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V. Bengin-Crnojevic
Djuradj Budimir

School of Informatics

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Novel Compact Resonators with Multiple 2-D Hilbert Fractal Curves

V. Crnojevic-Bengin, and D. Budimir

University of Westminster, Department of Electronic Systems, Wireless Communications Research Group, 115 New Cavendish Street, W1W 6UW, London, UK

Abstract — **A novel capacitively coupled microstrip resonators with multiple 2-D Hilbert curves embedded in and under the microstrip are presented in this paper. The proposed resonators achieve length reduction of over 84% when compared to the conventional resonators. By using the proposed resonators, a compact bandpass filter is designed to work in the GPS frequency band while exhibiting very high attenuation in the neighbouring 1.8 GHz GSM band.**

I. Introduction

Recently, there has been much interest in the field of photonic bandgap (PBG) engineering. Microstrip lines with periodic elements etched in the ground plane have been found to behave like PBG a structure, [1]. A number of different PBG structures have been proposed in order to increase the slow-wave effect and improve the performances [2]-[4].

Fractal curves are well known for their unique space-filling properties. Recently, a number of applications of different fractal shapes emerged: fractal-shaped planar resonators revealed superiority of the two-dimensional (2-D) fractal structures over the conventional non-fractal ones, [5], while multilayer resonators with embedded three-dimensional (3-D) fractal curves outperformed equivalent planar structures, [6]. Fractal curves were also used to form a multilayer PBG structure, [7] or high impedance surfaces, [8]-[9].

In this paper, multiple 2-D Hilbert fractal curves were embedded in and under the microstrip resonator, to foster the PBG effect. The proposed structures were simulated using values typical for standard Thick-film (TF) technology and the results were compared to the conventional capacitively coupled resonator.

To illustrate the results, a narrow-band bandpass filter incorporating the proposed resonator was designed to work in the GPS frequency range, while demonstrating high attenuation in the neighbouring 1.8 GHz GSM range.

II. Resonator Configurations

Resonators presented in this paper are based on the traditional capacitively coupled microstrip resonator with 50-Ohm feeding microstrip lines and gaps equal to 200 um. The resonators are constructed on a 625 um thick Alumina substrate having relative dielectric constant εr=9.6 and dielectric loss tangent equal to 0.0006.

In the single-layer variant, the conventional microstrip resonator is replaced with *N* 2-D Hilbert curves having the line width and spacing equal to 100 um, Fig. 1.

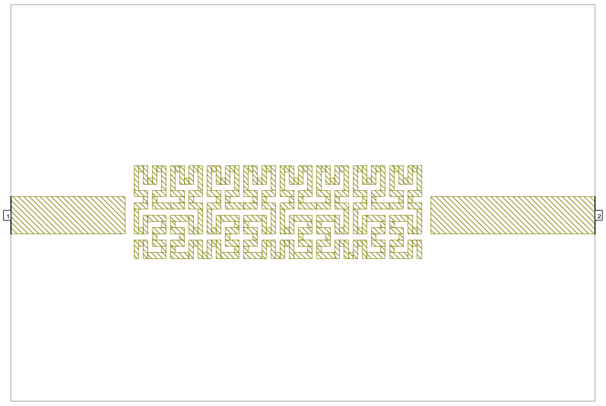

Fig. 1. Single-layer resonator comprising of *N=4* 2-D Hilbert lines.

In the multilayer variant, *N* 2-D Hilbert curves are placed under the microstrip, Fig. 2. Conductors in different layers are separated by the 50 um thick dielectric layers, having εr=9.6 and dielectric loss tangent 0.0006.

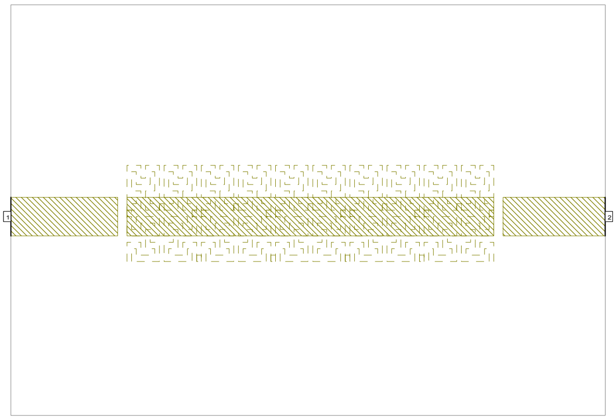

Fig. 2. Two-layer resonator with *N=4* 2-D Hilbert lines embedded under the microstrip.

III. Simulation Results

Performances of the resonators were determined by EMSight, EM simulator in Microwave Office. All material characteristics and dimensions were kept within boundaries of widely available standard TF procedure. The proposed configurations were analysed for different values of N and compared to conventional capacitively coupled microstrip resonator in terms of dimensions and unloaded and loaded Q-factor.

Simulation results for both configurations and various values of N are shown in Tables I and II, where L denotes the resonator length, while s_{21}^0 denotes insertion loss at resonant frequency.

TABLE I. SIMULATION RESULTS FOR SINGLE-LAYER RESONATOR COMPRISING OF N 2-D HILBERT CURVES

N	**6**	**5**	**4**	**3**
L, [mm]	9.45	7.9	6.3	4.7
fr, [GHz]	1.827	2.162	2.646	3.403
s_{21}^0, [dB]	-4.41	-3.32	-2.4	-1.65
QL	716	569	441	315
QU	**1123**	**1065**	**1038**	**997**

TABLE II. SIMULATION RESULTS FOR RESONATORS WITH N 2-D HILBERT CURVES EMBEDDED UNDER THE MICROSTRIP

N	**6**	**5**	**4**	**3**
L, [mm]	9.45	7.9	6.3	4.7
fr, [GHz]	0.96	1.148	1.428	1.884
s_{21}^0, [dB]	-16.6	-13.5	-11	-8
QL	1433	1400	1231	1047
QU	**1467**	**1465**	**1337**	**1244**

By comparing values in Tables I and II, it can be seen that placing multiple 2-D Hilbert curves under the microstrip offers more potential for size reduction of the resonator, as well as a significant improvement of unloaded Q-factor. However, due to the higher energy loss induced this way, this approach generates higher insertion loss.

In Table III, simulation results for two-layer 2-D Hilbert resonators presented above are compared to those of conventional capacitively coupled resonators tuned to the same resonant frequency. It can be seen that incorporating multiple 2-D Hilbert curves under the microstrip results in length reduction of more then 84% when compared to the conventional case, while the unloaded Q-factor remains approximately the same.

IV. Bandpass Filter Design

The proposed resonator with multiple 2-D Hilbert curves embedded under the microstrip was used to design a bandpass filter operating in the GPS range and having high attenuation in the neighbouring GSM range. The specifications used are given in Table IV.

TABLE IV. BANDPASS FILTER SPECIFICATIONS

Center Frequency	1.575 GHz
Bandwidth	2 MHz
Max. passband ripple	0.3 dB
Attenuation from 1.75GHz to 2GHz	> 60 dB

Designed filter is of second order, Fig. 3, and it was constructed on a 9.7 Alumina having dielectric loss tangent 0.0006. Dielectric layers between the feeding lines, resonators and multiple 2-D Hilbert curves are 50 um thick. Lengths of the resonators were simultaneously tuned to achieve specified center frequency. There is no gap in the direction of the X-axes between the feeding lines and the resonator, while the gap between the two resonators is equal to 1400 um.

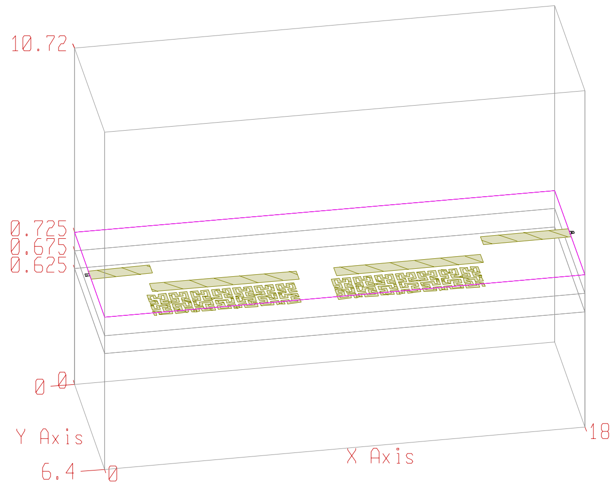

Fig. 3. A 3-D view of the designed bandpass filter.

Filter performances were determined by full-wave EM simulations. Simulation results are shown in Fig. 4, with the inset showing the passband. It can be seen that the filter complies with the specifications very well, achieving low passband ripple and attenuation of more then 100 dB in the unwanted GSM frequency band.

TABLE III. COMPARISON WITH THE CONVENTIONAL CAPACITIVELY COUPLED RESONATORS

fr, [GHz]	QU_{Hilb}	QU_{conv}	L_{Hilb}, [mm]	L_{conv}, [mm]	Length reduction
0.96	1467	1520	9.45	61.7	**84.6 %**
1.148	1465	1469	7.9	51.5	**84.6 %**
1.428	1337	1364	6.3	41.3	**84.7 %**
1.884	1244	1239	4.7	31.3	**85 %**

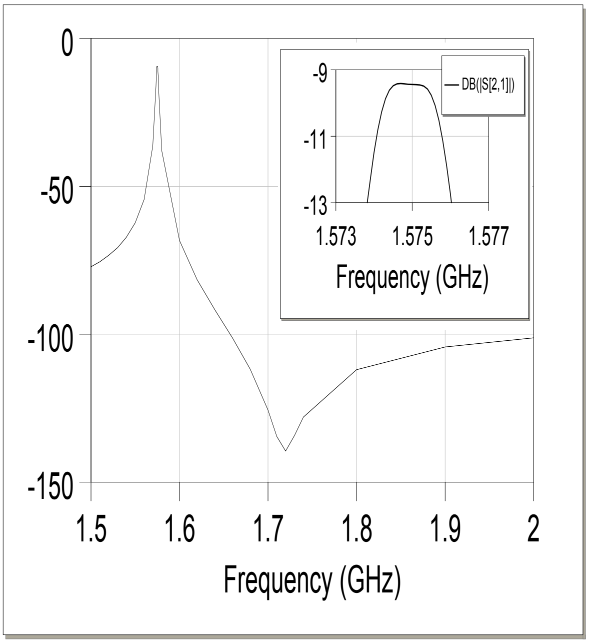

Fig. 4. Bandpass filter response; Inset: a passband detail

V. CONCLUSION

This paper has presented a novel compact resonators with multiple 2-D Hilbert curves embedded in and under the resonator. Performances of the proposed resonators were determined for different number of Hilbert curves (*N*) and compared to those of the conventional capacitively coupled microstrip resonator. Incorporating multiple 2-D Hilbert curves under the microstrip resulted in length reduction of more then 84% when compared to the conventional case, while the unloaded Q-factor remains approximately the same.

A bandpass filter was designed to work in the GPS range, using the proposed resonator with multiple 2-D Hilbert curves embedded under the microstrip. Simulation results conformed to specifications well, showing attenuation of more then 100 dB in the 1.8 GHz GSM range.

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