CHAPTER 9

CONCLUSION AND FUTURE SCOPE

9.1 Summary and conclusion

In the present investigations two different material systems, i.e. LMAP ceramic and MBS glass ceramic have been prepared and characterized thoroughly. The detailed analysis of phase, microstructure, thermal behaviour, density and dielectric measurements for these compositions are described in the respective chapters. The results show that a small addition of Al_2O_3 (x = 0.02) in LMAP ceramics lowers the sintering temperature by more than 100 ^{o}C giving good relative density of 94.13 %. Dielectric constant for LMAP ceramic compositions lies in the range 5.0 – 6.2 in X– band (8.2 – 12.4 GHz).

The effect of TiO_2 on the properties of MBS glass-ceramic compositions is analysed. TiO_2 has enhanced the crystallization process and results in an increase in the grain size. Reduction in percent thermal expansion was observed in MBS glass ceramics with increase in TiO_2 concentration in it. Addition of TiO_2 increases the dielectric constant. All the sintered MBS glass-ceramics exhibit low dielectric constant values of 3 – 5 and loss tangent values 0.002 – 0.006. MBS13Ti is more thermally stable in terms of thermal expansion and temperature coefficient of dielectric constant (τ_ε) as compared to other MBS glass-ceramic compositions. Dielectric constant is almost stable with the temperature and frequency for all the MBS glass-ceramic compositions.

It is concluded that both the proposed materials are suitable for LTCC applications, which can be used for dielectric resonator antennas. A table showing comparison of different properties for the optimized Li_2O–$1.94MgO$–$0.02Al_2O_3$–P_2O_5 ceramic and MBS glass-ceramic with 13 wt. % of TiO_2 with the conventionally available LTCC materials and FR-4 is given [Table 9.1].

Table 9.1 Properties of commercial LTCC materials and FR–4[Sebastian and Jantunen (2008b)], prepared ceramic (LMAP, x = 0.02) and glass ceramic (MBS13Ti).

Property	**Commercial LTCCs**	**FR–4**	**LMAP (x = 0.02)**	**MBS13Ti**
Permittivity	4.9 – 10	4.0	6.2	5
Loss Tangent	0.0002 – 0.0060	0.025	0.0006	0.0020
CTE, ppm K^{-1}	4.5 – 7.5	12-16	10.98	~7
Thermal Conductivity, $Wm^{-1}K^{-1}$	2.0 – 4.5	0.2	3.8	0.33
Metallisation	Au/Ag	Cu	Ag	Ag
τ_f (ppm/K)	–	+80	-63	–
Sintering Temperature	<1000 ^oC	–	825 ^oC	900 ^oC

A microstrip–fed aperture–coupled dual segment cylindrical dielectric resonator antenna (DS–CDRA) on the prepared LMAP LTCC substrate is designed and fabricated. The simulation and experimental results show favourable radiation patterns. The broadside radiation patterns are obtained in both E– and H– planes at the antenna resonant frequency with fairly low cross polar levels in E– plane. The measured results of the fabricated DS–CDRA have been found to be nearly in agreement with corresponding simulation results. The simulated and measured values of gain lie in the range 6.76 – 7.02 dB and 6.13 – 6.87 dB respectively over the operating bandwidth of antenna. Thus, the proposed DS-CDRA may find application in radar and radio navigation.

The simulation and experimental study of a coaxial probe-fed four element composite triangular dielectric resonator antenna (TDRA) in which antenna resonating elements are made up of Li_2O–$1.94MgO$–$0.02Al_2O_3$–P_2O_5 (LMAP) ceramic and teflon. The proposed antenna has provided simulated and experimental -10 dB reflection coefficient bandwidth of 6.97 GHz (61.65 %) and 7.6 GHz (66.09 %) with an average gain of 5.14 dB and 4.66

dB over their operating frequency range, respectively. Monopole like radiation patterns have been obtained over the operating frequency band of the proposed antenna with little distortion at higher frequencies. The proposed four element composite TDRA can potentially be used in broadcast base-station, radar and satellite communication providing wide area coverage.

The design and simulation study of a dual segment rectangular dielectric resonator antenna (DS–RDRA) on $MgO–B_2O_3–SiO_2$ with 13 wt. % TiO_2 (MBST) glass-ceramic LTCC substrate is performed. The simulation results for the RDRA on MBST substrate is compared with those for similar DS–RDRA on FR4 substrate. The simulation study was also performed for the composite substrate configuration i.e. FR4–air (FR4C) and MBST–air (MBSTC). It was observed that MBST substrate provides large impedance bandwidth of 680 MHz along with wide beam in E– plane. The composite substrate (MBSTC) has also been studied in order to get the advantage of higher gain and also reduction in substrate material as compared with uniform MBST and FR–4 substrates without significantly hampering the antenna characteristics. The proposed antenna can be used for X– band wireless communication applications.

Further, the different antenna parameters like excitation technique, operating bandwidth, generated mode, radiation pattern and gain for the three dielectric resonator antenna designs described in chapter 5 (DS–CDRA), chapter 6 (4–element TDRA) and chapter 8 (DS–RDRA) are also tabulated along with their suitable applications [Table 9.2].

Table 9.2 Comparison of various parameters of proposed DRAs

Parameters	DS–CDRA		TDRA		DS–RDRA
	(simulated)	**(measured)**	**(simulated)**	**(measured)**	**(simulated)**
Operating bandwidth	9.08 – 9.98 GHz	8.68 – 9.76 GHz	7.82 – 14.79 GHz	7.70 – 15.30 GHz	8.75 – 9.33 GHz
Bandwidth (%)	9.55 %	11.71 %	61.65 %	66.09 %	7.56 %
Average Gain	6.98 dB	6.67 dB	5.63 dB	4.6 dB	6.63 dB
Substrate	LMAP (x = 0.02)		Copper Plate		MBS13Ti
Resonator	Teflon and BSTG ceramic		Teflon and LMAP(x = 0.02)		Teflon and BSTG ceramic
Feeding Technique	Aperture Couple		Probe		Aperture Couple
Radiation Pattern	Broadside		Monopole		Broadside
Mode	$HEM_{11\delta}$		TM^{z}_{101}		$TE^{x}_{21\delta}$
Fabrication	Simple		Simple		Simple
Application	Radar, Radio navigation etc.		For Broadcast satellite services (TV Broadcast services)		Primary feed for military satellite communication

9.2 Future scope

The present study opens up the opportunity for the utilisation of the developed LTCC material in designing microwave devices and systems. Also, different dielectric resonator antenna can also be designed by using prepared ceramic compositions to get the enhanced antenna performance. Taking the material research to the device application level is very essential to understand the performance and reliability of the finally developed system. As fas as material application is concerned, following work objective can be taken for further advancements and growth of the microwave devices:

- Explore the dielectric resonator antenna designs with other attractive features such as circular polarization, excitation of different modes simultaneously for multi band operation, array structures and other DRAs configurations for 4G/5G, WiMAX, GPS, radar and other wireless communication applications.

- LMAP developed in the present study, being a low loss material, it can also be suitable for realization of microwave filters.