Fractal Antenna with RF MEMS Switches for Multiple Frequency Applications

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Abstract— A new concept of combining RF MEMS switches with Fractal antennas is presented. The idea is to connect several antenna configurations together using RF MEMS switches to cover several frequency bands. By using a 'smart combination' of fractal shaped antennas, wideband coverage can be achieved for satellite and wireless communications. Moreover the same antennas can be used for phased array applications as well. The analysis and design principles are discussed and presented in here. Several examples are shown to demonstrate the proposed concept.

Index Terms – *Re-configurable antennas, wideband, fractal, RF-MEMS, smart antennas*

I. Introduction

The requirements for increased functionality, such as direction finding and anti-jamming protection, within a confined volume, place more requirements in today's antenna systems. For single frequency operations, sufficient solutions can be achieved using switched beam arrays and adaptive array antennas [1,2]. For multiple frequency operations, a solution can be an array of fractal antennas. In this work, RF MEMS are used in conjunction with fractal antenna structures as the basis of a new re-configurable array antenna approach.

The RF MEMS switches permit the connectivity of sections of the antenna's conductive parts, and therefore enhance the coupling between the fractal elements allowing multiple frequency operation with one antenna. Also, the RF MEMS switches in conjunction with a neural network can develop a new type of re-configurable and smart antenna altogether, in which self-adaptation/learning theory plays a role in antenna optimization and gives the whole system great autonomy.

The use of fractal shapes provides the multiband characteristic through the property of self-similarity at equal or different physical scales. An array of fractal configurations that operate over different frequency bands providing different radiation patterns can be the basis for an ultra-wideband re-configurable antenna [3].

The electromagnetic performance of the RF MEMS switches is considered ideal, and their placement is accomplished by small physical connections of the antenna's adjacent conducting parts. Several configurations have been studied and analyzed and some of the results are shown in the sections to follow herein. The analysis of all antenna configurations is accomplished with IE3D®.

II. Fractal Antenna Configurations and Results

Most fractal antennas, including the Sierpinski Gasket antenna, have been studied extensively over the last few years [4,5]. A modified Sierpinski Gasket antenna shown in Fig.1 is chosen for this paper. The selection was based on the antenna's single element performance when used as a bow-

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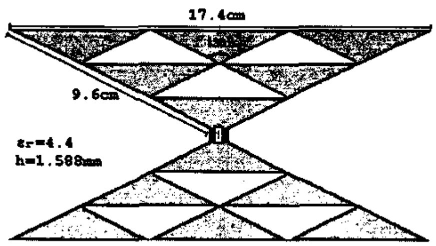
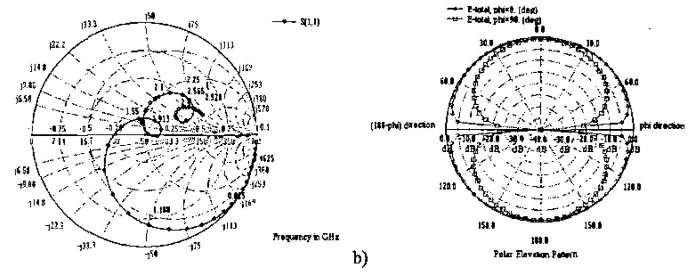


Figure 1. The design characteristics of the Sierpinski gasket antenna with obtuse angle.



a) b)

Figure 2(a,b). The radiation characteristics of the antenna with all switches in OFF state.

tie antenna, or setting all the switches to the 'OFF' state. The antenna has a flare angle of 130° and provides constant radiation pattern all over its bandwidth. The radiation characteristics for this antenna are shown in Fig 2(a,b,c). The bandwidth is from 1.5GHz to 2.1GHz and the radiation pattern is similar to the printed dipole antenna, making it ideal for receiver use.

III. RF MEMS Switches Configurations

In general, fractal antennas show weak coupling between the different elements of the structure. We consider the RF MEMS switches to be ideal. The switches have dimensions less than 1x1mm and are modeled as small patches that connect/disconnect the adjacent conducting patches changing the antenna's physical dimensions. In this implementation, gaps are created in the fractal antenna pattern, which are bridged by a number of MEMS micro-relays. The switches are embedded at the bottom side of the dielectric substrate.

The same antenna was simulated with all switches set to ON. The results can be seen in Fig.3. The coupling between the antenna's elements has drastically increased. Also, multiband characteristics have been accomplished at frequencies below 2GHz, as there are resonances at 0.6GHz, 1.55GHz.

Another switches state is tested. We set the far end switches to OFF, making the antenna work with reduced dimensions. This configuration can be seen in Fig.4a, and the results in Fig.4b show a resonance at 0.85GHz.

By turning other switches ON or OFF, interesting changes can be observed. By disconnecting the centered switches, we obtain the 2 lower resonances while we nullify the 1.95GHz as seen in Fig.5(a,b). Also, by activating the 6 diagonal elements we obtain an additional resonance at 1.35GHz while we nullify the resonance at 0.9GHz, and we also obtain large bandwidth at a higher frequency resonance from 1.65 to 2.35GHz as seen in Fig.6(a,b). Finally, by deactivating 2 of the 3 far end elements, we obtain an additional resonance at 0.75GHz as seen in Fig.7(a,b). As a result, we have at least 6 controllable frequency bands from 0 to 2Ghz with one antenna. These are frequency bands (0.6GHz, 0.75GHz, 0.85GHz, 1.3GHz, 1.55GHz and 1.8GHz) can be activated or deactivated using the RF MEMS switches, depending on the specific application and the circumstances.

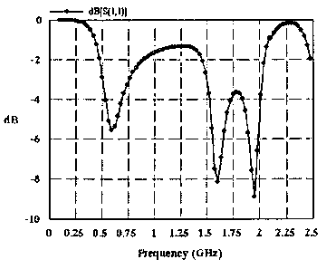
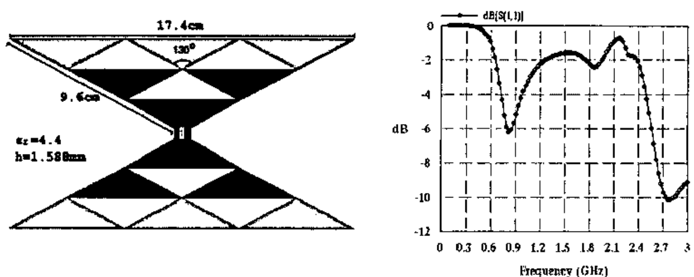
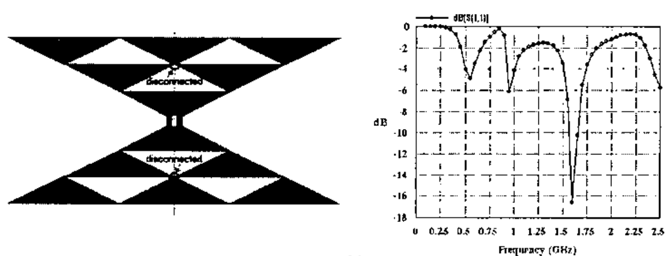


Figure 3. The S_{11} of the antenna with all the switches set to ON.



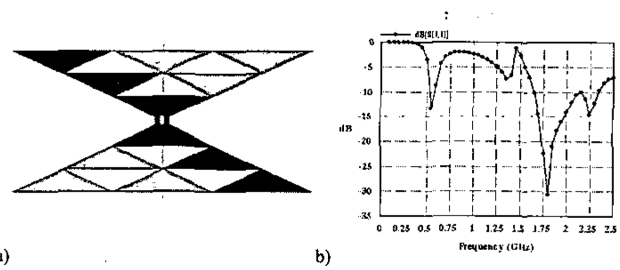
a) b)

Figure 4(a,b). The partially activated antenna with 3 switches ON, and its S_{11} response.



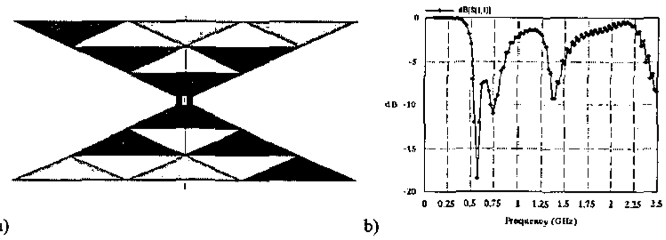
a) b)

Figure 5(a,b). The antenna with disconnected central switches and its S_{11} response.



a) b)

Figure 6(a,b). The antenna with diagonally activated elements and its S_{11} response.



a) b)

Figure 7(a,b). The antenna with 2 far elements disconnected and its frequency response.

V. CONCLUSIONS

A new approach to multiple frequency fractal antennas using RF MEMS switches was presented. RF MEMS switches in combination with neural networks have the potential of leading to large increases in system performance. Further study is required to achieve better matching at as many frequency bands as possible. Several cases are analyzed to find the optimum configuration and some results are presented here.

VI. REFERENCES

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