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Microwave Propagation in Circular Quarter Wave Transformer made of Teflon and K-12 Composite

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Abstract:

Introduction: The business is developing at an extremely quick rate and the prerequisite for the recently made material is generally there for the high-recurrence applications. There are different polymers and clay materials and there are composites currently accessible in the business for high-recurrence applications. Polymer ceramic composites are being used for high frequency applications. The quarter-wave transformer offers a relatively simple method of impedance matching for many RF applications. Low loss circular quarter wave transformer is important for the circular microwave devices like phase shifters antennas etc which is realizable using Fused silica and K12 polymer ceramic composites.

Objectives: Objective of this research work is simulation and fabrication of the circular quarter wave transformer at X-band using TEFLON-K-12 polymer ceramic composites.

Methods: The Teflon and K-12 composite was used to fabricate the circular Quater wave transformer for microwave applications. The composite slab was machined to create the bare circular rod. The bare quarter wave transformer was sputtered in a closed chamber in the silver target. The sputtered rod creates a circular Quater wave transformer that is filled with Teflon-K-12 composite.

Results: The insertion loss of the circular Quater wave transformer was found 0.05 dB. Thus, a circular Quater wave transformer is formed with polymer and ceramic composite a new material for low loss microwave applications. The practical value holds good in agreement with the theoretical approaches.

Conclusions: The Teflon and K-12 composite was used to fabricate the circular Quater wave transformer for microwave applications. The measured S –parameter results of the circular Quater wave transformer were found satisfactory, and it is found suitable for the low loss microwave propagation. The quarter wave transformer is able to match impedances 50 ohms and 100 ohms.

Keywords: waveguide, composites, polymer, microwave.

1. Introduction

The business is developing at an extremely quick rate and the prerequisite for the recently made material is generally there for the high-recurrence applications. There are different polymers and clay materials and there are composites currently accessible in the business for high-recurrence applications. Nonetheless, they have limits in their utilization on account of the constraint in the mechanical, warm, and electrical properties. Their handling cost is a significant variable for creating gadgets which is usable in the microwave recurrence district. Pottery materials have prevalent microwave dielectric, attractive, warm, and mechanical properties. Notwithstanding, the creation cost

of ceramics is high [2]. The weakness and high handling temperature of ceramics lead to trouble in the manufacture of mind-boggling shapes or machining substrates during circuit creation. The significant disadvantage of the polymers is their high worth of the coefficient of warm development, mediocre attractive properties, and low warm conductivity [3-5]. A blending of polymers and clay materials can successfully determine the handling cost as well as handling challenges with adjusted electrical, warm, and mechanical properties [1, 6-8].

Teflon has been utilized at large scale in numerous sorts of RF and microwave applications like radome, substrates, and tars for conductive surfaces for joining the gadgets. They have fantastic synthetic and consumption obstruction properties. The assembling of Teflon has been less expensive, and it tends to be handled at lower temperatures. The dielectric misfortune (€r 0.0003 @10 GHz) of the Teflon has been high and this limits the utilization of the material for different other microwave applications. Their greatest working temperature ultimately depends on 300 °C just [9].

Melded Silica is a fantastic straightforward material in the microwave frequency range for radio transmission and radome applications. They have magnificent thermal properties, and their greatest working temperature depends on 900 °C. Their dielectric consistent is 3.7 in the X band range dielectric misfortune is 0.0004 [9]. Notwithstanding, its handling cost is extremely high, and it required a sintering temperature of 1220 °C roughly.

The blending of the K-12 and Teflon makes a polymer ceramic composite that shows excellent machinability, lower powder handling coat, and lower digression misfortune properties. The intertwined silica has been utilized as a filler material in the Teflon powder.

Teflon-based Silica composite has proactively been explored in different avenues regarding development in its electrical, warm, and mechanical properties. [5-6]. The high-recurrence proliferation in a Circular Quater wave transformer made of Teflon-K-12 Composite has been explored in this paper. This recently made material was utilized as a roundabout Quater wave transformer for the microwave engendering at X-band. The inclusion loss of the roundabout Quater wave transformer was estimated.

The quarter-wave transformer offers a relatively simple method of impedance matching for many RF applications. It is easy to implement using standard transmission lines or coaxial cables and does not require complex circuits or components. Quarter-wave transformer is a widely used and effective method for achieving impedance matching, minimizing reflections, and ensuring optimal power transfer in high-frequency circuits.

2. Objectives

Objective of this research work as follows.

- Simulation of the circular quarter wave transformer
- Fabrication of the quarter wave transformer using polymer ceramic composite material TEFLON and K-12.
- Results analysis and discussion.

3. Methods

The Teflon and K-12 composite material are easier to manufacture, and it has got a better property with respect to the unfilled Teflon. The composite is low-loss material with respect to unfilled Teflon. The tangent loss for the unfilled Teflon was 0.0120 and the tangent loss for the Teflon and K-12 composite was found 0.0012. The Thermal and mechanical properties of the composite are better with respect to the unfilled Teflon the summary of the properties is given in the table below.

Sl. No	Properties	Bare Polymer (Teflon)	Ceramics (K-12)	Properties of the Composite (Teflon and K-12)
1	Dielectric Constant	2.1	12	5.4
2	Tangent Loss	0.0003	0.0002	0.0004
3	Density	2.19 gm/cc³	-	2.34 gm/cc³
4	Tensile Strength	35MPa	50 MPa	47 MPa
5	Coefficient of Thermal Expansion	142 ppm/°C	117ppm/°C	105 ppm/°C

From the properties given in the table above it is better in terms of thermal and mechanical properties. It can be used as a low lossy material for microwave applications.

The roundabout Quater wave transformer was planned in HFSS for TEM Mode. The limited component strategy is perhaps the best recurrence space computational technique for electromagnetic recreation. The technique's fundamental benefit is its ability to treat any sort of math and material inhomogeneity without a need to adjust the definition or the PC code. That is, it gives mathematical loyalty and unlimited material treatment. A roundabout Quater wave transformer is a cylindrical, roundabout guide. A plane wave spreading through a roundabout Quater wave transformer brings about cross-over electric (TE) or cross over attractive (TM) mode.[15]

The plan of the roundabout Quater wave transformer is made in the HFSS recreation programming. The determined model arrangement is chosen for the recreation. The design in the HFSS is as below in Fig. 1. The Quater wave transformer is filled with the vacuum and the assigned boundary condition is finite conductivity. The excitation is provided at both the wave port.Fig.1 Circular Quater wave transformer in HFSS, The Design of a circular Quater wave transformer with a diameter of 5.336 mm in HFSS. The outer wall of the Quater wave transformer is assigned a boundary condition called finite conductivity or perfect E. with this assumption, the port is defined within a Quater wave transformer. The frequency range for the simulation is 1-18 GHz. The input impedance of the transformer is 50 ohms and output impendence of the transformer is 100 ohms. The output for the different modes of the port was analysed. In simulations, the dialectic constant of the Teflon-K-12 composite was chosen to 5.4 and tangent loss was chosen to 0.0004.

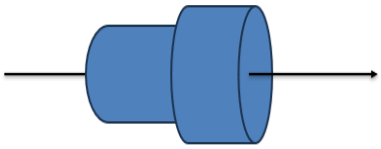

Fig: 1 Circular Quater wave transformer Simulation in HFSS

The size of the quarter wave transformer was found to be approximately 7.5 mm. In simulation results, the insertions loss of the circular Quater wave transformer was found 0.05 dB. The circular Quater wave transformer was fabricated using the machining processes.

Teflon & K-12 composite was fabricated using the powder processing technique [1]. The fabricated slab was used to make a circular Quater wave transformer of lengths 7.5 mm. in the machine shop using the surface grinding machines.

The bare rod was then brought to the lapping area and the following processes were carried out.

- The Teflon-K-12 rod was first cleaned in an ultrasonic cleaner for 5 minutes so that deposited dust particles are washed out.
- The rod was then heated to 150 deg° under an oven so that moistures content at the surface of the rod was removed and evaporated.
- The rod was then fitted on a rotating jig a kind of structure that takes that is suitable to provide a rotation. The rod rotates in a circular motion around its axes. This arrangement will provide a accurate machining of the rod for making a quarter wave transformer.

The Fabricated Circular Quater wave transformer made of Teflon and K-12 Composite has been shown in figure: 3.

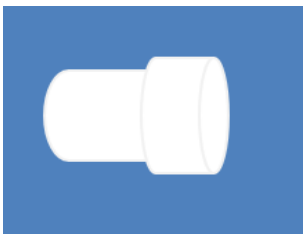

Fig: 2 Fabricated Circular Quater wave transformer using Teflon & K-12 Composite

The fabricated Teflon-K-12 composite rod was then tested using the Keysight Performance Network Analyzers. The test setup was calibrated first the nullify the cable and Quater wave transformer to coaxial and the test set up losses. The test setup for the measurement has been shown in fig: 2.

4. Results

The S21 results found for the fabricated Quater wave transformer rod is 0.05 dB. S11 and S22 were found to be -10.8 dB. From these results, it is observed that the dielectric material inside the Quater wave transformer was entirely changed. Its new material is called Teflon and K-12 composite. The composite is behaving properly with respect to microwave propagation. The size of the quarter wave transformer was found to be approximately 7.5 mm. In simulation results, the insertions loss of the

circular Quater wave transformer was found 0.045 dB. Circular quarter wave transformer is able to match the impedances 50 ohms and 100 ohms.

5. Discussion & Conclusion

The S-parameters (scattering parameters) are key measurements in evaluating the performance of microwave components, reflecting how signals are transmitted and reflected by the device.

The Teflon and K-12 composite was used to fabricate the circular Quater wave transformer for microwave applications. The composite slab was machined to create the bare circular rod. The bare rod was sputtered in a close chamber in the silver target. The sputtered rod creates a circular Quater wave transformer that is filled with Teflon-K-12 composite. The measured S –parameter results of the circular Quater wave transformer were found satisfactory, and it is found suitable for the low loss microwave propagation. The satisfactory results of 0.05 dB indicate that the transformer performs well in terms of signal transmission with minimal loss. This matching transformer will match impedance 50 ohm to 100 ohm. The quarter wave transformer is a low-loss channel to propagate the signal from one end to another end that may function as a low-loss channel for propagating microwave signals from one end to another.

References

[1] Dr. Pallavi Gupta, Surendra Kumar, A Review on Ceramic and Polymer Materials for Radome Applications, 2019 IEEE Indian Conference on Antennas and Propagation (InCAP), DOI: 10.1109/InCAP47789.2019.9134479.
[2] Dr. Pallavi Gupta Surendra Kumar, An Overview on the Ceramics & Polymers for Microwave Propagation, 2019 IEEE Indian Conference on Antennas and Propagation (InCAP), DOI:10.1109/InCAP47789.2019.9134608.
[3] Microwave Processing of materials, National Academy Press 2101 Constitution Avenue, NW Box 285 Washington, D.C. 20055 800-624- 6242 or 202-334-3313
[4] Esa M, Malik N.N.N.A, Latif N.A, Marimuthu J. performance investigation of Microstrip expo-exponential tapered line impedance transformer using math CAD, Progress in Electromagnetics Research Symposium Proceedings. 2009 Aug; p. 1209−13.PMid:19786392.
[5] Panda J.R, Kshetrimayum R.S. Notched antenna with triangular tapered feed lines for tri-band operation, International Journal of Recent Trends in Engineering.2009 May; 1(3):277−79.
[6] Pozar D.M. Input impedance and mutual coupling of rectangular Microstrip antennas, IEEE Transactions on Antennas and Propagation. 1982 Nov; 30(6):1191−96
[7] Sussman-Fort S.E. Microwave matching network synthesis software and user's manual, Automated Synthesis of Low Pass, High-Pass, and Bandpass Lumped and Distributed Matching Networks. MA: Artech House,1991.
[8] Pozar, D. M., Microwave Engineering, John Wiley & Sons, 2005.
[9] Klopfenstein, R. W., "A transmission line taper of improved design," Proc. IRE, Vol. 44, 31–35, 1956