RF MEMS and Its Applications in Wireless Networks

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***Abstract*- Microelectromechanical systems (MEMS) is the technology of very small devices which merges both mechanical and electronic devices on a monolithic microchip to produce superior performance over solid-state components, especially for wireless applications. Popular MEMS switches for wireless applications include transmit/receive duplexers, band-mode selection, time delay for phased-array antennas, and reconfigurable antennas. This paper talks about the use of MEMS switches in conjunction of fractal antennas to achieve multi-frequency, reconfigurable antennas that can be used for a variety of communication applications and how micromachining can be used to fabricate new 3-D MEMS antenna structures for very high frequency applications.**

***KeyTerms*- Re-configurable antennas, Numerical integration wideband, fractal, RFMEMS.**

I. INTRODUCTION

Polarization and radiation pattern re-configurability, and frequency tunability, are usually achieved by incorporation of semiconductor components such as varactor diodes. However, these components can be readily replaced by RF MEMS switches in order to take advantage of the low insertion loss and high Q factor offered by RF MEMS technology. In addition, RF MEMS components can be integrated monolithically on low-loss dielectric substrates, such as borosilicate glass, whereas compound semi-insulating and passivated silicon substrates are generally lossier and have a higher dielectric constant. A low loss tangent and low dielectric constant are of importance for the efficiency and the bandwidth of the antenna.

By combining low-loss, high-isolation RF MEMS switches with resonant microstrip or fractal radiators, we can physically reconfigure antennas and their feed structures in order to provide frequency band and polarization diversity. The MEMS micro-relays are used to alternately connect or isolate sub-structures on the planar antenna element, creating a geometrically distinct radiator for each combination of switch positions. In addition, phase-shifters can be used in conjunction with multiple antenna elements to realize novel monolithic low-cost electronically steerable arrays (ESAs).

These ESAs will facilitate future integration with active devices and signal processors to realize ‘smart’ antenna. Passive subarrays based on RF MEMS phase shifters may be used to lower the amount of T/R modules in an active electronically scanned array. RF bandpass filters can be used to increase out-of-band rejection, in case the antenna fails to provide sufficient selectivity. In the past, re-configurable antennas have been restricted to the use of non-fractal elements. Here the use of fractals is mainly for multi-frequency applications. A fractal antenna can be designed to receive and transmit over a wide range of frequencies.

II. RF MEMS

MEMS RF contact switch has lower insertion loss for multi-mode applications. They have superior isolation/harmonics with performance, 15dB greater compared with solid state. The radio frequency microelectromechanical system (RF MEMS) acronym refers to electronic components of which moving sub-millimeter-sized parts provide RF functionality. RF MEMS resonators are applied in filters and reference oscillators. RF MEMS switches, switched capacitors and varactors are applied in electronically scanned subarrays, phase shifters and reconfigurable antennas, tunable band-pass filters.

III. FRACTAL ANTENNAS

A fractal antenna is an antenna that uses a fractal, self-similar design to maximize the length, or increase the perimeter (on inside sections or the outer structure), of material that can receive or transmit electromagnetic radiation within a given total surface area or volume.

Such fractal antennas are also referred to as multilevel and space filling curves, but the key aspect lies in their repetition of a motif over two or more scale sizes or "iterations". For this reason, fractal antennas are very compact, multiband or wideband, and have useful applications in cellular telephone and microwave communications.

A fractal antenna's response differs markedly from traditional antenna designs, in that it is capable of operating with good-to-excellent performance at many different frequencies simultaneously. Normally standard antennas have to be "cut" for the frequency for which they are to be used—and thus the standard antennas only work well at that frequency. This makes the fractal antenna an excellent design for wideband and multiband applications. In addition the fractal nature of the antenna shrinks its size, without the use of any components, such as inductors. The fractal antenna has performance parameters that repeat periodically with an arbitrary “fineness” dependent on the iteration depth. Therefore, although the finite iteration depth fractal antenna is not frequency independent, it can cover frequency bands arbitrary close together. Also, remembering that radiation comes from accelerating charges, the typical fractal shape (with all those little bends and kinks) makes for good radiation (higher radiation resistance) because of all that acceleration going on as the charges are forced to negotiate all those sharp turnstors or capacitors.

IV. THE SIERPINSKI ANTENNA

Fractals have self-similarity in their geometry, which is a feature where a section of the fractal appears the same regardless of how many times the section is zoomed in upon. Self-similarity in the geometry creates effective antennas of different scales. This can lead to multiband characteristic antennas, which is displayed when an antenna operates with a similar performance at various frequencies.

The Sierpinski Gasket antenna is used for this paper. A bowtie dipole antenna generates the fractal. The middle third triangle is removed from the bowtie antenna, leaving three equally sized triangles, which are half the height of the original bowtie. The process of removing the middle third is then repeated on each of the new triangles.

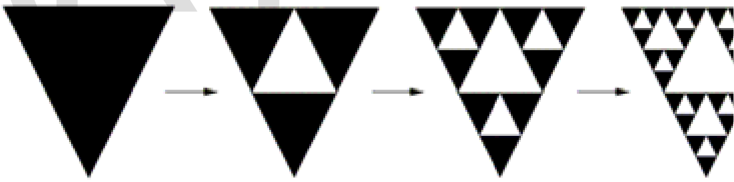

Fig. 1- Generation of Sierpinski Antenna Pattern

The Sierpinski Gasket antenna has the following characteristics:

The antenna has a flare angle of 60” and provides constant radiation pattern all over its bandwidth. Each element’s side-length is 2.7cm. The antenna is etched on a monopole, which is placed vertically on a ground plane to create an image. It is then fed from the tip using a coaxial cable whose outer metal is connected to the ground plane and its inner conductor to the monopole itself.

The benefits of the multiband behavior can be seen in the far field pattern plots for these antennas. The far field patterns for the antennas at their first, second, and third resonances are shown in Fig 2,3 and Fig 4.

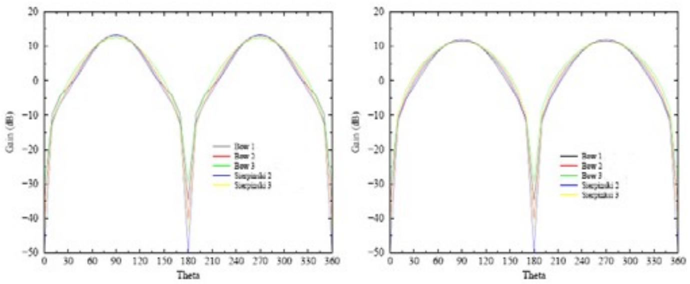

Fig. 2- Far field pattern (first resonances)

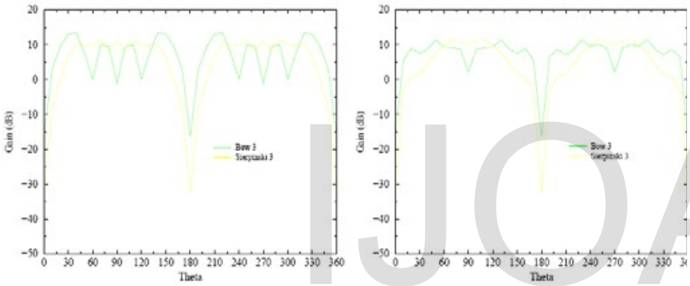

Fig. 3- Far field pattern (third resonances)

The above figures show the effect of use of Sierpinski fractal antennas on the far field patterns.

The Sierpinski pattern has a multi-frequency performance, as its active shape can be altered in many different ways providing different current paths, frequency bands and radiation patterns.

The radiation pattern of the fractal antenna is similar to that of a dipole antenna as shown in Figure 4.

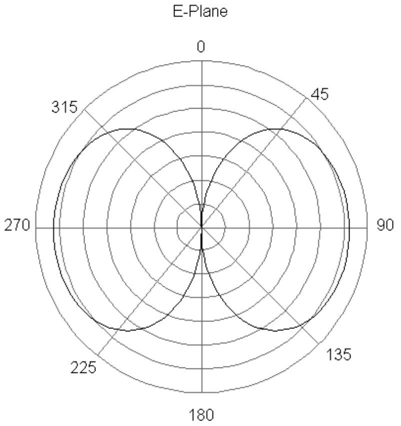

Fig. 4-The radiation pattern of a fractal antenna with all switches off

V. ANTENNA AND MEMS SWITCHES

In general, the coupling between the elements of a fractal antenna is very weak. Here we consider that the elements are connected with almost ideal switches. Therefore a switch conductively connects two adjacent antenna's elements when it is activated, changing the antenna's physical dimensions. Small gaps are created in the etched fractal antenna, which are bridged using MEMS switches.

Several cases were analyzed with the switches turned ON and OFF at different locations of the fractal antenna. First, the antenna was simulated with all switches set to ON (i.e. the antenna acted as regular fractal antenna with all of its conductive parts connected to each other).

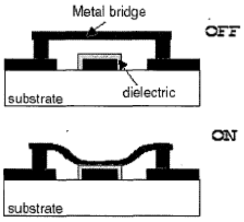

Fig. 5- Side view of a shunt MEMS switch

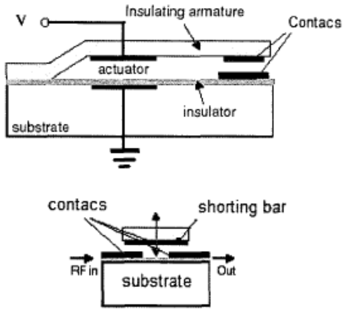

Fig. 6 -Side and front view of a series MEMS switches

VI. THz ANTENNAS USING MICROMACHINING

Micromachining can also be used to fabricate 3 Dimensional structures, such as helical antennas, singular and arrayed, for the millimeter and THz range. The THz antenna structures are fabricated by using Laser Chemical Vapor Deposition (LCVD) to form fibers that can be grown into complex three dimensional structures directly on semiconductor substrates. By focusing the laser through a diffractive optic, arrays of antennas can be fabricated at the same time.

Several applications can be realized using the antenna structures with other THz MEMS devices such as THZ waveguides, bolometers etc. An MEMS helical antenna has been shown in Fig. 7.

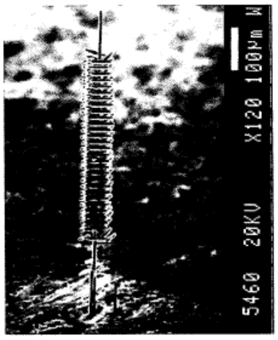

Fig. 7 A MEMS Helical Antenna

VII. ADVANTAGES AND DISADVANTAGES OF FRACTAL ANTENNAS

Advantages include miniturazization, better input impedance matching, wideband/multiband, frequency independent, reduces mutual coupling among fractal antennas.

Disadvantages include gain loss, complexity and numerical limitations. Also, the benefits begin to diminish after a few iterations.

VIII. APPLICATIONS OF FRACTAL ANTENNAS

The sudden growth in the wireless communication area has sprung a need for compact integrated antennas. The space saving abilities of fractals to efficiently fill a limited amount of space create distinct advantage of using integrated fractal antennas. Examples of these types of applications include personal hand-held wireless devices such as cell phones and other wireless mobile devices such as laptops on wireless LANs and networkable PDAs.

Fractal antennas can also enrich applications that include multiband transmissions. This area has many possibilities ranging from dual-mode phones to devices integrating communication and location services such as GPS, the global positioning satellites. Fractal antennas also decrease the area of a resonant antenna.

IX. CONCLUSIONS

A new approach to multiple frequency fractal antennas using RF MEMS switches was presented. Instead of utilizing only the resonance frequencies offered to the designer by the nature of the fractal antennas, additional resonances can be achieved by making use of RF MEMS switches. The placement of each switch can control the current on each conductive part of a fractal antenna. That affects the resonance behavior of the entire antenna and its radiation pattern. Several other fractal antennas such as the Sierpinski gasket antenna can be used in conjunction with FW MEMS switches to create a re-configurable and more versatile antenna. Such an approach to re-configurable antennas permits deliberate alterations in antenna performance to accommodate changes in mission, environment, tolerance to defects and faults in modern communication systems.

Further work is required to get an understanding of the relationship between the performance of the antenna and the fractal dimension of the geometry that is utilized in its construction. It is important that the design of the antenna approaches an ideal fractal as much as possible. Several iterations can be studied to understand the trends that govern the antenna to better understand the physics of the problem.

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