SMART RECONFIGURABLE ANTENNAS FOR SATELLITE APPLICATIONS

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Abstract— A new approach to wideband and smart re-configurable antennas using RF MEMS switches and fractal antennas is presented.

Index Terms – Smart antennas, wideband, fractals, RF-MEMS.

I. INTRODUCTION

Smart antenna technology is considered to be the last technology frontier in antennas that has the potential of leading to large increases in systems performance. Smart antenna systems combine multiple antenna elements with signal processing to optimize the radiation pattern in response to the signal environment. Switched beam arrays and adaptive array antennas are widely used for this purpose [1,2]. When applied to satellite communications, smart antennas can increase coverage and capacity, improve link quality, lower power consumption, help with direction finding of any jamming or RF threatening sources [3,4].

In this paper, a new wideband and smart reconfigurable antenna system exploits RF MEMS switches is presented. Unlike fixed antennas, which can only radiate in one pattern, re-configurable antennas have the ability to radiate multiple patterns through adjustment of their physical configuration. The introduction of MEMS switches (micro-relays) extends previous work, for example, in electronically steerable antenna, by permitting physical connection/disconnection of sections of the antenna conductive structure relative to each other and relative to other electromagnetic tuning structures. This agility offers enabling benefits for modern radar and telecommunication systems by permitting deliberate alterations in antenna performance to accommodate changes in mission, environment; tolerance to defects and faults; and enabling new algorithmic approaches that extend complementary techniques such as software radio and direct digital synthesis. Consequently, new types of devices and architectures are being developed which can enable the realization of steerable antennas that can operate successfully over a large bandwidth. In this work, RF MEMS are used in conjunction with fractal and non-fractal antenna structures as the basis of a new re-configurable array antenna approach. A fractal antenna can be designed to receive and transmit over a wide range of frequencies through the property of self-similarity at different physical scales [5,6]. An array of different fractal configurations, with different radiation patterns, that operate over different bands can yield a new ultra-wideband re-configurable antenna. The use of RF MEMS switches permits the overall fractal pattern to be dynamically “shattered” into subsets, some of which do not respond uniformly to the entire theoretic spectrum. This property may permit the spectral isolation of impinging RF energy through binary search algorithms. Also, RF MEMS switches in conjunction with neural networks can be used to develop a new type of re-configurable and smart antenna altogether, in which self-adaptation / learning theory plays a role in antenna optimization. This new type of antenna system can be designed for protection and geo-location applications as well.
The analysis of antenna configurations and the array performance is accomplished using Ansoft’s electromagnetic simulation software ‘ENSEMBLE’. The electromagnetic performance and placement of RF MEMS switches, and their DSP-driven integration with the receiving fractal antennas are very important in the design of the overall re-configurable system. Several cases have been analyzed to find the optimum configuration and some results are shown here.

II. FRACTAL ANTENNA CONFIGURATIONS

Several antenna configurations, mainly fractal, have been tested, such as the Koch dipole, the Minkowski island, the Minkowski patches, the Sierpinski gasket, the printed dipole and the Sierpinski bowtie antenna, shown in figure 1. Most of them have been studied extensively over the last few years, each one revealing its advantages and disadvantages in relation to the others [7, 8]. In general, most fractal antennas show multiband characteristics, but a lot of work needs to be done to excite the faraway patches at lower frequencies, as the coupling between the repeating elements is very small [9]. A new feeding method is also introduced to overcome software’s capabilities limitations. Most antennas have a small ground plane, which does not affect their radiation patterns. The geometry of a bowtie antenna, and its characteristics are based on the single triangular patch [10] with the additional feature that the bowtie is more broadband. A fractal modification of this antenna is the Sierpinski bowtie, where repeating small triangles form the larger ones, as can be seen in figure 5. Its wider than normal angle and its almost constant radiation pattern in all over the bandwidth, are easily achievable. This single element can be implemented in an array structure of a conventional or a fractal form, taking the characteristics of the corresponding array factor. Furthermore, this array of antennas can be monolithically co-integrated on-a-chip with RF MEMS and can also radiate steerable multi-beams, by using the correct DSP-driven switches, thus making the whole array a smart antenna. Since the surface area of an integrated circuit die is physically small, it is likely that advanced flexible circuit or multilayer printed wiring board technologies would also be used to implement the fractal structures. In this implementation gaps are created in the fractal antenna pattern, which are bridged by a number of very small MEMS micro-relays (as small as 1mm x 1mm) surface mounted to the fractal structure using chip-scale, ball grid array packages. These compact, flip-solder packages would minimize the effect of electromagnetic discontinuities introduced by the packaging structures. Alternately, patterned overlay packaging can be used to form small antenna panels, in which the conductive structures of the antenna are sputtered and electroplated directly onto the contact termini of a large number of individual micro switches.

III FRACTAL ANTENNA RESULTS

The results for a simple bowtie antenna are shown on Figs. 2-4. The first resonance occurs at 2.4GHz and the radiation pattern is very close to a dipole’s. The half power beamwidth (HPBW) is 84°. The results for the Sierpinski gasket bowtie antenna are shown in Figs. 5-9. The antenna is more broadband, with a bandwidth of 30% (1.1GHz to 1.5GHz), and an almost steady imaginary part of input impedance below –10Ω. The radiation pattern is almost constant and resembles the dipole’s in all over the bandwidth. Also, at the center frequency the (HPBW) is 82°, and the maximum occurs at theta=32°.

IV ARRAY CONFIGURATIONS

Several possible array configurations have been considered and multiple results have been obtained. Different array configurations can be achieved by the use of RF MEMS switches, in a way to increase or decrease the element area, or connect and disconnect the elements between themselves. Here we present a simple array of 2 elements. The dielectric used had εr=2.33 and thickness h=0.1588cm. The guided wavelength
at the center frequency was found to be $\lambda_c = 19.4\text{cm}$. We place the second element at different distances and get different radiation patterns shown in Figs. 10-11. Similarities to the dipole patterns can be observed.

![Figure 2. The equilateral bowtie antenna](image)

![Figure 3. The S11 of the bowtie antenna](image)

![Figure 4. Far field at the resonant frequency for the Bowtie antenna.](image)

![Figure 5. The Sierpinski gasket with obtuse angle antenna.](image)

![Figure 6. S11 of the Sierpinski gasket antenna.](image)

![Figure 7. Real and Imaginary part of input impedance.](image)

![Figure 8. The Smith chart of the Sierpinski gasket obtuse angle antenna.](image)
V CONCLUSIONS

A new approach to wideband and smart reconfigurable antennas using RF MEMS switches and fractal antennas was presented. Smart antenna technology has the potential of leading to large increases in systems performance. The combination of multiple antenna elements with optimized radiation beams is promising and has to be investigated in further details. Several cases were analyzed to find the optimum configuration and some results are presented here.

VI REFERENCES