A 60 GHz Image Rejection Filter Manufactured Using a High Resolution LTCC Screen Printing Process

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Abstract – An LTCC test panel including various mm-wave test circuits has been designed and manufactured using a recently developed screen printing process (Thales Microelectronics) having a highly optimised resolution, here evaluated using a minimum microstrip line width/ gap of 2 mil (50.8 µm). In this paper we report on a 60 GHz microstrip coupled lines bandpass filter manufactured on a 3.7 mil (94.0 µm) thick Ferro A6S substrate using a minimum line gap of 2 mil. The electromagnetic effects caused by the top conductor recess were taken into account using direct full-wave simulations (Ansoft HFSS) but also by a circuit simulation methodology based on the use of effective relative permittivity and substrate height parameters [1]. Preliminary measurement results show a 3 dB bandwidth of approximately 5 GHz, a passband insertion loss of 4 dB and a center frequency slightly above the simulated value. This bandpass filter could e.g. serve as an image rejection filter together with the 60 GHz WLAN chipset [2] where it would demonstrate a 55 GHz image suppression of approximately 20 dB.

I. Introduction

Mm-wave applications require the adoption of novel low-cost manufacturing and packaging technologies to become more commercially appealing. LTCC (Low Temperature Co-Fired Ceramic) has demonstrated itself as an extremely robust and flexible manufacturing technology with widespread use ranging from cellular phones to space qualified applications. For mm-wave frequencies the use of LTCC has been limited by the performance of the available material systems and the achievable processing resolution. The use of thin-film manufacturing technologies overcomes the mentioned problems but at a many times unacceptably high manufacturing cost. The objective of our work has been to investigate the possibility to use state-of-the-art LTCC processing for mm-wave applications (30-110 GHz). This requires access to low-loss dielectric (and conductor) pastes for such applications. We have chosen to evaluate Ferro A6S because of its low loss tangent (< 0.002 up to 90 GHz) and suitability for mass production [3]. We have chosen to evaluate the Thales Microelectronics [4] LTCC foundry which has made available a highly optimized screen-printing process which we have evaluated using a minimum line width/gap of 2 mil and a minimum via dimension of 4 mil (101.6 µm). The high resolution is made possible by the use of a highly matched combination of conductor materials, screens and printing equipment. We have designed a number of test circuits, such as e.g. filters, resonators and patch antennas, for mm-wave applications from 30 to 110 GHz in both microstrip and stripline technology. In this paper we report on the design, manufacturing and preliminary measurements on a 60 GHz coupled lines bandpass filter.

II. Filter design

The designed test panel is manufactured using 3.7 mil thick layers of Ferro A6S, internal Ag conductors and external Au conductors. As has been reported elsewhere there is a problem with the design of transmission line components using co-fired external conductors; the conductor is partially embedded into the substrate during manufacturing. The electromagnetic effect of this recess is an increased concentration of the field into the substrate under the microstrip line which leads to a higher effective permittivity than expected. The impedance of the line, $Z = (L/C)^{1/2}$, will decrease because the distributed capacitance, C, increases owing to the higher effective permittivity and the reduced substrate height.

The electromagnetic effects caused by the top conductor recess were taken into account using direct full-wave simulations (Ansoft HFSS) but also by a circuit simulation methodology based on the use of effective relative permittivity and substrate height parameters [1]. These parameters were obtained using the ADS LineCalc program and modifying the MSUB relative permittivity and height parameters until the characteristic impedance and substrate wavelength matched HFSS simulation results for the actual recessed structure (assuming a 60% recess). Modified MSUB items were then used to optimize the filter using ADS. The optimized filter was then simulated using HFSS directly taking into account the anticipated recess. The layout of the filter is illustrated in Fig. 1 and the simulated performance using HFSS is shown in Fig.2. The minimum line gap used for the filter shown in Fig. 1 is 2 mil. The transition from microstrip to CPW required for the RF pads was designed using HFSS which yielded a first resonance at approximately 120 GHz.

The filter was designed for use as an image rejection filter together with a 60 GHz WLAN chipset [2] and should transmit a 60 GHz signal but reject the image at 55 GHz (using a 57.5 GHz LO). The center frequency was designed to be 60 GHz with a passband bandwidth of approximately 5 GHz. The image suppression should be better than 15 dB.

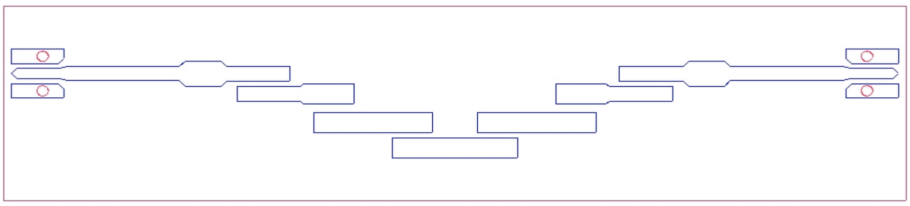

Fig. 1. Layout of 60 GHz coupled lines bandpass filter.

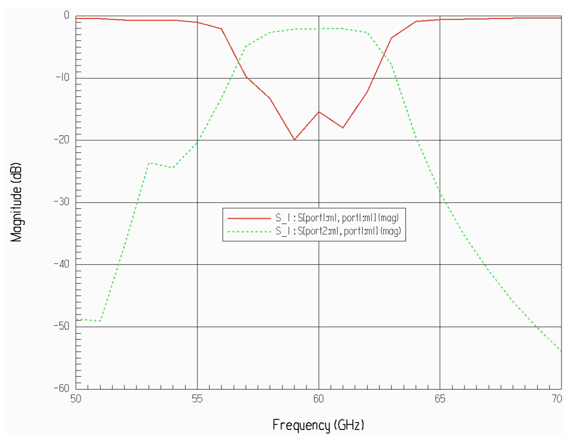

Fig. 2. Simulated performance of the filter in Fig. 1.

III. Results

A photo of the manufactured 2 inch x 2 inch test panel is shown in Fig. 3. Aside from the discussed 60 GHz coupled lines filter it contains various other mm-wave test circuits covering the frequency range from 30 to 110 GHz. Preliminary measurements of the image rejection filter were carried out using an HP8510XF network analyzer and a Cascade Summit 9000 probe-station with Cascade 1 mm GSG 150 µm probes. The obtained performance is plotted in Fig. 4. The insertion loss is about 4 dB, which is a bit higher than simulated and the center frequency is 61 GHz, which is 1.3% higher than the design frequency. However, this is considered to be in adequate agreement with the simulations considering the tolerances for relative permittivity, dimensions and shrinkage etc. Furthermore, for use as an image rejection filter for transmission of 60 GHz signals and rejection of an image at 55 GHz the achieved suppression of approximately 20 dB is more than adequate.

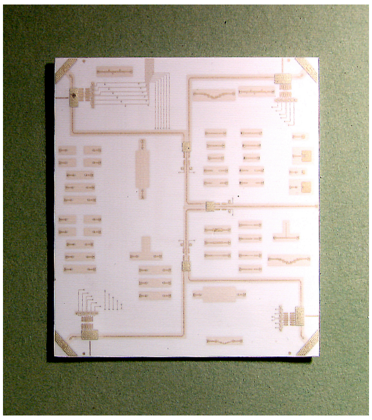

Fig. 3. Photo of LTCC test panel.

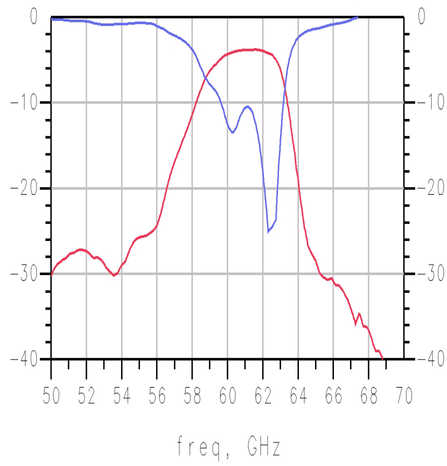

Fig. 4. Measured filter performance.

IV. Conclusions

We have designed various mm-wave test circuits for a novel LTCC process developed by Thales Microelectronics. The objective was to evaluate the use of LTCC as an alternative to more expensive thin-film techniques to achieve a low line loss and the required resolution of 2 mil. As the Thales process is based on standard screen printing it can potentially be used for mass production of low-cost circuits. The design and measurements of a 60 GHz coupled lines bandpass filter to be used as an image rejection filter in a 60 GHz WLAN was discussed. Preliminary measurements results have been obtained and show a good agreement with simulations.

References

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[3] http://www.ferro.com

[4] http://www.thales-microelectronics.com