ABSTRACT

Frequency selective surface (FSS) is an array of periodically arranged patches on the dielectric substrate/apertures in the metallic screen, which exhibits total reflection and transmission, respectively despite of the fact that the patch/aperture is just a small fraction of the total FSS area. It is the most relevant periodic structure, which finds various applications in microwave regime of the electromagnetic spectrum such as satellite communication, radio broadcasting, radomes, electromagnetic shielding, improving the purity of the received signal and enhancing the gain/directivity of the antenna. However, the electromagnetic behavior of the FSS structures is a function of frequency, angle-of-incidence (AOI) and polarization of the incident waves, which make it a potential candidate to use as spatial filters in variety of microwave applications such as radomes and satellite communication. The unit-cell geometry of FSS structure that is used in the microwave regime of the electromagnetic spectrum has to be very simple because the fabrication cost is an important issue. In the microwave regime of electromagnetic spectrum, the development of novel geometrical shapes of FSS structures is an attractive area for researchers. In addition to this, the miniaturization as well as angular and polarization stability of the structure are the potential issues. Therefore, it is required to design a FSS structure, which provides a stable bandpass/bandstop filtering characteristics over a wide range of AOIs and over different (perpendicular and parallel) polarization states.

However, in the wireless communication, the larger reflector antennas dimensions have been utilized to significantly enhance the signal received by antenna at the fixed operating frequency. The design and maintenance of such antennas are economically expensive as well its utilization for various applications is also a potential problem for research. Therefore, the demand of multiband FSS structures that allows the same reflector antenna to operate at two or more frequencies is increased. There are various techniques, which provide the multiband frequency characteristics such as layered/stacked, convoluted, perturbed and multi-resonant element technique. The layered/stacked planar FSS structure separated by a dielectric layer provides an added degree of freedom in designing a filter with multiple resonances in the desired frequency response. The layered/stacked FSS structures are difficult and costly to
construct, which increase its cost/complexity as compared to that of the single planar FSS structure. In addition to this, the numerical analysis of the layered/stacked FSS structure is very complicated due to the occurrence of coupling effects between the stacked FSS structures. The convoluted and perturbed FSS structures have required high degree of iterations, which are difficult to manufacture and the frequency response is sensitive to different polarization states of the incidence wave.

In this thesis, the state-of-the-art of FSS structure and its potential applications (mainly in wireless/satellite communication) are also overviewed. In addition to this, the FSS structures have been numerically analyzed using the equivalent circuit (EC) technique, which is further supported by using the commercial simulators such as CST Microwave Studio, Ansoft HFSS and Ansoft Designer. The EC technique is simple and has the potential of providing the better understanding of physical mechanism of the FSS structure and models the FSS structure in terms of energy storing inductive and capacitive components in series or parallel combination at the resonance frequency depending on the element shape. This thesis discusses the analytical, simulation and experimentally tested performance of the newly proposed FSS structure in the microwave regime, particularly S-, Ku- and Ka-band of the electromagnetic spectrum. Moreover, a generalized synthesis technique to obtain the geometrical parameters of single square loop FSS (SSLFSS) structure using its normalized mathematical expressions has been developed. However, the design of FSS structure becomes significantly easier with the knowledge of relationship between geometrical parameters (periodicity, shape, width (strip/slot) and size) of the FSS structure. The numerical analysis of the SSLFSS is extended to obtain the geometrical parameters of the novel modified circular patch/slot type FSS structure designs. In addition to this, the analysis and simulation of the circular ring FSS structure also has been explored to achieve the better angular stability than that of the SSLFSS.

With reference to the simple unit-cell geometry of FSS structure, the resonance mechanism and reflection/transmission characteristics of proposed modified circular ring single layer FSS geometries comprising patch/aperture element, which offer significantly better angular (up to 50°) and polarization (perpendicular and parallel) stability as compared to that of the various reported FSS structures are examined in
detail. In this thesis, a novel (modified circular ring) FSS structure for the bandstop and bandpass filtering characteristics with significant miniaturization and angular/polarization stable frequency response is explored at 26 GHz and 13.5 GHz with approximately 15% fractional bandwidth (FBW). In order to demonstrate the practicality of the proposed modified circular ring FSS structure, we have experimentally measured the s-parameters of the proposed FSS structure at X-band, which provides the comparable frequency response as compared to that of the simulated response.

Further, two simplified and light weight multi-resonating FSS structures (patch/slot), which provide multiband frequency characteristics, have been discussed. A single layer multiband slot-type FSS, which consists of a modified circular ring loaded with concentric conventional circular ring, is discussed for the angular and polarization stability with reflection characteristics in S-band (2-4 GHz)/Ku (12-18 GHz) and transmission characteristics in X-band (8-12 GHz)/Ka-band (24-28 GHz). The resonance frequency of the slot-type multiband FSS structure downshifts with 0.093 % and 0.74 % in the 1st and 2nd transmission band, respectively for perpendicular polarized wave incidence. In addition to this, the resonance frequency downshifts with 0.096 % and 0.76 % in the 1st and 2nd transmission band, respectively for the parallel polarized wave incidence up to 50° AOI with reference to the normal incidence. In addition to this, a patch-type multiband FSS structure, which consists of two concentric modified circular rings, is discussed for the angular and polarization stable frequency response at S/Ka and Ku-band of the electromagnetic spectrum. The resonance frequency of the patch-type multiband FSS structure downshifts with 0.367% and 0.93% in the 1st and 2nd transmission band, respectively for perpendicular polarized wave incidence. In addition to this, the resonance frequency downshifts with 0.234% and 0.673% in the 1st and 2nd transmission band, respectively for the parallel polarized wave incidence up to 50° AOI with reference to the normal incidence.

Furthermore, an azimuthally periodic wedge shaped circular ring FSS structure for the bandstop and bandpass filtering characteristics with significant 3-dB/fractional bandwidth and angular/polarization stability at S-band, Ku-band and Ka-band is discussed. The azimuthally periodic wedge shaped circular ring bandstop FSS
structure provides the 0.4% downshift in the resonance frequency for wave incidence up to 50° AOs as compared to that of the normal wave incidence at Ku-band. In addition to this, an azimuthally periodic wedge shaped circular ring bandpass FSS structure provides 0.013% and 0.198% shift in the resonance frequency for the perpendicular and parallel polarized wave incidence up to 50° AOI, respectively as compared to that of the normal wave incidence at Ku-band.

Finally, a generalized mathematical expression for the synthesis of geometrical parameters of SSLFSS structure is presented. In addition to this, a method to control the reflection coefficient of FSS structure at a given frequency is proposed. Moreover, in this thesis, novel geometrical shapes of FSS structures have been proposed, which provide single and multiband frequency response with significant angular and polarization stability in the microwave regime of the electromagnetic spectrum. The proposed modified circular ring FSS structure (for single-band frequency response) provide 1.09 % and 0.07 % downshift in the resonance frequency for perpendicular and parallel polarized wave incidence up to 50° AOI as compared to that of the normal wave incidence as well as approximately 15% FBW. However, the multiband frequency response with significant angular and polarization stability is presented using the proposed FSS structure, which provides transmission in S-band and reflection in Ku/Ka-band for satellite communication.

The frequency response of the proposed modified circular ring bandpass FSS structure is measured for the normal wave incidence only, which will be extended to study the effect of the AOs and polarization states of the incidence wave in future. In addition to this, the experimentally measurement of the scattering characteristics of the multiband FSS structure has also been considered for the future perspective. Moreover, the design issues of the conformal FSS structure and exploiting the bandpass/bandstop behaviour of the FSS structures at terahertz frequencies will be considered in future communication.