameter variations on antenna properties (gain, radiation pattern, and etc.)
4. Fabricate the simulated lens using rapid prototyping 3D printing technique and then measure the antenna properties and compare it with the simulated results.
5. Write the thesis.

Requirements

- Good knowledge in Electromagnetics and antenna design.
- Skills: Matlab, CST Microwave Studio (Preferable).

References


Contact: Ali Alhaj Abbas, room BB-121, email: ali.alhaj-abbas@uni-due.de
More information about DSV and application form at http://www.dsv.uni-due.de