# Chapter 8

# RESEARCH CONTRIBUTION

## 8.1 Research outcome

In this research work, various parameters of MIMO antenna for different configurations have been investigated, designed, simulated and measured. Emphasis is given to increase the gain and to reduce ECC and coupling between two radiating elements by maintaining compact size of antenna.The size reduction and isolation enhancement in structures has been done by adopting different configurations like rectangular, circular,hexagonal structures etc.and different isolation techniques such as DGS, the parasitic element, slot technique etc.

### 8.1.1 High gain MIMO antenna

High gain MIMO antenna for multiband applications has been proposed and investigated in Chapter 3. Firstly, 2- element planar antenna has been designed. Simulated results shows poor isolation between two elements.'I' shape with vertical slot structure is etched on the ground plane to improve isolation between two elements. Isolation of -26.94 dB and -24.60 dB has been achieved for two different bands. Return loss characteristics shows two resonant frequencies 5.72 GHz and 8.11 GHz with bandwidth 270 MHz (5.55 GHz - 5.86 GHz) and 427 MHz (7.93 GHz- 8.36 GHz) with maximum gain of 6.05 dBi. The other structure with three elements has been designed to improve gain of MIMO antenna.Slits has been introduced in the structure to achieve wide bandwidth. The measured impedance bandwidth for 3-element MIMO antenna is 200 MHz (3.2 GHz - 3.4 GHz), 330 MHz (5.51 GHz - 5.84 GHz) and 770 MHz (7.16 GHz

- 7.93 GHz) and 800 MHz (10.8 GHz - 11.6 GHz). Also parametric study have been performed for distance between two antenna radiating elements so as to optimize the isolation which is less than -20dB. This structure works for multi-band applications. Peak gain of 7.3 dBi is achieved for wireless LAN applications. Thus, theoretical and experimental investigations have been presented for gain enhancement of MIMO antenna by increasing the number of radiators and use of modifications in ground plane and addition of slits improves isolation and bandwidth.

### 8.1.2 UWB MIMO antenna

Three different configurations for Ultra Wide Band MIMO antennas have been proposed in Chapter 4. The bandwidth for these antennas covers range from 2 GHz - 12 GHz covering UWB applications. Spanner shape 2-element antenna with monopole structure gives ultra wideband response as well as maintains compactness of designed structure.Good isolation i.e. less than -15 dB is achieved by keeping distance between two radiators as 0.25$\lambda$. The peak gain varies from 3.65 dBi to 4.79 dBi across UWB band. The average radiation efficiency is more then 60% across UWB with maximum value 90% at 5.2 GHz. 4-element structure has different antenna elements oriented orthogonal to each other. This gives dual polarization for proposed structure. Simulated characteristics of ECC have values near to zero over entire spectrum. This shows proposed structure is useful for diversity applications. Simulated maximum gain is 5.27 dBi at 7.93 GHz frequency. The circular MIMO antenna structure incorporating DGS and parasitic elements improves gain of MIMO antennas as well as reduces the coupling between antenna elements. Verification of the simulated and measured results proves that proposed antenna structures are suitable for UWB application. The gain variation from 2.8 dBi to 6 dBi is observed for entire UWB. But practically antenna gives gain of 5.6121 dBi when measured in semi anechoic chamber at 5.8 GHz frequency. Graphical representation of ECC which is less than 0.5 proves proposed antennas are useful for diversity applications.

### 8.1.3 MIMO antenna with band-notched characteristics

A MIMO antenna configuration is presented in Chapter 5 with band-notch characteristics so that same antenna can act as a filter for certain band of spectrum. Initially, planar 2-element antenna with truncated corner and monopole configuration has been designed and investigated. This structure gave ultra wide band response with dual polarization characteristics. To achieve notch band at 5.29 GHz and 9.41 GHz slots has been etched on radiating element as well as on feed line respectively. The parametric study has been performed on distance between two radiating elements to maintain good isolation i.e. less than -20 dB in MIMO antenna.Stable radiation patterns were observed for entire band. Low ECC value obtained to have diversity performance.

### 8.1.4 MIMO antenna for satellite application

MIMO antenna for $K/K_u$ and applications is proposed in Chapter 6. Slot cut elliptical shaped 3-element MIMO antenna provides very high bandwidth making antenna useful for satellite applications with diversified nature. Quarter wave transformer is attached to feed line to reduce reflections and achieve good matching. The three element structure has return loss i.e. $|S_{11}| <$ -10 dB for frequency bands of 14.8 GHz to 16.76 GHz, 18.44 GHz to 19.28 GHz with respective bandwidth of 1.96 GHz, 840 MHz.The coupling between the elements have been reduced by inserting slot in the radiating structure. The gain of 10.94 dBi is achieved for designed MIMO antenna. 27.4mm×27.4mm fabricated MIMO antenna structure make the use of such antenna for compact transmitter and receiver systems.

### 8.1.5 MIMO antenna with polarization diversity

6-element MIMO antenna to achieve polarization diversity is discussed in Chapter 7. Polarization diversity in MIMO antenna has been achieved by orienting a set of antenna radiators orthogonal to each other. The shape of the radiator is designed in such a way to have appropriate aperture area to maintain adequate gain. The gain of the antenna is increased up to 6.7dBi by increasing the number of radiators. Wide impedance bandwidth is achieved by using a monopole structure. Isolation can be enhanced by modifying the ground plane structure. Radiation pattern shows omnidirectional nature in H- plane and bidirectional nature in E- plane.Correlation coefficient is found to be 0.7 ensures given structure is suitable for MIMO application. Hardware measurements for all designed antennas were carried out using VNA for the characteristics such as VSWR, isolation loss which are found in agreement with simulation results. Radiation pattern characteristics were measured in semi-anechoic chamber. The summary of all results presented in Table 10.1 for proposed MIMO configurations.

| Name of Configuration | Size($mm^2$) | $S_{21}(dB)$ | Bandwidth | Gain (dBi) |
|---|---|---|---|---|
| DGS MIMO | 50.54 ×21.29 | -18.70 | 270 MHz/ 427MHz | 6.05 |
| 3 Element MIMO antenna | 76.76×22.74 | less than -15 | 270 MHz,479MHz,461 MHz | 6.7 |
| Spanner shape MIMO | 59.5 ×52 | less than -15 | 2.4-10.6GHz | 6.79 |
| Four Element dual polarised | 61 ×57 | less than -15 | 3.4-12 | 4.5 |
| UWB notched | 23 ×47 | less than -10 | Notched at 4.59-6/8.92-9.9 | 5.45 |
| Parasitic and DGS MIMO | 66.2 ×40 | less than -15 | 2.4GHz-11GHz | 6 |
| K band slotted MIMO | 25.4 ×25.4 | less than -15 | 14.52-17.03/18.21-19.37/22.78-23.98 | 10.94 |
| Flower shape monopole MIMO | 45.24 ×34.22 | less than -20 | 12.25-16.6/20.62-22.82 | 9.3 |
| Six-element diversity antenna | 45×43 | less than -15 | 1.44-2.88/3.96-4.68/6.84-10.8/15.48-17.28 | 6.7 |

Table 8.1: Summary of results for proposed structures

The results and discussion presented in this research work will provide an intuitive perspective on the fundamental requirements of the antenna with diversity applications. All MIMO antennas designed to cover different bands of spectrum to support various wireless applications such as ISM band, bluetooth, WLAN, WiFi, short-range radar, satellite applications etc. All structures proposed in thesis tested practically with WiFi dongle for wireless internet connectivity and it has been observed that as the number of elements of the antenna increases the data rate of wireless data transfer increases.