ABSTRACT

The microstrip antenna (MSA) offers an attractive solution to compact, conformal and low cost design of modern wireless mobile communication equipment. The mobile communication systems require small antenna with small ground plane along with good radiation efficiency at several frequency bands. The motivation for the thesis is to investigate methods to develop multi-frequency microstrip antennas with improved characteristics mainly for wireless applications. Patch designs can have some operational limitations such as restricted bandwidth of operation, low gain and a decrease in radiation efficiency due to surface wave losses. It may reduce the efficiency of planar antennas on high dielectric substrates or may produce unwanted coupling between different parts of circuits.

In this research we attempted several modifications to microstrip ring/loop antennas to design multi-frequency antennas through systematic approaches. Such multi-frequency antennas can be useful while building compact multi-functional terminals to operate at multiple wireless standards. One of the primary contributions was the use of a capacitive feed arrangement that enables simultaneous excitation of multiple concentric rings from an underlying transmission line. The main advantages of this feed mechanism are improved impedance matching, radiation efficiency, and the capability to simultaneously excite the multiple rings. Discontinuities are introduced in a feeding microstrip transmission line on a different substrate, for efficient coupling to the ring antennas at their resonance frequencies. This feed approach also overcomes the perceived disadvantages of such ring geometries when used as radiating resonators. A lossy
transmission line model has been used to analyze the behavior of this antenna. It has been found that by increasing the width of two sides of the square ring parallel to the feed transmission line, the bandwidth can be increased significantly.

In this work we initially designed several single-band microstrip ring antennas for specific applications such as ISM and WiMAX on a two-layer substrate. The simulation studies of antennas reported in this thesis are carried out using commercial software programs Zeland IE3D and Agilent ADS. One of the dielectric sheets has all the rings on one side of it. The other sheet has the transmission line and the feed strips on one side and ground plane on the other. An SMA connector is attached to the end of this line to feed the antenna. An aluminum sheet of 150x150mm$^2$ supports the antenna structure.

The ring antenna is considered a single-frequency antenna even though it is resonating at another resonance frequency, because the radiation pattern has null in the boresight direction at the second resonance frequency.

The basic square ring microstrip antenna has also been modified for dual-frequency operations. One of the modifications is to replace the side opposite to the feed arm with a fractal Minkowski geometry; dual-frequency operation can be achieved. All these antennas are excited by the capacitive feeding mechanism as discussed for single-frequency antenna. These antennas are analyzed using multi-port network modeling (MNM) approach to obtain their input characteristics. This modeling scheme exploits the ordered nature of fractals in simplifying the analysis, and avoids computation redundancy. The behavior of antennas with the first and second iteration fractal geometries have been accurately modeled with this approach. A number of prototype
antennas were fabricated and tested. By changing the indentation factor and ratio of ring widths, the relative placement of these frequencies could be controlled. Furthermore the inclusion of fractal geometries has been shown to reduce the size of the ring for a given resonance frequency.

It is also shown that the improvement in the radiation characteristics at the second resonance frequency that make this a dual frequency antenna can be attributed to the changes in currents on the antenna structure caused by inclusion of fractals. Similar changes in the current distribution are also obtained with suitable stub loading of the square ring antenna. The placement of resonance frequencies in this case can be controlled by changing the dimensions of the stub and the width ratio of sides of the ring.

Another extension to the study of microstrip square-ring antenna was to design an antenna with several concentric rings to arrive at a multi-frequency antenna. The purpose of this design is to provide a multi-frequency microstrip antenna that embraces all the advantages exploited thus far. To attain this, the proposed design contemplates a unique multi-ring microstrip antenna having two- or more distinct frequency bands with necessary amount of frequency separations with two- or more concentric microstrip rings in a single structure. The combined antenna operates in the same resonance bands as the individual rings and avoids some of the bands at harmonic frequencies.

As a demonstration, an antenna with three resonance frequencies is designed, fabricated and characterized. The co- and cross- polarization patterns in the E- and H-planes of the antenna are presented at the three resonance frequencies. These radiation patterns confirm that all these resonance frequencies correspond to $\text{TM}_{10}$ modes of
individual rings. The antenna shows a cross polarization level better than -15dB at all these frequencies.

The fabricated antenna shows excellent radiation pattern and good gain at the resonance frequency. The simulated, measured and analytical return loss characteristics of the antenna with non-uniform width square-ring are compared well. The far-field patterns in both E- and H-planes of these antennas are measured in an in-house anechoic chamber.