CHAPTER 10

CONCLUSIONS

10.1 NEWNESS

1. Modification of the conventional microstrip antenna within the given area with innovative fractal creativity to result in novel structures.

2. The structures Minkowski-Koch combined Fractal Antenna, Meander Fractal Antenna, New Hilbert Curve Fractal Antenna, Hilbert Curve Fractal Antenna on CSRR Metamaterial, Square Fractal Antenna and Square Fractal Antenna on Metamaterial MSRR presented in the Chapters 4, 6, 7 and 8 respectively are original contributions and have emerged from intuitive innovation.

3. Realization of the unique antennas using thin strips (instead of the conventional patch structures).

4. Combination of Fractal Antenna and Metamaterial is a maiden attempt and the usage has been made for performance improvement of the antenna operating in the lower frequency region of the microwave spectrum.

5. The V shaped Metamaterial array structure in Chapter 9 is novel idea which has been introduced newly for the first time in the LPF performance improvement.

6. New Hilbert Curve Fractal Antenna structure realized for the first time in a small dimensions which helps in getting multiple resonances and lower frequencies (as normally expected to work at high frequencies).

10.2 THESIS CONTRIBUTION

This thesis has covered the complete design details of various fractal antennas. The microwave CAD designs and simulations using IE3D and HFSS have been dealt completely. First few designs have been made in the meander form both in patch and thin strip shaped structures. Next stage of design has included the novel square fractal patch antenna structure and its iterations. The improvement in performance of this antenna has been attempted with the inclusion of metamaterial structures in the substrate. The final stage has covered the possibility of the fractal metamaterial loaded square patch as well as Hilbert curve antennas for use in implantable applications for communication to and from biological environment.

The results obtained from the simulations have been analyzed for each fractal antenna. From the concept of metamaterial and the properties of negative medium both slip ring resonators and complementary slip ring resonators structures have been verified separately using Nicolson-Ross-Wier parameter retrieval method from the obtained S parameters. The objectives of the thesis have been fulfilled by way of simulating the metamaterial loaded fractal antenna to know the performance. Two of such antennas have been experimentally verified and validated with and without metamaterial loadings using network analyzer and anechoic chamber.

The main objectives of attaining novel low profile fractal antenna structures, reducing the physical size and obtaining multiple resonances with possible improvements in VSWR, return loss, gain, bandwidth and radiation pattern have been satisfactorily achieved. As a concise summary, all the antenna designs made throughout the research period, have been well demonstrated with the help of simulated and experimental results achieved, using the readily available FR4 substrate. The newly shaped meander type fractal antennas, square fractal antennas and modified Hilbert curve fractal antenna in this thesis have been recommended for many wireless communication devices and implantable device communication applications. As explained in the Chapter 8 under the Section 8.4 the simulation results have been obtained for

i. Pattern generation and
ii. Resonance characteristics for the patterns generated

The suitable experiments may be conducted and the results can be matched so as to validate the theoretical research work.

The design and simulation of some fractal shaped antennas for implantable applications have been the final part of this thesis. The experimental verification and validation for these implantable antennas was very remote to achieve within the research period due to time constraint as it involved the need of experimental set up to have real test on rat, pig or human body. Hence the thesis covered only the simulation level analyses of such antennas.

10.3 FUTURE SCOPE

The future directions of research would take the following into consideration:

1. To develop a new automated algorithm for metamaterial parametric variations in the antenna designs, for obtaining resonance characteristics for optimized metamaterial substrate and metamaterial antenna

2. To explore the new possibility of using the above algorithm for further reduction in size of the proposed square fractal antenna in a variety of SRR or CSRR loaded substrate environments. Suitable experiment may be performed to match the results.

3. To develop radio frequency micro-electro mechanical systems (RF MEMS) based reconfigurable antenna with many small square patches, with suitable flexible organic substrate and proper biasing methods.

4. The design of fractal shaped MTM antenna should be tested for real time applications using suitable bio-compatible materials and authenticated for the bio-medical usage.