TF vs. LTCC TECHNOLOGY FOR FABRICATION OF MICROWAVE PASSIVE CIRCUITS

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Abstract: *In this paper, we present a super-compact dual-band resonator based on 3-D Hilbert fractal curve that has been fabricated in both TF and LTCC technology. Also, we compare characteristics of these technologies and their posibilities for fabrication of microwave passive devices.*

Key Words: ***thick-film, LTCC, dual-band, miniature resonator***

1. INTRODUCTION

Due to rapid growth of various mobile communication systems there is ever-increasing demand for low-cost, high-performance and compact microwave devices. Since passive circuits such as resonators and filters are key elements in any communication system, miniaturization and improvement of performances of such devices is of great importance.

The most prominent way to reduce the area that a resonator occupies is employment of fractal curves, which are well-known for their space-filling properties. In [1] we have shown that a planar resonator based on two-dimensional Hilbert fractal curve is superior to all other non-fractal configurations, both in quality factor and in circuit size reduction.

The idea of using Hilbert fractal shape has been extended to multilayer configuration. In [2] we have proposed a structure that incorporates embedded three-dimensional Hilbert fractal curve and 3-D Hilbert resonator has been proved to be superior to its 2-D counterpart revealing much higher potential for miniaturisation.

Multilayer technologies, such as Thick-film (TF) or Low Temperature Co-fired Ceramics (LTCC), allow fabrication of long transmission lines folded over several layers, thus occupying relatively small substrate areas. These technologies, offer significant potentials for the development of microwave passive components, since they are capable of combining high level of integration, low cost and high volume production with the high electrical performances needed for microwave devices.

In this paper, we present a super-compact dual-band resonator based on 3-D Hilbert fractal curve that has been fabricated in both TF and LTCC technology. Also, we compare characteristics of these technologies and their possibilities for fabrication of multilayer microwave passive devices.

2. 3-D HILBERT RESONATOR

Hilbert fractal is an open curve that has ends on the opposite sides, and thus it is convenient for usage in structures such as the end-coupled microstrip resonator. Also its fractal dimension is equal to 2, i.e. the highest possible. After infinite number of iterations Hilbert fractal curve completely fills a square area.

By analogy with its two-dimensional counterpart, three-dimensional Hilbert fractal is a space-filling curve which completely fills a cube region after infinite number of iterations. Fig. 1 shows schematic view of 3-D Hilbert fractal of the third order.

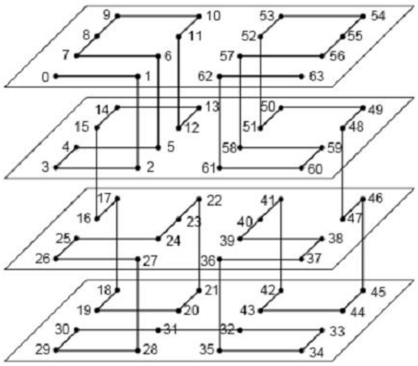

Fig. 1. *Schematic view of 3-D Hilbert fractal curve of the third order*

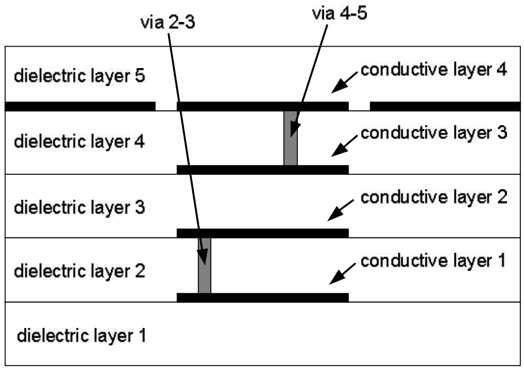

Fig. 2. *Cross section view of 3-D Hilbert resonator*

3-D Hilbert resonator is capacitively coupled to the 50-ohm feed lines. It consists of four conductive and five dielectric layers, Fig. 2. Adjacent conductive layers are connected by vias and the fractal line width and spacings are equal in all layers. The role of the top dielectric layer is to provide that the conductive lines in the fourth layer have the same characteristic impedance as those in the lower layers.

2.1. 3-D HILBERT RESONATOR IN THICK-FILM TECHNOLOGY

In the design based on thick-film technology all dielectric layers have the same thickness, H=108 µm, and relative permittivity ε_r=9. Gaps between the feed lines and the resonator are 50µm wide. Conductor losses are modelled by using bulk conductivity for silver. The values of line width, *w,* and spacings, *g,* are equal to 150µm and the overall dimensions of the resonator are 1.05x1.05x0.54 mm i.e. $\lambda_g/19\mathrm{x}\lambda_g/19$ for a given substrate.

The response of the proposed structure is shown in Fig. 3 and it reveals that the resonator exhibits dual-band behaviour. Two narrow passbands are positioned at 6.48 GHz and 9.55 GHz, both characterized by good selectivity.

In the configuration that was to be fabricated, line width and spacings were equal to 283 µm, while the gaps between the feed lines and the resonator were 200 µm. However, manufacturing process caused remarkable line degradation and discrepancies between simulation and fabricated dimensions.

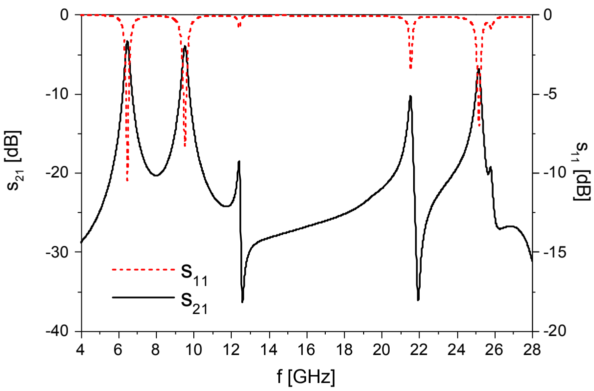

Fig. 3. *Response of the initial thick-film 3-D Hilbert resonator*

Table 1 shows values of line width and spacings in fabricated resonator. It can be noted that there is a relatively good agreement between the values of the line width in conductive layers 1 and 2 and expected values, while in the conductive layers 3 and 4 these discrepancies are significant. This is a consequence of the process of the printing of the conductive paste in TF technology. Namely, the squeegee that is used for the printing encounters a physical obstacle, i.e. multilayer structure formed by that moment. The higher the conductive layer to be printed is, the more significant the obstacle is and it causes non-uniform deposition of the paste and consequently remarkable discrepancies between simulation and fabricated dimensions.

Table 1. *Line width and spacings in the resonator fabricated in TF technology*

conductive layer	w [µm]	g [µm]	w_{avg} [µm]	g_{avg} [µm]	s [µm]	s_{avg} [µm]
4	320-380	195-225	350	210	112-115	115
3	285-340	225-270	310	250	-	-
2	260-300	255-300	275	285	-	-
1	285-290	255-285	280	270	-	-

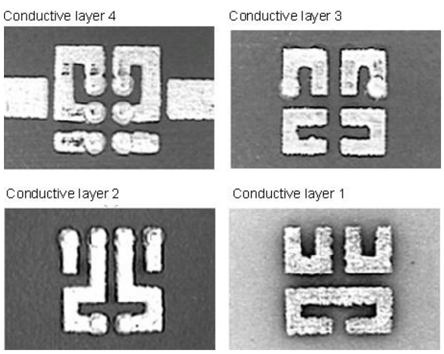

Fig. 4. *Photographs of the conductive*

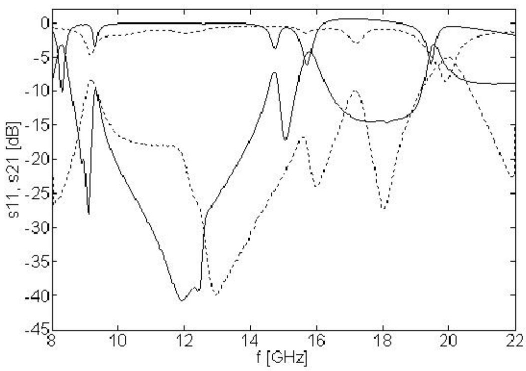

Fig. 5. *Simulation (full line) and measurement*

layers of the resonator after firing in TF *(dotted line) results for the fabricated structure*

Fig. 4 shows photographs of the conductive layers after firing in TF. Remarkable differences in line width and spacings between conductive layers can be observed which caused significant discrepancies between the simulation and measurement results, Fig. 5, as well as significantly greater insertion losses in the response of the fabricated structure.

2.2. 3-D HILBERT RESONATOR IN LTCC TECHNOLOGY

Unlike TF, Low Temperature Co-fired Ceramics (LTCC) technology involves single-step lamination and firing which makes it far more reliable technology than TF and particularly advantageous for complex structures having many layers. Furthermore, LTCC offers wide choice in terms of thickness of dielectric layers and minimum available line width.

The configuration that was to be fabricated in LTCC technology, was previously optimised. LTCC dielectric in the available fabrication process was characterised by somewhat lower dielectric constant equal to ε_r=7.8 and higher dielectric loss tangent than in the TF case, equal to 0.006. The configuration with 400 μm dielectric layers and line width and spacings equal to 300 μm offers the best trade-off between the insertion losses, attenuation and selectivity which makes it the best candidate for the fabrication. Its passbands are positioned at 2.67 GHz and 4.98 GHz and insertion losses are -1.83 dB and -1.64 dB, respectively, while the maximum stopband attenuation is -19.59 dB. However, since minimum available spacing between two lines in the available fabrication process was 120 μm, the resonator with 120 μm gaps has been fabricated.

It should be noted that the overall dimensions of the resonator are 2.1x2.1x2 mm i.e. λg/25xλg/25 in a given configuration which makes it ultra-compact.

DuPont 951 Green Tape has been used for dielectric layers in manufacturing process. Dielectric constant and dielectric loss tangent of the tape are 7.8 and 0.006, respectively, while its thickness is equal to 114 μm. Since the layers of the resonator are 400 μm thick, four green tapes have been used for each layer. After firing and shrinkage of the green tapes, the thickness of the layers has been approximately reduced to 400 μm.

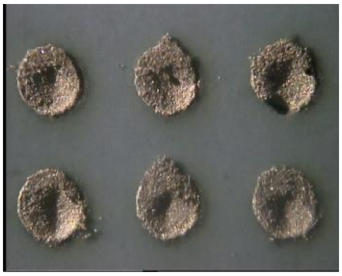

Fig. 6. *Microscope view of the filled via holes that connect the third and fourth conductive layer.*

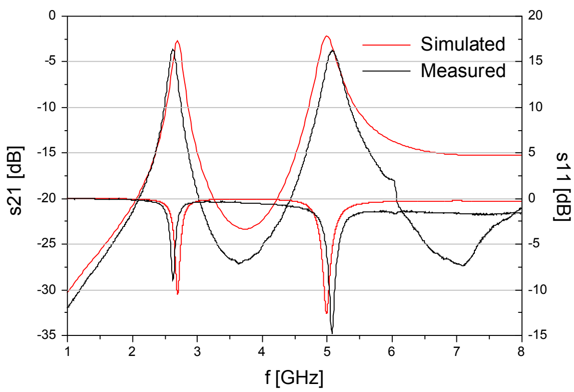

Fig. 7. *Simulation (dotted line) and measurement (full line) results for the fabricated structure*

For via filling and printings of conductive layers, DuPont 6141 and 6142D silver pastes compatible with green tapes have been used. Since the vias diameter is equal to line width, a great degree of precision during the process was required. Also, considerable attention was paid to the via filling to ensure a good connection between adjacent conductive layers. Fig. 6 shows microscope view of the filled via holes that connect the third and fourth conductive layer.

The simulation and measurement results are shown in Fig. 7. A good agreement can be observed except for the attenuation above the second passband and a small frequency shift of the passbands. This can be explained by the discrepancy between simulated and actual line width, spacings and dielectric layers thickness. It should be noted that the fabricated structure exhibits greater attenuation above the second resonance and therefore better selectivity of the second passband.

Low-temperature cofired ceramic (LTCC) technology enables the creation of monolithic, three-dimensional, cost-effective microwave circuits and offers significant benefits in terms of design flexibility, density, and reliability. LTCC has evolved from TF but, since it involves single-step lamination and firing and allows testing of each layer separately, it is far more reliable technology and thus better candidate for fabrication of multilayer structures.

3. CONCLUSION

In this paper, a super-compact dual-band resonator is presented, based on 3-D Hilbert fractal curve that has been fabricated in both TF and LTCC technology. Characteristics of these technologies and their possibilities for fabrication of multilayer microwave passive devices have been presented and compared.

It has been shown that TF fabrication process suffers from drawbacks that cause remarkable line degradation and discrepancies between simulation and fabricated dimensions of the resonator. Also, LTCC technology has been proved to have better potentials for fabrication of multilayer passive devices.

4. REFERENCES

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