FILTENNA WITH DEFECTED GROUND STRUCTURE OPERATING IN TWO REGIMES

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Abstract: In the paper, we discuss the design of a filtenna with a fractal defected ground structure operating in two regimes. In the first regime, this filtenna works as a dual-band filter and the second regime, this device behaves like a filtenna with the same operation range. The filtenna was simulated in CST Microwave Studio and its functionality was verified by measurements.

Keywords: defected ground structure; dual-band filter; filtenna; fractal filter

1. INTRODUCTION

Today's wireless communication systems are expected to be small and provide easy mobility. Therefore, filters, antennas and other components should be of minimal dimensions. Dimensions of planar filters can be reduced by using fractal geometries [1][1] or exploiting defected ground structures (DGS) [2].

In this paper, we describe a microstrips low-pass filter with a fractal DGS [3] which is redesigned to a filtenna with DGS operating in two regimes. In the first regime, this device behaves like a dual-band filter and in the second regime, it behaves like the filtenna.

A fractal low-pass filter is a good candidate for the intended conversion:

- Radiating elements are on both sides of the filter – we have slots on the back side and microstrips on the top side of the substrate.
- Fractal geometry prolongs current lines and enhances radiation of the structure.

Due to the described conversion, we can integrate a filter and an antenna into a single device called the filtering antenna or the filtenna [4],[5].

2. FILTER WITH FRACTAL DGS

Firstly, we focus on the design of a low-pass filter with a fractal DGS. This low-pass filter is designed on the substrate FloamClad (ε_r = 1.25, h = 1.88 mm). The filter consists of a low-pass filter of the 11th order on the top side of the substrate and six units of a reduced fractal DGS on the bottom side of the substrate.

On the top side of the substrate, the low-pass filter is created by stubs separated by transmission lines [6]. On the bottom side, the fractal DGS is composed of Minkowski couples connected by narrow slots. The iteration factor of the Minkowski couple is one third of the side of the initial square. The reduction of dimensions of Minkowski couples connected by a slot follows the values of the normalized Chebyshev coefficients.

The layout of the described structure is shown in Figure 1. All the dimensions of the low-pass filter are given in Table 1, where w_{si} is the width and l_{si} is the length of stubs, w_{ti} is the width and l_{ti} is the length of transmission lines. The dimensions of the DGS squares are marked a_i and the narrow gap between two squares is described by w_g (the width of the gap) and l_g (the length of the gap). The layout of the low-pass filter is symmetric with respect to the vertical axis. The frequency response of the reflection coefficient (blue line) and frequency response of the transmission coefficient (red line) of the low-pass filter are depicted in Figure 2.

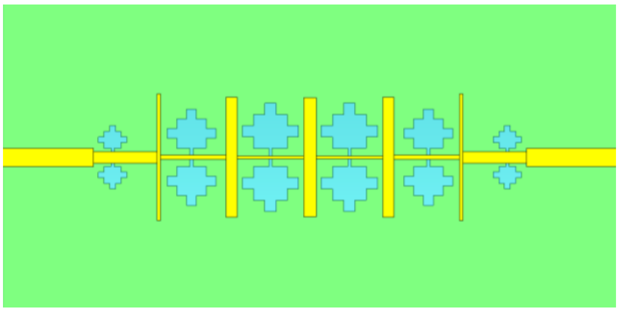

Figure 1: Layout of the low-pass filter (blue color shows the bottom side, yellow color displays the top side and green color illustrates substrate)

Parameter	Dimension (mm)	Parameter	Dimension (mm)	Parameter	Dimension (mm)	Parameter	Dimension (mm)
l_g	1.79	w_g	0.30	l_{t2}	6.18	w_{t2}	1.12
l_{s1}	12.33	w_{s1}	0.35	l_{t3}	6.38	w_{t3}	0.44
l_{s2}	11.70	w_{s2}	1.09	l_{t4}	6.44	w_{t4}	0.29
l_{s3}	11.61	w_{s3}	1.26	a_1	1.65	a_3	3.30
l_{t1}	8.91	w_{t1}	1.79	a_2	2.85		

Table 1: Geometrical parameters of the low-pass filter

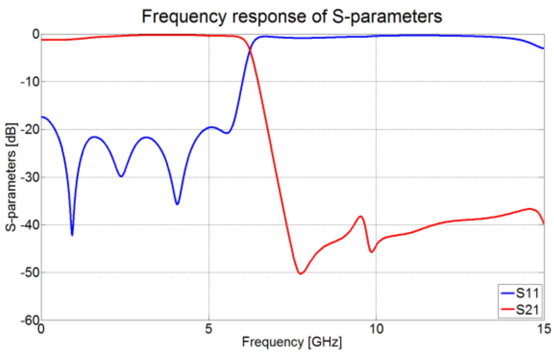

Figure 2: Frequency response of the *S*-parameters of the low-pass filter

3. FILTENNA OPERATING IN TWO REGIMES

As described in the introduction, the filtenna is a device that combines the filter (in a two-port configuration) and the antenna (in a one-port configuration). In a fact, the antenna is a serial array with in-phase feeding of elements.

We design a filtenna with the fractal DGS operating in two regimes from the low-pass filter with fractal DGS only adding three capacitive elements and small changes of the dimensions of the low-pass filter. Due to these changes, we obtain the filtenna operating in two regimes.

Figure 3 shows the structure of the filtenna operating in two regimes. On the top side of the substrate, the filtenna is represented by the low-pass filter where the ends of the first stub, the central one, and the last stub contain capacitive elements. The final dimensions of the filtenna are sumarized in Table 2 where the width of the capacitive elements is marked w_{ci} and the length of the capacitive elements is denoted by l_{ci}.

In the first regime, this structure behaves like the dual-band filter (two ports structure). The first band is created by a low-pass filter with the cutoff frequency which is shifted down from the original value 6.21 GHz to a new value 2.79 GHz (shows Figure 4) without big changes of the dimensions of the filter. Due to described changes we can use smaller dimensions of the substrate about 55 % compared to the conventional filter. And the second band is created by a band-pass filter with the center frequency 6.80 GHz. Frequency response of reflection coefficient (blue line) and frequency response of transmission coefficient (red line) of the filtenna in the first regime are shown in Figure 4.

In the second regime, when the output 50 Ω port is removed and terminated by an open end, the structure behaves like the filtenna at the frequency 6.80 GHz. Frequency response of the reflection coefficient (blue line) and frequency response of the normalized realized gain (green line) of the filtenna in the second regime are shown in Figure 5.

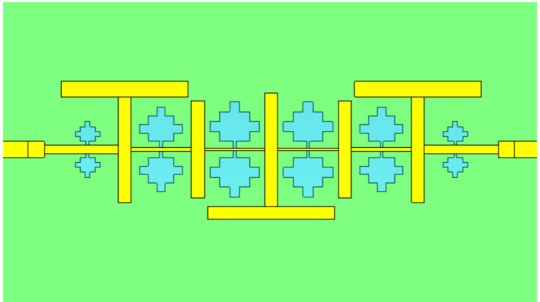

Figure 3: Layout of the filtenna (blue color shows the bottom side, yellow color displays the top side and green color illustrates substrate)

Parameter	Dimension (mm)	Parameter	Dimension (mm)	Parameter	Dimension (mm)	Parameter	Dimension (mm)
l_g	1.79	w_g	0.30	l_{t1}	4.86	w_{t1}	1.79
l_{c1}	14.06	w_{c1}	1.69	l_{t2}	8.18	w_{t2}	1.01
l_{c2}	14.06	w_{c2}	1.41	l_{t3}	6.70	w_{t3}	0.48
l_{s1}	11.76	w_{s1}	1.42	l_{t4}	6.70	w_{t4}	0.32
l_{s2}	10.80	w_{s2}	1.41	a_1	1.65	a_3	3.30
l_{s3}	12.64	w_{s3}	1.46	a_2	2.85		

Table 2: Geometrical parameters of the filtenna

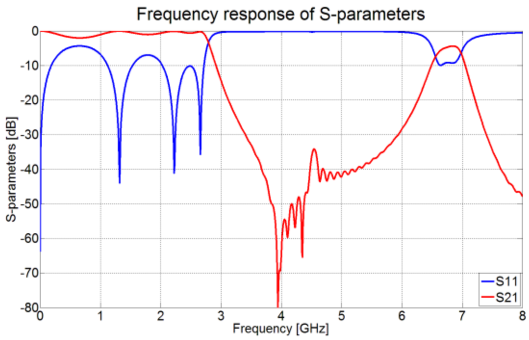

Figure 4: Frequency response of the filtenna in the first regime

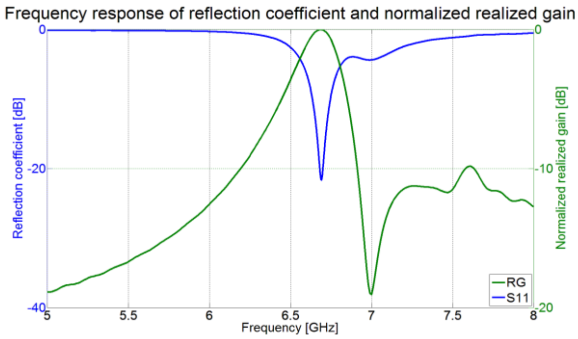

Figure 5: Frequency response of the filtenna in the second regime

4. MEASUREMENTS

In this section, we describe a confrontation of simulated results and measured ones. Figure 6 shows the comparison of simulated (solid lines) and measured (dashed lines) the reflection coefficient (blue lines) and the transmission coefficient (red lines) for the filtenna in the first regime. Figure 6 indicates that the cutoff frequency of the low-pass filter is shifted from 2.80 GHz to 2.63 GHz and the center frequency of the band-pass filter is shifted from 6.80 GHz to 6.63 GHz. The selectivity of the low-pass filter is 43 dB/GHz and selectivity of the band-pass filter is 42 dB/GHz. The band-pass filter exhibits a 3 dB pass band of 400 MHz. The reflection coefficient of this filter is worse about 1 dB compared to the simulation, and the insertion loss is worse about 1.5 dB compared to simulated results.

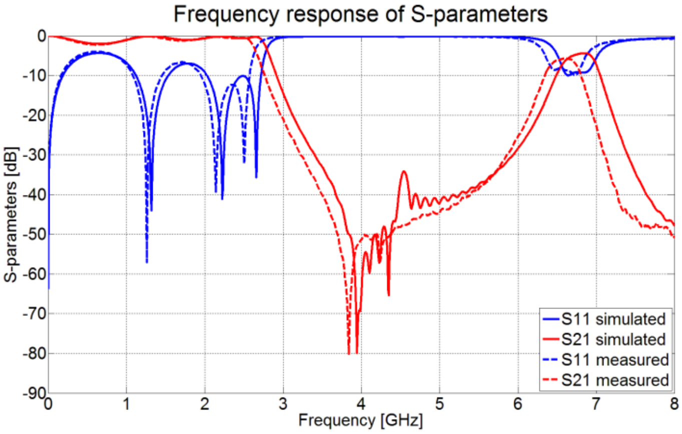

Figure 6: Frequency response of the filtenna in the first regime

Figure 7 shows a confrontation of the simulated results (blue line) and measured results (red line) of the reflection coefficient of the filtenna in the second regime. Obviously, the frequency of the maximum reflection coefficient -22.14 dB is shifted from 6.64 GHz to 6.75 GHz. The measured reflection coefficient is better about 11 dB compared to simulations. The pass band of the filtenna is widened from 111 MHz to 200 MHz.

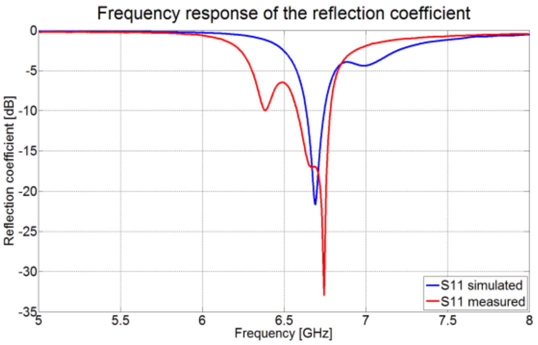

Figure 7: Frequency response of the filtenna in the second regime

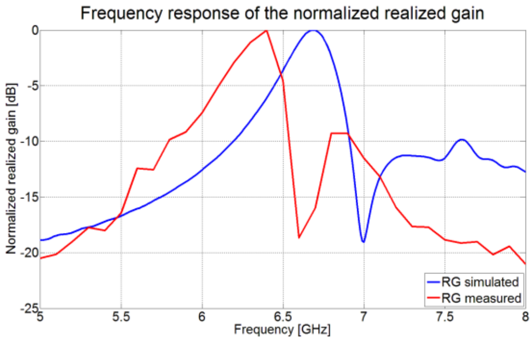

Figure 8: Frequency response of the normalized realized gain of the filtenna

Figure 8 shows a comparison of the measured frequency response of the normalized realized gain (red line) and the simulated one (blue line). Obviously, the pass band of the filtenna is shifted from the original value 6.64 GHz to a new value 6.40 GHz. The measured maximum value of the realized gain is 7.97 dB and the 3 dB pass band is 300 MHz.

5. CONCLUSION

In the paper, we discussed a conversion of a low-pass filter with a fractal DGS to the filtenna which after small optimizations can be used in two regimes. In the first regime, this filtenna acts as the dual-band filter and in the second regime this device behaves like the filtenna. The filtenna was fabricated and measured.

In the future, this work can be extended about an equivalent circuit of the filtenna and using approach of low-pass prototype filter for design of the filtenna.

ACKNOWLEDGEMENT

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