PhD Thesis Abstract: Sayan Sarkar

Thesis Title: Textured Surfaces for Electromagnetic Applications

Introduction to Textured Surfaces

Textured surfaces usually refer to 1D/2D periodic structures in Electromagnetic Theory. These periodic structures have many unique properties which can be used for multifarious applications in the field of Electromagnetics. The different types of such surfaces are shown in Fig. 1.

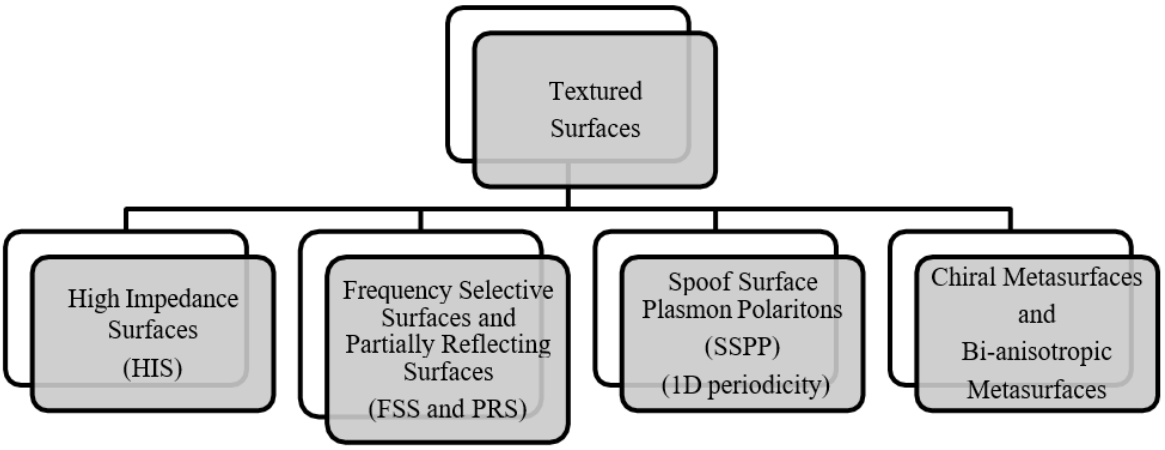

Fig. 1. Different types of textured surfaces

Sievenpiper High Impedance Surfaces (HIS) can act as Artificial Magnetic Conductors (AMCs) providing in-phase reflection properties and/or Electromagnetic Band gap (EBG) structures which result in surface wave suppression. They can be used to design filters, phase shifters as well as quasi-TEM waveguides, which have near uniform E-field distributions across the waveguide aperture.

Textured surfaces also include Frequency Selective Surfaces (FSS) which can be used as Partially Reflecting Surfaces (PRS) to design Fabry-Perot Cavities (FPC) which can enhance the gain and directivity of antennas significantly.

In this context, Spoof Surface Plasmon Polaritons (SSPPs; which are the low frequency equivalent of Surface Plasmon Polaritons observed at optical frequencies) can also

be realized by using 1D periodic structures. They can lead to very high confinement of electromagnetic fields and provide many interesting features.

Bi-anisotropic metasurfaces have been used extensively in literature to convert the polarization of an incident wave. Linearly polarized incident waves undergo cross polarization conversion as well as linear to circular polarization conversion either in reflection or transmission when they are incident on such metasurfaces. Many chiral bi-anisotropic metasurfaces are used to obtain a special property called asymmetric transmission whereby the polarization conversion properties of the metasurface depend upon the side from which the plane wave is incident on it. This is somewhat similar to non-reciprocity.

Textured surfaces have been used with antennas, in microwave circuits as well as for wave-front engineering. They have been an area of extensive research for decades and continue to be so even to this day.

Contributions of the Thesis

A Dual-band AMC Reflector with UHF-RFID Reader- A dual-band RFID reader antenna is presented which radiates CP waves within both the UHF-RFID band and 2.4GHz WLAN band. Using an AMC reflector below the reader antenna, the gain of the antenna is enhanced within the UHF-RFID band which in turn increases the read range. The resulting antenna plus reflector system is easy to fabricate, has a low profile height and can detect RFID tags irrespective of their orientation due to the CP nature of the radiated waves. The information received from the tags can then be sent by the reader to a base-station through the 2.4GHz WLAN band.

An AMC having very high Angular Stability **-** An AMC is designed using self-complementary unit cells. The resonance frequency of the proposed AMC remains fixed for different *E*-field orientations as well as for incident angles up to 88^0 for both transverse electric and transverse magnetic incidence. It is very useful in applications which are sensitive to the shift in resonance frequency. The proposed AMC has the best angular stability out of all AMCs present in literature till date. It is also easy to fabricate and ultrathin, making it easily reproducible.

FPC Antenna with AMC ground and Reduced Cavity Height - A dual-band FPCA is presented. It radiates CP waves within the 2.4GHz WLAN band and LP waves within the 5.8GHz WLAN band. The PRS is made using a single dielectric layer having metallization on both sides and a positive reflection phase gradient. The positive reflection phase helps the antenna achieve a wide 3dB gain bandwidth. The radiating antenna placed within the cavity is surrounded by an AMC ground plane. This ultimately helps in reducing the height of the FPCA. The resulting FPCA has very high gain, wide 3dB gain BWs within both the bands and a reduced cavity height of around $\lambda/6$ (as opposed to the conventional cavity height of $\lambda/2$) with respect to the 2.4GHz band. All these features make the proposed antenna desirable in applications requiring high gain antennas with small vertical heights.

A Multiband Multifunctional Chiral Metasurface - A multiband and ultrathin CMS is presented which has seven operational frequency bands. It can perform asymmetric transmission of LP waves within five bands, asymmetric LTC within one band and symmetric co-polarized transmission within one band. The antenna can be used as a direction of propagation dependent cross-polarization and liner-to-circular polarization converter. It can also be used as a direction of propagation independent co-polarized spatial pass-band filter. All the operational bands of the proposed CMS can be tuned and adjusted to meet user specifications. Multiple bands ensure that the CMS can be integrated with different applications in different frequency bands.

A Multiband Meta-Mirror – An ultrathin multiband CMS is designed. It acts as a meta-mirror for incident CP waves. The handedness of the CP wave remains preserved before and after reflection from the meta-mirror. The proposed CMS has five operational bands. All the bands can be shifted and tuned by varying the different parts of the unit cell. The CMS is very easy to design and fabricate.

A Tri-band SSPP based End-fire Antenna– An SSPP based tri-band antenna is designed which exhibits end-fire radiation within the three operating bands. It can also perform end-fire beam scanning within the third operating band, achieving a scan range of 21^0 in the plane of the antenna. The antenna has good radiation efficiency and gain within all three bands. The proposed antenna is the first SSPP based antenna which exhibits end-fire radiation within three distinct frequency bands.

Future Research Areas

Graphene based MSs for THz applications are an interesting prospect. Although they have been studied to some extent, more work can be done on this topic. Such arrangements can provide large BWs as well as tunability. With the advancement of fabrication techniques, realizing such structures will also become easier.

In this dissertation, we only deal with passive MSs whose properties are fixed with respect to the geometries of the unit cell. However, introducing switching elements like PIN diodes or tuning elements like varactor diodes to each unit cell can increase the operating range as well as functionality of the MS. Such reconfigurable MSs can be useful in many applications which require dynamic control of the MS properties.

Space-time modulated metasurfaces, although not a part of this dissertation, have become a hot area of research in recent times. Such MSs are ultrathin, planar and can break reciprocity without the use of magnets. They can be used to design nonreciprocal metasurfaces for advanced wave-front engineering. A lot of research can still be conducted on these space-time modulated metasurfaces.

Huygens' metasurface is another type of metasurface which has become popular in recent times. Such an MS consists of both electric and magnetic dipole moments which are orthogonal to each other. They can be used to achieve reflection-less refraction and they can also control the refraction angle for a given incident angle. Huygens' metasurfaces have also been used to design thin lenses for beam collimation. These MSs hold a lot of potential for future research.

The field of metamaterials and metasurfaces is evolving rapidly with a lot of research being conducted worldwide by some of the leading researchers and academicians. It is expected that metasurfaces and metamaterials with new and unique properties will be developed in the forthcoming years which will revolutionize the domain of electromagnetic engineering.