Design and Development of Dielectric Resonator Antennas Using Glass Added Barium Strontium Titanate Ceramic Materials

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Doctor of Philosophy

by

Pankaj Tripathi

DEPARTMENT OF CERAMICS ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY
(BANARAS HINDU UNIVERSITY)
VARANASI – 221 005

ROLL NO: 13031005

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CHAPTER 8

CONCLUSION AND FUTURE SCOPE

8.1 Summary and Conclusion

In the present investigation two different types of low melting temperature glasses PbO-B_2O_3-BaO-SiO_2 (PBBS) and Bi_2O_3-B_2O_3 (BB) are prepared and added to the calcined powder of $Ba_{0.5}Sr_{0.5}TiO_3$ (BST) ceramic. The synthesis process of PBBS and BB glass added ceramic is described thoroughly in Chapter 3. The detailed analysis of thermal behaviour, phase, microstructure, density, dielectric measurements in wide temperature and frequency range, for BST-PBBS and BST-BB compositions are described in chapters 4 and 6, respectively.

The results for PBBS glass added BST show that a small PBBS glass addition (BST-10P) to BST lowers the sintering temperature by 375K giving good relative density of 90.2 %. Average dielectric constant values for BST-3P to BST -10P ceramic compositions lie in the range 13.8 – 27.0 over the frequency range of 8.2 – 11.0 GHz. Analysis of dielectric property over the temperature range of 20K-500K and frequency upto 1 MHz reveals that transition temperature increases with increase in glass concentration up to 5 wt% and then it starts decreasing by further increase of the glass concentration (>5 wt%). Dielectric constant of all PBBS glass added BST samples have been observed almost stable over the frequency range 8.5 - 11 GHz at room temperature with highest value for BST-10P. Remarkable properties of PBBS glass added BST sample are listed in Table 8.1.

A microstrip-fed aperture-coupled single segment RDRA, dual segment RDRA (DS-RDRA) and filleted RDRA (F-RDRA) have been designed and simulation studies have been was performed. The -10 dB reflection coefficient-frequency plot for the three DRA configurations reveals that the maximum bandwidth is obtained for the filleted-RDRA (F-RDRA) configuration. The simulated -10 dB reflection coefficient bandwidth of the proposed antenna has been found to be 4.875 GHz (47.92 %), which is 8.57 % greater than 3.65 GHz (39.35 %), the bandwidth of conventional dual segment RDRA. The experimental -10 dB reflection coefficient bandwidth of the fabricated F-RDRA is 6.048 GHz (7.00 – 13.048 GHz) with nearly 60% impedance bandwidth. Also, radiation pattern of proposed F-RDRA remains nearly stable with variation in frequency as compared to DS-RDRA. Due to more discontinuities in the conventional DS-RDRA, diffraction from the edges occurs which causes generation of ripples in radiation pattern. The proposed F-RDRA provides widest bandwidth with reasonable gain among all the RDRAs studied and those reported in literature. The proposed F-RDRA provides broadside radiation pattern with reasonably good realized gain over its operating frequency range. Performance comparison of proposed F-RDRA with existing antennas reported in literature is given in Table 8.2.

Table 8.1 Comparison of properties of BST ceramic, PBBS and BB glass added BST ceramics.

Composition	**Properties**				
	Sintering Temperature (K)	**Curie Temperature**	**Relative Density (%)**	**Average Dielectric constant @ GHz**	**Average Loss Tangent @ GHz**
BST	1523	225	92.06	84.0	0.013
PBBS Glass Added BST					
BST-3P	1223	267	83.9	15.0	0.354
BST-5P	1198	271	85.5	13.8	0.596
BST-8P	1173	257	88.8	25.8	0.237
BST-10P	1148	229	90.2	27.0	0.121
BBS Glass Added BST					
BST-3B	1223	241	92.43	17.0	0.169
BST-5B	1223	248	96.42	43.2	0.496
BST-8B	1223	234	95.08	37.1	0.328
BST-10B	1223	231	93.65	22.5	0.472

The results of BB glass addition on BST ceramic show that increasing weight percentage of glass significantly reduces the sintering temperature of BST. Composition BST-5B shows the highest density at sintering temperature of 1223 K as compared with all other compositions. Analysis of dielectric property has revealed that transition temperature increases with increase in glass concentration up to 5 wt% and then it starts decreasing by further increase of the glass concentration (>5 wt%). Highest value of dielectric constant (ε_r= 43.2) for BST-5B has been observed over the frequency range 8.5 - 12 GHz at room temperature. Dielectric constant values of glass added BST samples lie in the range 17 – 43.2 and thus these types of samples can be potentially useful for the design of microwave dielectric resonator antennas. Remarkable properties of BB glass added BST sample are listed in Table 8.1.

The BST-3B ceramic of average dielectric constant of 17 and average loss tangent of 0.169 (which exhibits minimum value among all other composition) has been used for the design of CDRA with three different composite feed configurations PPP (Probe with plus patch), PSP (Probe with swastik patch) and PXP (Probe with xor patch), with the objective of obtaining monopole like radiation patterns. The proposed antenna with PXP feed has been found to provide the widest bandwidth when compared with other antennas reported in literature which produce monopole like radiation pattern. The benefits of the proposed antenna is in its simple design and simple feed layout for obtaining monopole like radiation characteristics. The composite feed employed here can be exploited for excitation of different DRAs using wide range of available dielectric materials, which can provide much flexibility to cover wide range of frequencies. Performance comparison of proposed CDRA with other antennas reported in literature is given in Table 8.3.

Table 8.2 Performance comparison of proposed F-RDRA with other antennas reported in literature.

S.No.	DRA Shape	ε_d	Resonant Frequency (GHz)	Excitation	BW (GHz)	BW (%)	Ref.
1	Notched Rectangular shape	10.8	11.9	Slot coupling	10.1-13.7	28	Ittipiboon et al. (1996)
2	RDRA consisting of intermediate substrate.	2.2/10.2	12.3	Slot coupling	9.0-16.4	59	Coulibaly et al. (2006)
3	Rectangular	9.8	6.9, 9.7, 11.1, and 13.2	Parallel standing strips	-	60	Rashidian et al. (2012)
4	Proposed F-RDRA	2.1/15	7.62, 12.3	Aperture coupling	7.00-13.05	60.34	proposed

BW: Operating bandwidth

Table 8.3 Performance comparison of the proposed CDRA with other antennas reported in literature.

Parameters	Reference [Guha et al. (2006b)]	Reference [Gangwar et al. (2017)]	Proposed CDRA
Type of Feed for Excitation	Modified coaxial probe (coaxial probe surrounded by small dielectric rod)	Coaxial probe	Composite feed
Resonator Type	4-element Cylindrical resonator	4-element triangular resonator	Single element cylindrical resonator
Operating Frequency Range (GHz)	~3 – 4	4.7 – 6.8	7.03 – 11.98
Bandwidth (%)	~29	~37	~52
Gain (dB)	4.0	4.7	3.3
Fabrication Complexity	Complex	Moderate	Easy

The simulation and the experimental results of the proposed antenna have been found to be nearly in agreement with some deviations in the results especially for reflection coefficient-frequency characteristics which may be due to fabrication and measurement errors. Comparison of various antenna parameters such as feeding technique, operating bandwidth, generated mode, radiation pattern and gain for the proposed dielectric resonator antenna designs described in chapter 5 (F-RDRA), and chapter 7 (CDRA) are tabulated along with their suitable applications [Table 8.4].

Table 8.4 Comparison of results for various parameters of proposed DRAs

Parameters	**F–RDRA**		**CDRA**	
	(simulated)	**(measured)**	**(simulated)**	**(measured)**
Operating bandwidth	**7.74-12.61**	**7.00-13.05**	**7.44-11.25**	**7.03 – 11.98**
Bandwidth (%)	47.92	60.34	40.77	52.08
Average Gain (dB)	6.12	5.84	3.34	3.30
Substrate	**FR4**		**FR4**	
Antenna materials	Teflon and BST-3P ceramic		BST-3B ceramic	
Feeding Technique	Aperture Couple		Composite feed	
Radiation Pattern	Broadside		Monopole	
Mode	TE^{x}_{211}, TE^{x}_{2n1} where $0 < n < 1$		TM^{z}_{101}	
Fabrication	Simple		Simple	
Application	Primary feed for parabolic reflector in radar and satellite communication		An element in antenna array in radar and satellite communication	

8.2 Future scope

Taking the material research to the device application level is very essential to understand the performance and reliability of the finally developed system. The present study opens up the opportunity for the utilisation of the developed low temperature glass added BST ceramic material in the design of microwave devices and systems. Also, different dielectric resonator antennas can also be designed by using prepared ceramic compositions with suitable dielectric constant values to get the enhanced antenna performance. As far as material application is concerned, following work objective can also be undertaken for further advancements of the microwave devices:

- The novel glass compositions may also be utilised for the liquid phase sintering of other high temperature ceramic materials, keeping in check that the glass must not react with the ceramic materials.
- Since, BST ceramic compositions described in the thesis, have different Curie temperatures, and therefore these materials can be suitably utilized for the design of tunable phase shifters.
- Different phase shifters in phased arrays can also be realized with the utilization of these materials.
- The novelty in DRA shape and the feeding technique can also be tested/realized for other DRA configurations for WiMAX, GPS, radar and other wireless communication applications