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DESIGN AND MEASUREMENTS OF A HYBRID RF-MEMS RECONFIGURABLE LOOP ANTENNA ON A FLEXIBLE SUBSTRATE (PREPRINT)

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Aerospace Components & Subsystem Division

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14. ABSTRACT
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Design and Measurements of a Hybrid RF-MEMS Reconfigurable Loop Antenna on a Flexible Substrate

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Abstract — Reconfigurability in an antenna system is a desired characteristic that has been the focus of much research in recent years. In this work, a hybrid reconfigurable RF-MEMS loop antenna was designed, fabricated (on a flexible substrate) and measured. The design concepts and measurement results are presented and discussed.

Index Terms ***– Loop, MEMS, Reconfigurable***

Introduction

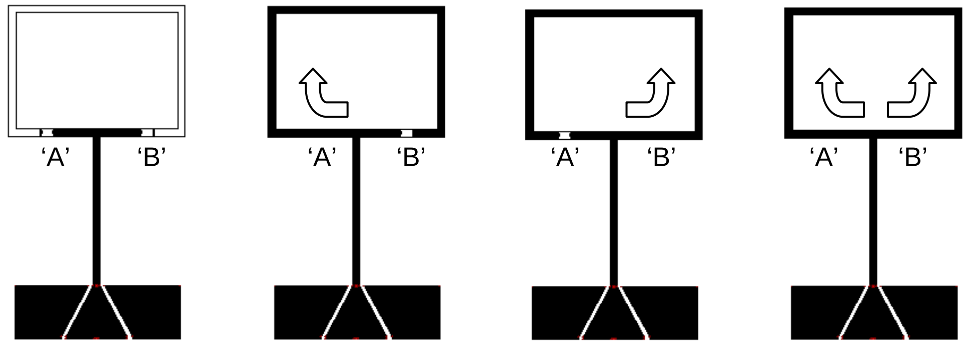
Reconfigurability is a characteristic that offers multifunctionality on modern communication systems. One of the components that, when reconfigured, can lead to performance improvements, is the antenna itself. This has been the focus of much research in recent years [1], as well as of this work.

Loop antennas can be fed on its perimeter, making possible its integration into a planar array configuration. In addition, the sense of polarization rotation can be switched from left-hand to right-hand, and vice versa, by altering the gap positions using radio-frequency (RF) switches such as micro-electro-mechanical systems (MEMS), optoelectronic switches, or PIN diodes [2, 3]. Here, a hybrid reconfigurable MEMS rectangular loop antenna was designed, fabricated and measured. For purposes of this work, the word “hybrid” implies an antenna in which the reconfigurability element or device was fabricated separately and then integrated with the antenna using wire bonding techniques. The goal is to investigate the integration issues of the packaged MEMS in this hybrid configuration. A similar effort with spiral antennas was made in [4], but this would be the first time that this technique is used with a loop antenna. The measured results using the loop antenna are presented and discussed herein.

Design Concept and Structure

The designed loop antenna consists of a coplanar waveguide-fed (CPW) loop that is intercepted by two RF-MEMS switches, one on each side of the feeding terminal. The two MEMS switches allow a total of four different configurations.

The design at its different states of reconfigurability is shown in Figure 1(a-d), where the MEMS locations are denoted with ‘A’ and ‘B’. The entire structure is 9.5×18 mm long. The loop is 9.5×7 mm, and the switches are placed approximately 2mm from the feeding terminal.



a) b) c) d)

Figure 1. The different possible configurations of the loop antenna with two MEMS switches, and the current flow path, indicated with arrows.

Fabrication

The different components were fabricated using independent manufacturing procedures. The antenna was fabricated on a Rogers™ TMM4 *high frequency flexible laminate*, 381µm thick and with a dielectric permittivity of $\varepsilon_r = 4.5$. Half oz of copper (~17-18 µm thick) was plated on the substrate, with 5µm of *Ni* and 1µm of *Au*. The purpose of the Ni/Au layers was to increase the adhesion of the wire bonds with the antenna surface.

The packaged MEMS switches used in this work were the commercially available RMSW200 RF-MEMS switches (Single-Pole-Single-Throw) from Radant MEMS Inc., which are hermetically sealed and operate form DC to 40GHz. These switches have <0.4 dB insertion losses and >20dB isolation for frequencies ranging from DC to 10GHz, which is the highest employed frequency in this work. The antenna fabrication was done at the Air Force Research Laboratories (AFRL) at Wright Patterson Air Force Base (WPAFB). The MEMS switches were placed directly on the antenna's substrate and fixed using a dielectric epoxy. The connections from the switch to the antenna, and from the antenna to the DC posts were made using gold wire bonding techniques. Figure 2(a) shows a diagram of the connections done between the antenna, the switches and the DC bias, while figure 2(b) shows a picture of the system set-up. This configuration eliminated the need of bias tees, since the DC bias was applied to the switch's gate and source and a complete loop that included the antenna feed was never created for any of the antenna states. The integration of the antenna and the switches took place at the UPRM's *µanDReG research laboratory*, and the measurements were made using an Agilent 8510C vector network analyzer.

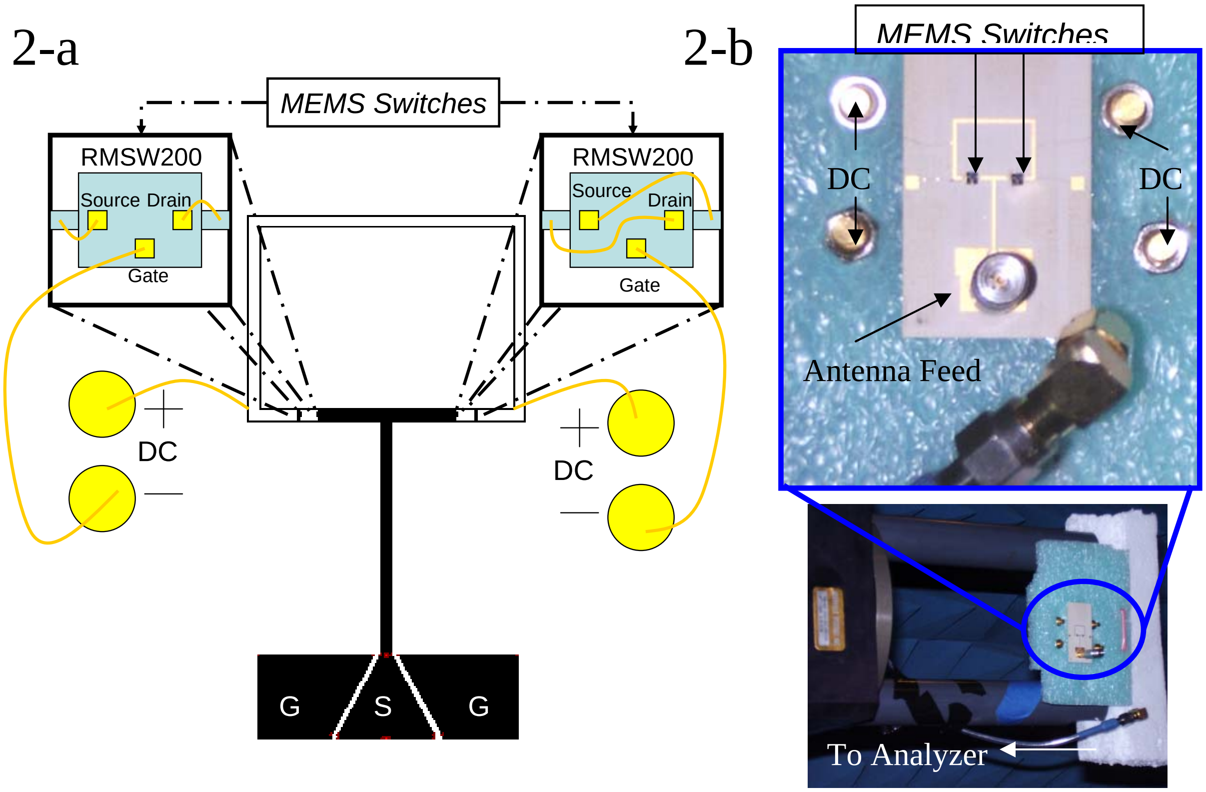


Figure 2. Diagram (a) and photos (b) of the antenna set-up during testing.

Simulated and Measured Results

At the initial state (all switches 'off', Fig.1a), the antenna is not serving any specific radiating purpose since the current on the one arm of the horizontal monopole has the opposite direction of the current on the other arm, and thus the input impedance presented at the antenna terminals at the resonant frequencies becomes very high.

When one switch is turned 'on' and the other 'off' (Fig. 1b or Fig. 1c), the antenna functions as a traveling-wave loop at its main resonant frequency of operation. The simulated results (Fig. 3), showed a first resonance (where the phase of the reflection coefficient is 0°) at f_1=5.2GHz. Both these configurations are symmetric, and so independent of which switch is 'on' or 'off', as long as they are in alternate states. Measurements indicated that the resonant frequency shifted down to 4.3GHz and the quality of matching was affected. This difference is attributed to the effect of the large feeding connector being near the radiating element during the measurement setup, and to the existence of the bulky packaged RF-MEMS switches on the antenna's surface, instead of small integrated ones. This is an issue the RF engineer is often faced with as the volume of measurement accessories interfere with the near fields of radiating elements. A suggested approach is to integrate the radiating elements with the MEMS switches, and to place both to the microwave circuit, avoiding any external biasing circuitry.

When both switches are 'on', the current flows in parallel on the left and right branches of the loop (Fig.1d), and the antenna has two resonant frequencies with broadside pattern. The simulated broadside patterns are shown in Fig. 4. The first simulated resonance is at 4.2 GHz and the second at 8.6 GHz. The measured antenna performance (Fig. 5), shows that the two resonant frequencies were detected by the simulation, however, the mismatch and frequency shift occurring from the large connector and the packaged MEMS, deteriorated the performance once more. The measured resonances occurred at 4 GHz and 7.5 GHz. The antenna under measurement setup is shown in Fig. 5.

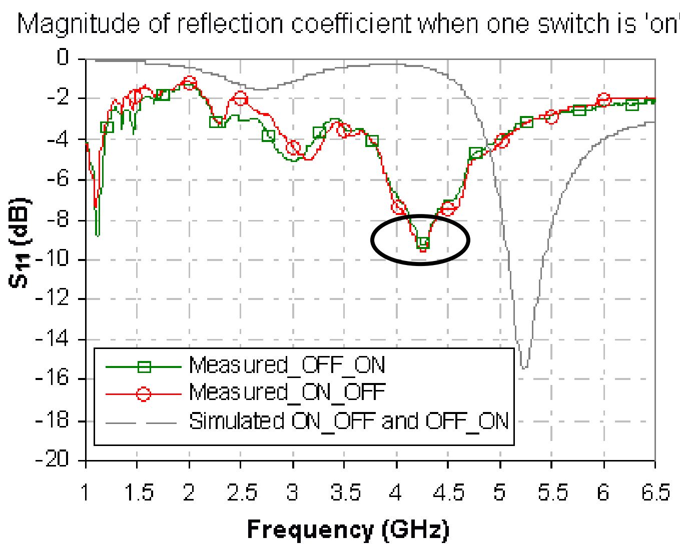


Figure 3. Measured and simulated frequency response for the 'on'-'off' state. The exact performance of the 'on-off' and 'off-on' states is noticed.

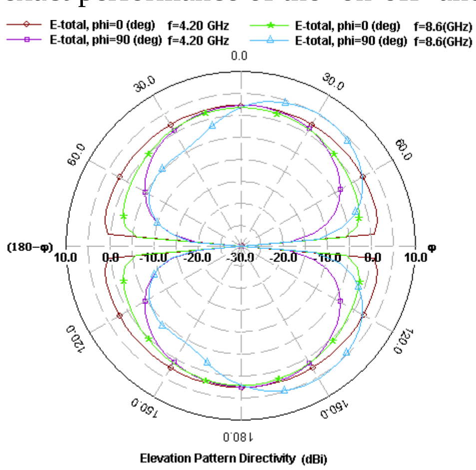


Figure 4. Simulated directivity pattern at 4.2 GHz and 8.6 GHz for the 'on'-'off' state.

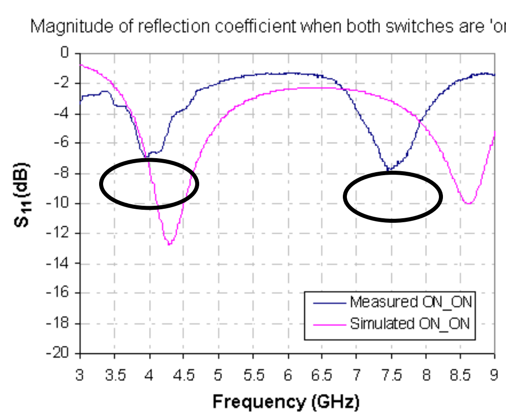


Figure 5. Measured and simulated frequency response for the 'on'-'on' state.

Discussion and Conclusions

In this work, a reconfigurable loop antenna was simulated, fabricated on a flexible substrate, integrated with packaged MEMS switches, and measured. Comparison showed that the integration of the MEMS switches is an important performance factor that needs to be considered in the most seamless way, in order to minimize performance deterioration. The effect of bulky components such as the packaged MEMS switches and the RF connector itself can significantly alter the antenna performance. A more detailed discussion along with additional examples and results of this and other antennas will be presented at the conference.

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