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Ku-band Circulators Manufactured by LTCC Technology

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Summary

This paper presents Ku-band miniaturized circulators based on special ferrite materials developed to enable manufacturing by Low Temperature Cofired Ceramics (LTCC) technology. Since three different materials are co-fired together, special care is taken for these materials to shrink equally during firing. Simulation results give 0.5 dB insertion loss and 14% -20dB bandwidth for the Spinel3800 based circulator including motherboard and SMD transitions.

1. Introduction

Ferrite based devices such as circulators are commonly used in RADAR applications and in Active Electronically Scanned Arrays (AESA). Their bulkiness limits the required miniaturization, especially for AESAs that contain a huge number of transmit/receive modules (TRX). One way to overcome this limitation is to develop ferrite and dielectric cofireable materials to manufacture surface mountable miniaturized circulators using LTCC technology.

2. Material development

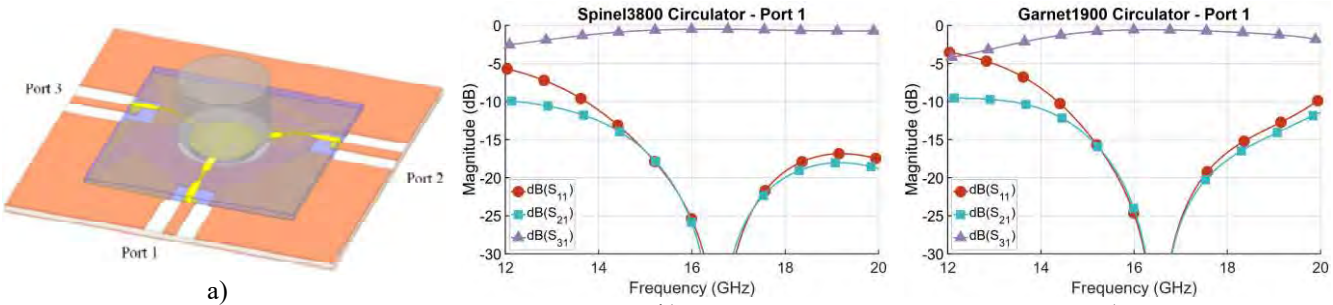
To enable manufacturing according to LTCC production standards, two new ferrimagnetic powders; garnets derived from Yttrium Iron Garnet (YIG) and spinels derived from nickel-zinc ferrites, were developed. These two powders were formatted by tape-casting into sheets and matched to a tape casted VLF220Q4 dielectric material. Special care was taken for the materials to be compatible with silver metallization and allow sintering at 920°C, a strong project requirement. The materials' electrical and magnetic properties are given in Table 1.

Table 1. Circulator materials

Material	ε_r	***tanδ***	***4πMs (G)***	***ΔH (Oe)***
Garnet1900	*21*	*3.10-3*	*1900*	*100*
Spinel3800	*13*	*1.10-3*	*3800*	*100*
VLF220Q4	*21*	*3.10-3*	-	-
Teflon™	*2.1*	*1.10-3*	-	-

3. Circulator design

The circulator design was made by the help of Ansys HFSS™ electromagnetic simulator and based on the theory in [1]. From specification requirements, the maximum allowed circulator's dimensions are fixed at 7 mm × 7 mm × 3 mm and to simplify its integration it should be a surface mountable device (SMD). Figure 1 shows the 3D model of the circulator mounted on a motherboard, together with the simulation results for the complete structure using the two ferrite materials. Insertion losses thus considers the circulator and motherboard. The motherboard is a 13 mm × 13 mm × 0.203 mm Roger 4003C sheet.



a) b) c)

Figure 1. a) Circulator 3D model, b) Spinel3800 simulation results and c) Garnet1900 simulation results

The simulated S-parameters of these two circulators are compared in the Table 2. The Spinel3800 version of the circulator shows better results than the Garnet1900 ferrite version.

Table 2. Simulated performances of both circulators

	Spinel3800 Circulator	**Garnet1900 Circulator**
Minimal IL	0.5 dB @ 16.4 GHz	0.57 dB @ 16.3 GHz
-20 dB Bandwidth	2.33 GHz (14%)	1.77 GHz (10.6%)
-20 dB Maximum IL	0.61 dB	0.71 dB

4. Manufacturing method

The manufacturing of these circulators is done as follows: a) laser cut out of inserts, via holes and alignment holes, b) via hole screen printing, c) stacking, d) lamination, e) ground plane screen printing, f) Y-junction screen printing, g) firing and h) dicing. The firing step implies a 15 % shrinkage. At this step, it is of utmost importance that the three materials dielectric tape, ferrite tape and silver paste all have the same shrinkage profile, or else deformation will occur and ferrite inserts may fall out.

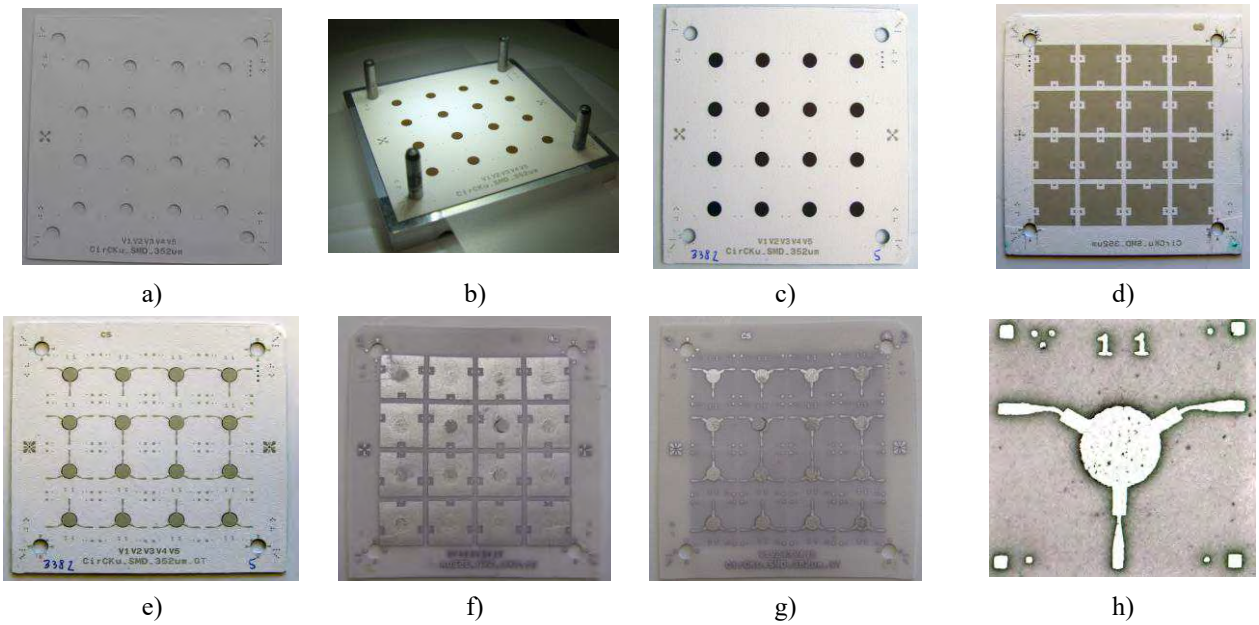


Figure 2. Circulators' manufacturing steps: a) laser cut out and via screen printing, b) stacking, c) lamination, d) ground plane screen printing, e) Y-junction screen printing, f) ground plane view after firing, g) top surface view after firing, h) final circuit after dicing.

4. Results

Manufacturing of these first circulator samples proves the feasibility of the chosen LTCC approach. Some distortion can be seen after firing, so some fine tuning of tape features and manufacturing process will be necessary. Measurement are on its way.

6. Acknowledgements

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