# Reconfigurable Antennas and RF Front Ends for the Development of a Universal Wireless Receiver

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Abstract — Reconfigurable integrated RF front end and antenna have been considered for the development of a universal wireless receiver. Tools of reconfigurability include passive and active devices such as MEMs, PINs, and CMOS components. Design concepts of various reconfigurable structures are presented here.

## I. INTRODUCTION

Various design techniques of multi-standards, multi-bands, and multi-functional wireless receivers are currently being investigated, and different compact designs of antennas and RF front-end components are being considered for the development of the most sought of--a novel universal receiver.

In anticipation of such technical evolution [1], we believe that researchers should begin addressing potential interfacing issues today. This includes multi-standards, multi-bands, and multi-functions as identified nowadays by many wireless service manufacturers and providers. We simply utilize one receiver set to support many standards such as GSM, GPRS, EDGE, UMTS/3GSM for cell-phones, many other services (such as Bluetooth, WiMax, WLAN, Zigbee, GPS) and many more to come. This task is highly challenging and technically demanding; therefore, we need to minimize components' redundancy in the design of the integrated RF front-end circuits and antennas to keep both the size and cost down.

Reconfigurable structures and circuits are the best candidate for such a challenge as they are compact, lightweight, and affordable. Reconfigurable structures are generally designed to be adaptive to provide the needed multi-functionality and to offer either one or more service at a time.

Examples of utilizing various passive and active switching and tweaking tools to provide reconfigurability for the integrated RF front-end and antenna are presented here.

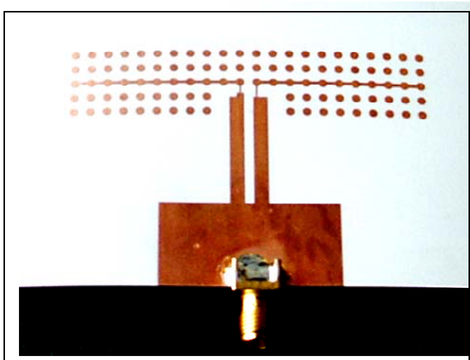
## II. DESIGN CONCEPTS

### A. Reconfigurable Antenna Structures:

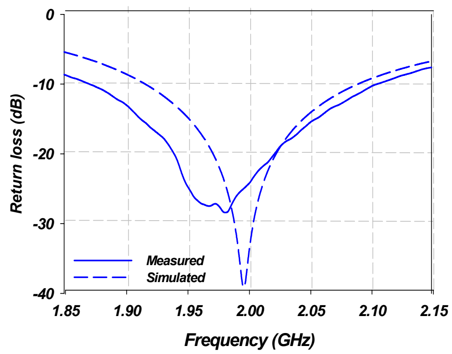
Antennas are generally bulky and relatively large, especially at the lower wireless frequency range, such as 800-900 MHz. Hence the use of dedicated antennas for each service is costly, requires relatively large real estate, leads to unwanted proximity-coupling of these multiple antennas, and significantly degrade the overall performance. But, upon reconfiguring these antennas, structures with less complexity can be used, and their form, shape, and function can be dynamically reconfigured to be service-specific.

To demonstrate the flexibility and wide coverage of the reconfigurable antenna structures, we designed and fabricated a simple reconfigurable generic dipole antenna (shown in Fig. 1), which is comprised of a series of metallic pixels with various interconnectivity options. For example, a dipole can be formed to operate at a certain frequency, and upon changing its length, termination, and type and number of these interconnected pixels, it can be easily re-tuned to another frequency. Adjustment can be achieved by controlling the number of the ON-bridging switching devices that connect these pixels. The effect of the utilized and neighboring "parasitic" pixels was theoretically as well as experimentally evaluated to determine the necessary spacing required to minimize their parasitic effects. Fig. 1 shows (as an example) the dipole's measured radiation pattern and input match when configured to operate at 2 GHz. Similar performances at other discrete set of frequencies were measured upon reconfigurability.

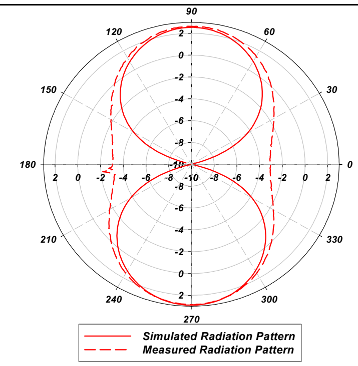
Similarly, we have designed a multi-band, reconfigurable loop antenna (a maze antenna). Its design is based on a reconfigurable fractal structure with slight tuning. Switches are used to adjust the antenna's resonance at specific discrete frequency bands (services) including DCS/PCS/UMTS/IEEE 802.11a/b/g. Radiation patterns have been measured and compared to the theoretical results and an example is shown in Fig. 2. The selected interconnected loop defines the maximum area of the whole antenna and corresponds to a 2.4 GHz center frequency.



Reconfigurable dipole antenna

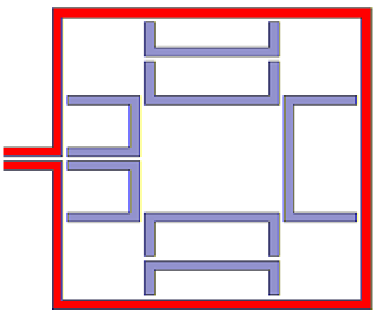



Measured and Simulated input return loss at 2GHz

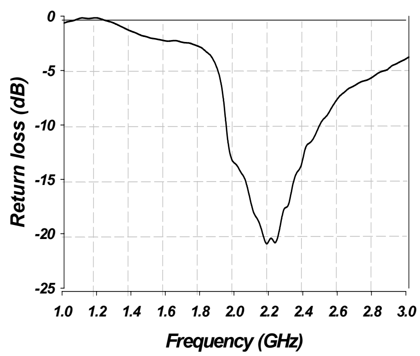



Radiation pattern of the reconfigurable dipole

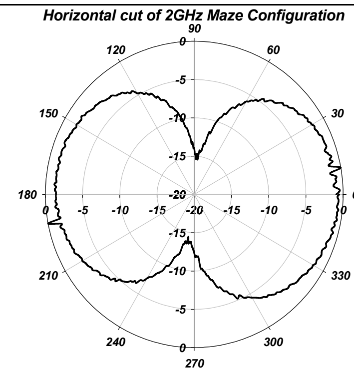
Figure 1



Reconfigurable loop antenna




Measured input return loss at 2.2GHz




Radiation pattern of the reconfigurable loop

Figure 2

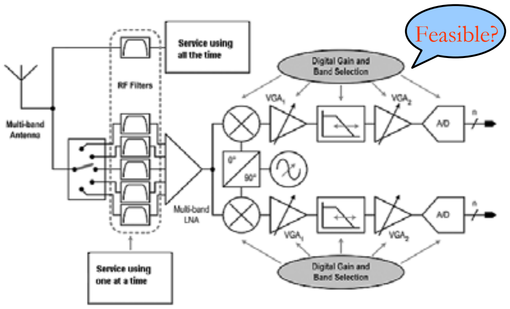
Previous examples with limited reconfigurability were based on utilizing switches to hop from one frequency to another [2]. However, this concept can be extended to full reconfigurabilty as demonstrated by Fathy et al. [3], Whereas PIN devices were used to form switchable semi-metallic radiating pixels. However, even though the full reconfigurability approach is very flexible, it is power hungry. For wireless services, DC power consumption is a prime concern, and limited reconfigurability will suffice to keep power dissipation relatively low.

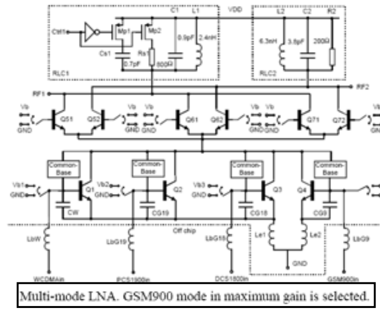
**B. Reconfigurable RF Front End Concepts:**

Many redundant components are currently utilized in the design and fabrication of the RF front-end and can be easily minimized in a reconfigurable system (see Figs. 3, 4, after [1]). Instead of using many blocks with identical components, systems can be reconfigured to provide similar functionality exactly as in the case of using many individual receivers as shown in Fig. 3. Hence, oscillators, gain blocks, and low noise amplifier (LNAs) circuits were designed for reconfigurability. Components can be combined and circuits can be designed to dynamically adjust and address various specific requirements for gain, S/N, IIP3 and dynamic range to minimize the components' count which is consistent with our goals.

A proof of concept experiment was developed and used as an example of a reconfigurable low noise amplifier (LNA) (shown in Fig. 5). The circuit is used to demonstrate how we can dynamically adjust the matching circuitry to address various demanding requirements or specifications. The circuit is fabricated on FR4 substrate and has only one RF input and one RF output for all operating frequencies. The gaps between the lines in Fig. 5 represent open circuits (i.e. emulating an OFF-switch); meanwhile hard-wired connections are used for emulating devices in the ON-state. The shown circuit operates at three different frequencies based on the selected interconnections. For example, to operate at the lowest frequency, L1_1 and L1_2, and capacitor C1 need to be connected to the common RF chain to operate at 5.2 GHz. This case's gain and noise figure results are shown in Fig. 6.

Similarly, if L2_1, L2_2 are connected instead, then it will operate at 2.4GHz, and the simulation results of this case are shown in Fig. 6, and so on for the third set of connections. Fig. 6b shows the simulation results when operating at 1.9, 2.5, and 5.2 GHz.



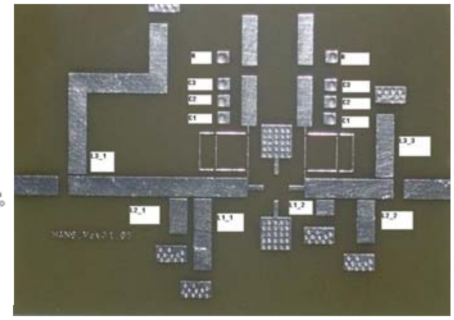



Figure 3 Basic building block of an integrated Rf Front-end

Figure 4

Figure 5

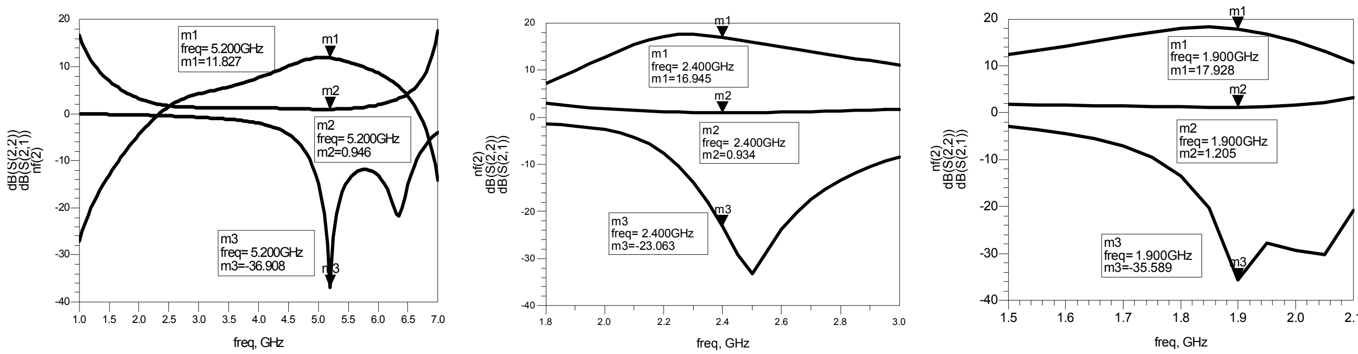



Figure 6: Simulation result of S21, Noise Figure and S22 of LNA working at 5.2GHz, 2.4, and 1.9 GHz respectively, where m1 represents gain, m2 indicates noise figure, and m3 for match.

## III. TOOLS

Reconfigurability for the RF front ends can be achieved using various passive and active switching devices such as MEMs, PIN diodes, or other active devices that are preferably compatible with the CMOS processing on silicon. It is essential to recognize that battery life is a prime concern, and MEMs technology is maturing very fast. But MEMs cost is still relatively very high, and its integration is an issue. Meanwhile, today, active switching, using PIN diodes and CMOS transistors, is used for switching applications and in many receivers even though they are dc power hungry , and they ultimately need to be replaced by MEMs.

Additionally, reconfigurable emulated active resistors, inductors, and capacitors can be utilized for fine-tuning. Applying either a current or a voltage can set these components to accommodate various operating conditions and be consistent with the different standards. Table 1 shows predicted tuning ranges for these active components for the 0.35μm Si-processing and the recommended circuits for their practical implementation. Circuits can be designed that will have one main switchable block for GSM, and PCS services, and a separate chain for other service that need to be ON all the time such as Bluetooth as indicated in Fig. 3.

## IV. SUMMERY AND CONCLUSION

We have investigated the use of reconfigurable structures for both the RF front end and antennas in order to develop a universal wireless receiver. Reconfigurable structures will have great impact on developing such receivers. It is recognized that MEMs are the best candidate for switching; as they have the lowest DC power dissipation if any. Efforts are underway to develop MEMs processing techniques that are compatible with CMOS technology and demonstrate low loss performance. Different designs have been demonstrated, and the idea of reconfigurability of both the RF front end and antenna platforms is feasible. We believe the processing of MEMs on low resistivity silicon, including integrated reconfigurable antennas, can be a reality in the near future.

Table 1: Tuning Ranges of active resistors, Varactors and active inductors.

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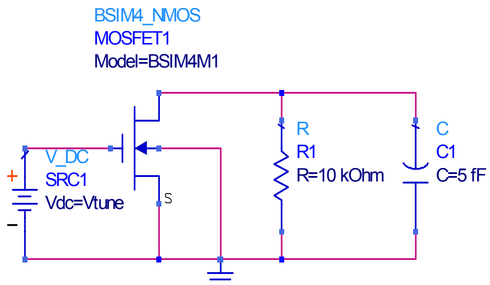
<td>
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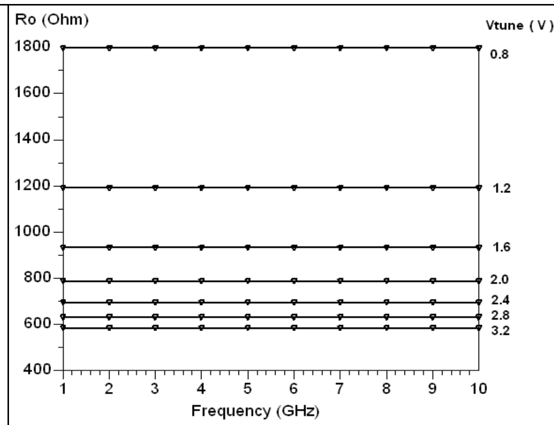
<td>
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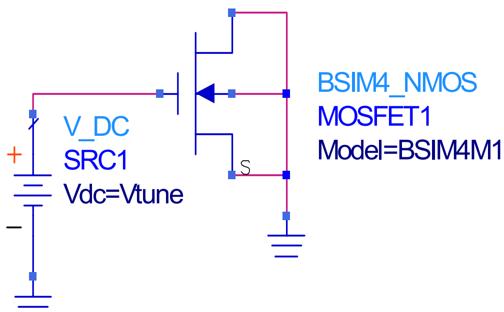
<td><u>Varactors</u><br><br>up to 10 GHz<br>0.35 pF to 1.7 pF<br>based on 0.35μm<br>Si- Processing</td>
<td>
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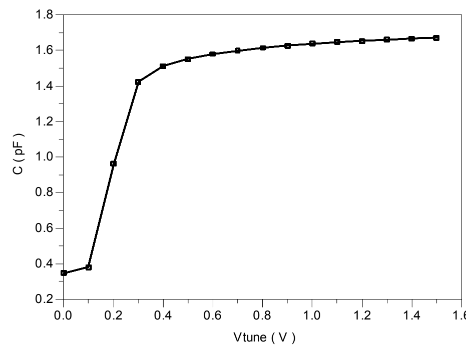
<td>
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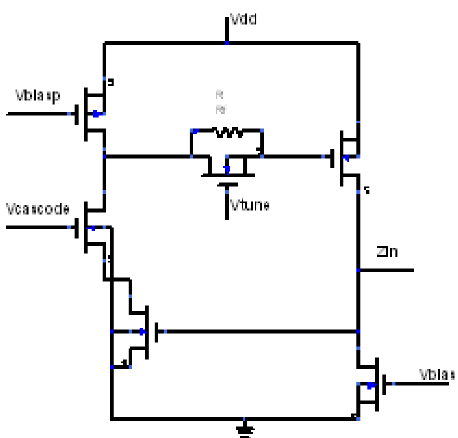
<td><u>Active Inductors</u><br><br><4GHz<br>0.1 nH to 15 nH<br>based on 0.35μm<br>Si- Processing</td>
<td>
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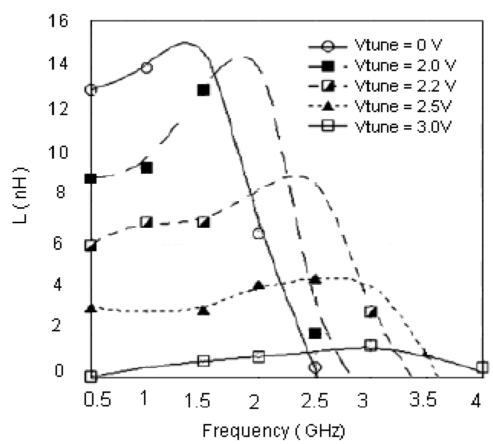
<td>
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[3] A E. Fathy et al., Silicon-Based reconfigurable antenna-Concepts, Analysis, Implementation, and Feasibility, IEEE-MTT, June 2003.