THERMOSET MICROWAVE MATERIALS FOR DRAs

Sanjeev Kumar

Research Scholar, University Department of Physics, B.R.A.B.U., Muzaffarpur, Bihar.

Abstract :

For the development of DRA, a block of dielectric ceramic material is required. The material play a vital role with a wide range of antenna's application. Thermoset microwave materials, TMM are ceramic hydrocarbon. TMM laminates are present in a broad range of dielectric contents and claddings. Having low thermal coefficient of dielectric constant allow for production of high reliability plated through holes and low etch shrinkage values. TMM 10, TMM 10i and RO 3010 are best materials for DRA on the basis of permittivity.

Keywords : Permittivity, resonant frequency, bandwidth, temperature coefficient.

Introduction :

TMM (thermoset microwave materials) are ceramic, hydrocarbon, thermoset polymer composites designed for high plated-through-hole reliability stripline and microstrip applications. TMM laminates are present in a broad range of dielectric constants and claddings. The electrical and mechanical properties of TMM laminates combine many of the profits of both ceramic and traditional PTFE microwave circuit laminates, without requiring the specialized output techniques common to these materials. TMM laminates do not require a sodium napthanate treatment prior to electroless plating.

TMM laminates have an specially low thermal coefficient of dielectric constant, typically less than 30 ppm/°C. The material's isotropic coefficients of thermal expansion, very nearly matched to copper, allow for production of high reliability plated through holes, and low etch shrinkage values. Further more, the thermal conductivity of TMM laminates is almost twice that of traditional PTFE/ceramic laminates, facilitating heat removal.

TMM laminates are based on thermoset resins, and do not soften when heated. As a result, wire bonding of component leads to circuit traces can be featured without concerns of pad lifting or substrate deformation.TMM laminates combine many of the desirable characteristics of ceramic substrates with the ease of soft substrate processing techniques. TMM laminates are present clad with 1/2 oz/ft2 to 2 oz/ ft2 electrodeposited copper foil, or bonded directly to brass or aluminum plates. Substrate thicknesses of 0.015” to 0.500” are present. The base substrate is obstructive to etchants and solvents used in printed circuit production. Consequently, all general PWB processes can be used to produce TMM thermoset microwave materials and are named as Roger's TMM materials.

Characteristics of Roger materials are : Broad range of dielectric constants Ideal for single material systems on a broad diversity of applications. Exceptional mechanical features resist creep and cold flow. Coefficient of thermal expansion matched to copper. High reliability of plated via holes. Resistant to process chemicals reduces damage to object during fabrication and assembly processes. Thermoset resin for dependable wire bonding. No specialized production technology required, TMM10 and 10i laminates can change alumina substrates.

Applications of Roger's TMM are : RF and microwave circuitry, Power amplifiers and combiners, Filters and coupler, Satellite communication systems, Global Positioning Systems Antennas, Patch Antennas (DRA), Dielectric polarizers and lenses, Chip testers.

The selection of better suitable material for greater precision is based on their features which are called material attributes (material indices and performance indices). These material indices affect the performance of objects in terms of performance indices. The fundamental steps of Ashby's methodology for matreial sections are translation, screening, ranking and supporting information. With these steps materials selected show the better performance and are selected by the Ashby's theory approach. The performance indices (p) of the element under consideration has the functional form p = {F, G, M}, where M describes material indices, G geometric parameters and F functional requirements. Material selection using performance indices can be better achieved by plotting the graph between material indices. This optimization is conventionally achieved usign graphs with axis corresponding to various material indices or material features.

DIELECTRIC MATERIALS FOR DRA

The material indices considered in this work are permittivity (ε_r) of the material, tangent loss (tan(δ)) and temperature coefficient of resonant frequency (τ_f), which directly affect the performance of the Dielectric Resonator Antenna. These features of the material form the performance indices of that material. Table-1 shows the characteristics of different possible materials used to design various configuration of DRAs (Rectangular, Cylindrical and Hemispherical in this research work).

Table 1 : DRA materials (Roger and their characteristics)

Sr. No.	DR Material	τ_f(ppm/^{0}C)	tan(δ)	Permittivity (ε_r)
1	Roger TMM3	37	0.002	3.45
2	Roger TMM4	15	0.002	4.7
3	Roger TMM6	-11	0.0023	3.6
4	Roger TMM10	-38	0.0022	9.8
5	Roger TMM 10i	-43	0.002	10
6	RO3010	-280	0.0023	10.2
7	RT-Duriod/Alumina	--	0.00015	12
8	$Sr(Zr_xTi_{1-x})O_3$, at x=1	-82	0.03825	25
9	$Ca(Ti_{1-x}Zr_x)O_3$at x=1	-19	0.0342	27

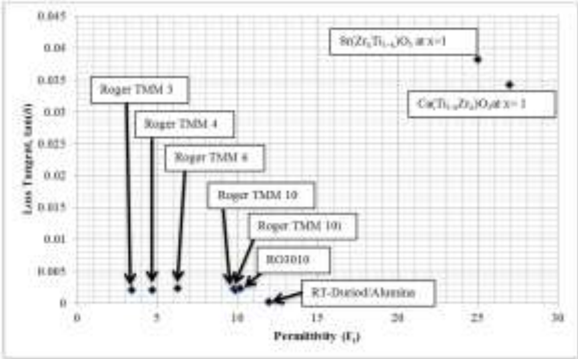
Roger TMM10i has high value of temperature coefficient (τ_f) as compared to Roger R03010 and lower tangent loss (tan(δ)) as compared to Roger TMM10 and RO3010. Thus Roger TMM10i and Roger TMM10 are better materials for DRAs (RDRA, CDRA and HDRA).

The four vital performance indices considered are resonant frequency (f_r), size of antenna (λ), impedance bandwidth (BW) and radiation efficiency (η) of antenna. All these parameters have already been defined in introduction chapter of this thesis. Good radiation efficiency can be maintained by choosing dielectric material with low-loss features. As the directivity increases radiation efficiency decrease and vice-versa while radiation efficiency is directly proportional to the profit of the dielectric resonator antenna (DRA).

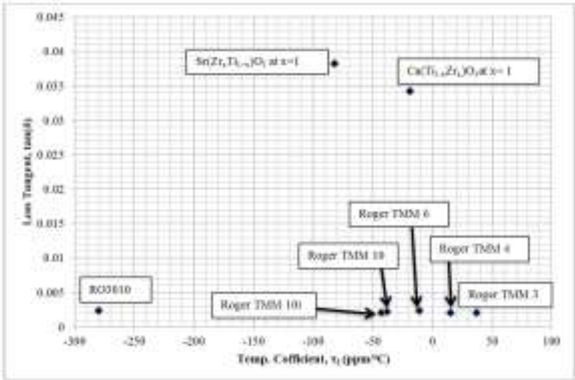
DRA requires high radiation capacity, small size, broad-bandwidth and near zero temperature coefficient of frequency for their better performance. So by these four parameters of DRA it is clear that Q &η are directly proportional to ε_r, while f_r(resonant frequency) and BW (bandwidth) are inversely proportional to ε_r. Thus there is a comparision (one parameter increases another decreases and vice-versa) between bandwidth and quality factor as well as the size and radiation capacity of the antenna for the resonant frequecyf_r. So there is a requirement and it is very important to choose the better possible material for DRA which may shows the better performance of DRA under consideration. In this chapter it has been tried to choose that material which have the features mentioned above.

ANALYSIS FOR SELECTING DR MATERIALS

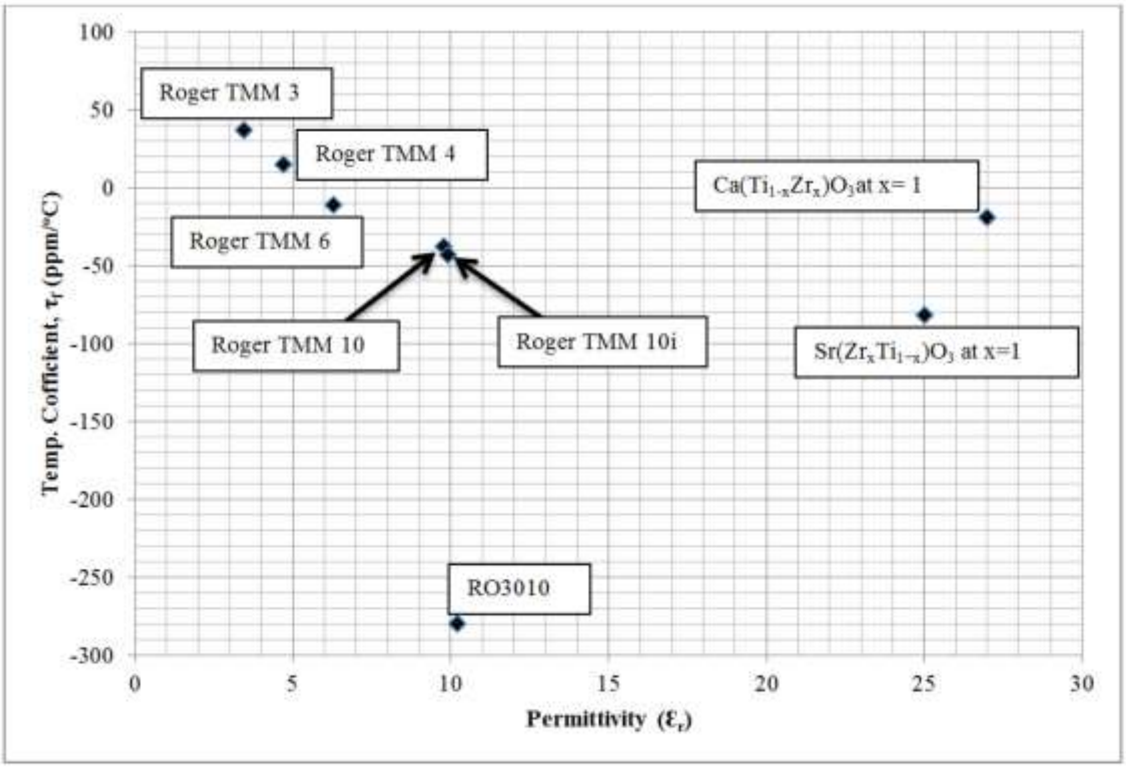
The performance of DR material changes with various performance indices. Here we have used graphs to choose the optimal candiate for DR material and to recognize the trade-offs between the conflicting material indices.



Graph 1 Tangent loss (Tan(δ) verses permittivity (ε_r) graph.



Graph 2 Tangent loss Tan(δ) verses Temperature Coefficient (τ_f) graph.



Graph 3 Variation between temperature coefficient and permittivity for all possible dielectric materials.

Graph 2 shows the variation between temperature coefficient of resonant frequency (τ_f) and tangent loss (Tan(δ)) for several DR materials. Roger TMM10 and Roger TMM10i are the better materials for DRA development.

Graph 3 shows that temperature coefficient (τ_f) for Roger TMM10 and Roger TMM10i is less compared to another Roger's materials. Hence these two can be selected for the development of DRA particularly (RDRA, CDRA, HDRA) in this research work. Graph 3 also shows that the variation between temperature coefficient and permittivity (ε_r) of resonant frequency (τ_f) for all possible DR materials. It is considered that a material with moderate values of permittivity and near zero temperature coefficient of resonant frequency (τ_f) is appropriate to minimize the size of the antenna and maximize the radiation efficiency (η). From the plot, it is specified that Roger TMM10 and TMM10i are better material to maximize the impedance bandwidth of the antenna.

Result :

From the theoretical analysis and from the Data, we have come to the conclusion that out of the Rogers materials, TMM10, TMM10i and RO3010 are better materials for DRA development. As permittivity (ε_r) is universly proportional to the resonant frequency (τ_f), we require low permittivity material which assists to minimize the size of antena and maximise the radiation efficiency. Permittivity (ε_r) = 9.8 for TMM10 is less compared to TMM10i (ε_r=10) and RO3010 (ε_r=10.2). Thus finally we choose Roger TMM10 is the superior possible material followed by TMM10i and RO3010 out of all materials taken into consideration in this research work. Thus to fulfill required criteria of DR material Roger TMM10 is the better for DR development. Thus the chapter deals with material selection considering the various parameters for DR material. The next chapter will explain comparative study of DRA (RDRA, CDRA and HDRA). DRA designs are used to explore the DR material. For example, Rectangular DRA using Roger materials is explained here.

A simple DRA agitated by the probe fed is used to analyse the performance of antenna. Dr has dimensions : a=b=18 mm and d=29 mm whereas the probe-fed has length 10mm from ground and diameter 1.2mm. The DR is connected on a Rogers RT5880 subtrate with permittivity ε_{rs} = 2.2, loss tangent of 0.0009, and thickness h = 0.762 mm. In Fig. 5, the comparative return losses of the DRA for possible DR materials are shown.

This Fig. 1 shows the emulated reflection coefficient for rectangular DRA as a function of frequency for TMM10 (ε_r = 9.8), TMM10i (ε_r = 10) and RO3010 (ε_r = 10.2). It can be observed that the resonant frequency decreases like the permittivity of DR material increases. Hence it is found that for the rectangular DRA, with variation in the permittivity of the DR material, frequency shift occur and it does not affect the other radiation featuress of DRA.

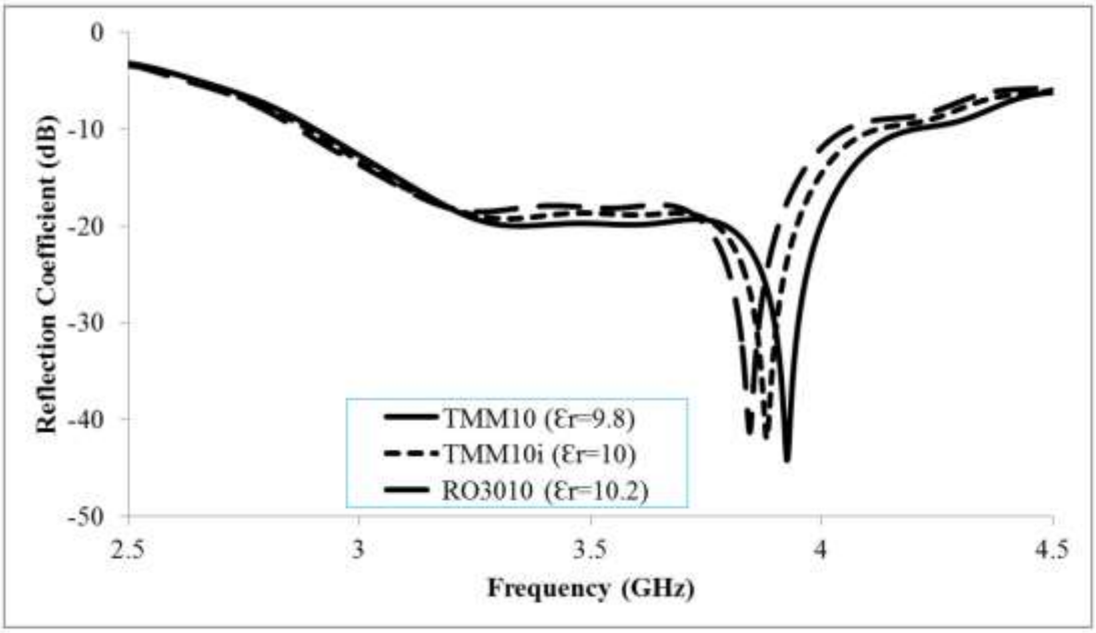


Fig. 1 Comparative return loss of DRA for different DR materials.

CONCLUSION :

In this chapter, object selection for DRA design, following the Ashby view point of material indices has been carried out successfully. Four performance indices based on various material indices to enhance the performance of the DRA, are discussed. Based on material selection charts, it is observed that Roger TMM10, RO3010 and Roger TMM10i are suitable materials to be used as DR in DRA to obtain the desired features to give the better performance of the antenna. As Roger TMM10i and RO3010 have a higher temperature coefficient compared to Roger TMM10 Roger TMM10 (ε_r = 9.8) is the most promising material for DRA as DR element. The Roger TMM10 (ε_r = 9.8) materials provide better bandwidth than the another materials. It provides the enhancement in impedance bandwidth without affecting the profit and efficiency of the antenna. Thus Roger TMM10(ε_r = 9.8) as DR material is a potential candidate for various DRA.

References

1. P. R. Haddad and D. M. Pozar, “Characterisation of aperture coupled microstrip patch antenna with thick ground plane”, *Electron. Lett.*, vol. 30, pp. 1106-1107, July 1994

2. S. A. Long, M. W. McAllister and L. C. Shen, “The resonant cylindrical dielectric cavity antenna”, *IEEE Trans. Antennas Propagat.*, vol. 31, pp. 406-412, May 1983

3. M. W. McAllister, S. A. Long and G. L. Conway, "Rectangular dielectric resonator antenna," *Electron. Letters,* Vol. 19, pp. 218-219, 1983.

4. M. W. McAllister and S. A. Long, "Resonant hemispherical dielectric antenna," *Electron. Letters*, Vol. 20, pp. 657-659, 1984.

[5. A.A.Kishk, *Different Integral Equations for Numerical Solution of problems Involving Conducting or Dielectric Objects and their Combination,* PhD Thesis, University of Manitoba, Manitoba, Canada, 1986.

6. Mongia, R. K. and Prakash Bhartia, "Dielectric resonator antennas-A review and general design relations for resonant frequency and bandwidth," *International Journal of Microwave and Millimeter-wave Computer Aided*

7. Nor N. M., Jamaluddin M. H., Kamarudin M. R., and Khalily M., "Rectangular Dielectric Resonator Antenna Array for 28 GHz Applications", Progress In Electromagnetics Research C, 2016, Vol. 63, 53–61,

8. Xu, Y. L., Yang H., Yu W., Liu X., Shen R., "Scattering analysis of nonperiodic composite metallic and dielectric structures using synthetic functions", *IEEE Antennas Wireless Propag. Lett.*, **2017**, vol. 16, pp. 3079-3083.