Frequency Tunable Antenna for LTE (4G) Handsets Operating in the 2.3-2.7GHz Global Roaming Band

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***Abstract*—A frequency tunable antenna for 4G global roaming devices operating in the 2.3-2.7GHz band is presented. Both the design and manufacturing methods are described and measured data are provided. Antenna is a half-patch with a reconfigurable aperture realized by a collection of shorting pins that are controlled by DC signals. The design follows the teachings of the patented self-structuring antenna technology and can be operated either in open or closed loop fashion. The frequency tunable feature of the antenna also makes it immune to detuning when used in a closed loop control system. Though the design is compatible with a multitude of manufacturing and embedding methods, the particular prototype was built by wire-bonding bare-die SPST switches onto the antenna board.**

I. Introduction

Long Term Evolution (LTE) standard, a.k.a. 4G, provides better spectrum efficiency, higher data rates, lower latencies, and flatter IP core network architecture when compared to 3G technologies. The International Wireless Industry Consortium (IWPC) commissioned a Working Group to identify tunable RF front-end (RFFE) architectures for an integrated RFFE module and the white paper released by the group identified 2.3-2.7GHz as the global roaming band with the potential to reach 55% of the world's population [1]. A tunable RFEE will need a tunable antenna operating in the above band and it is challenging to design as well as manufacture such an antenna with stringent requirements of a handset. This presentation will start by drawing a distinction between impedance tuning and aperture tuning, followed by the design and manufacturing method of a tunable small antenna covering the 2.3-2.7GHz band (which utilizes aperture tuning) and conclude with the measured data collected on the prototype.

II. IMPEDANCE TUNING VS. APERTURE TUNING

Current state of the art for frequency tunable antennas can be broadly characterized as "impedance tuning" antenna since the tuning is applied at the feed point of the antenna to provide impedance match at various frequencies as shown in Figure 1(a). Aperture tuning is achieved through altering the distribution of the electric current over the aperture and effectively generating a different antenna each time. While in both cases, as far as the radio is concerned, the antenna is matched to 50ohms at various frequencies, the radiation efficiency is much higher for the aperture-tuned antenna since the current is distributed over a larger area resulting in smaller Q and hence smaller RF losses. The patented Self-Structuring Antenna (SSA) technology (which forms the basis of the design of the tunable antenna presented here) employs a reconfigurable aperture and provides superior performance through dynamic restructuring of the aperture based on feedback from the radio [2].

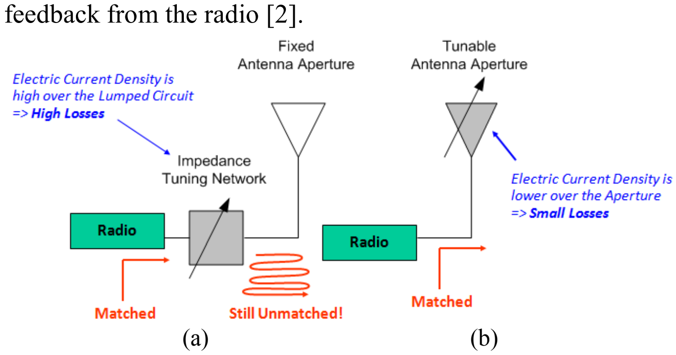


Figure 1: Difference between (a) Impedance Tuning and (b) Aperture Tuning.

III. DESIGN

Figure 2 shows the three-dimensional CAD view of a tunable half-patch antenna that can be packaged as a surface mount component or embedded into a circuit board. The design (patent pending) contains shorting pins distributed across the aperture that are actuated by radio frequency (RF) switches to provide impedance, frequency and pattern tuning within the framework of a self-structuring antenna in a closed loop control environment [3]. Open loop control, with the aid of a lookup table, is also possible. Both ohmic as well as reactive switching methods are possible but here only the ohmic switching is provided. Both digital as well as analog control methods are possible but again here only the digital control is presented. The design can be utilized for cell phone, machine-to-machine (M2M) communication and other wireless applications where small form-factor surface mount or embedded active is of particular value but the particular prototype described in the next section is targeting the handset use. The design is different from the self-structuring patch antenna presented in [4] is that the current design is half-the electrical size (half-patch), works at much higher frequencies and is suitable for surface mount placement on or integration into the circuit boards of the handset.

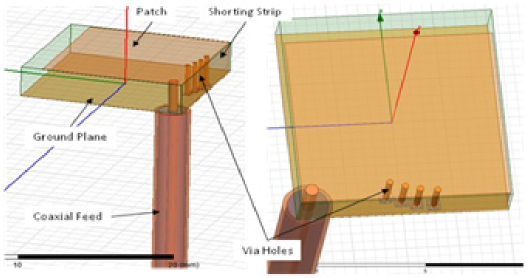
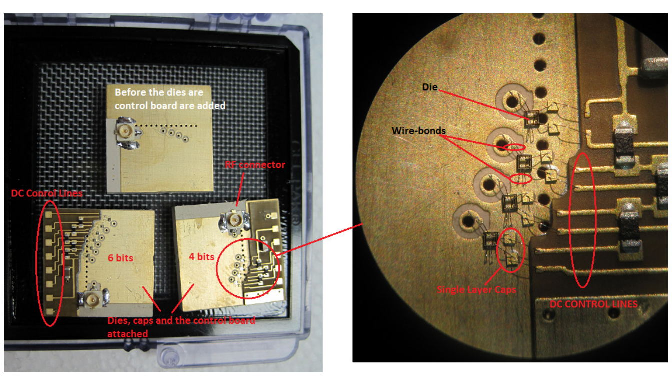


Figure 2: A half-patch antenna with one shorted edge containing four plated through via holes between the top patch and the ground.

IV. MANUFACTURING

Figure 3(a) shows the 6-bit and 4-bit versions of the prototype built (view from the side of the ground plane) and Figure 3(b) shows a close up view of the bare-die switches wire-bonded to the antenna board and connected to the DC control lines via single-layer capacitors. Bare-die versions of the SPST GaAs MMIC switch (Hittite Microwave Part Number HMC550) were used for connecting the plated-through vias to the ground plane. The switch has floating ground (i.e., can be biased at 0V and controlled with zero vs. negative 5 volts) and this negated the need for DC blocking capacitors, which reduced the part count and saved space. Antenna is manufactured on 3.8mm thick Rogers RO3010 substrate while the DC control circuitry is printed on a separate 0.5mm thick FR4 with the ground sides of the two boards put against each other using conductive glue. Finished antenna assembly measures 16mm x 16mm x 5mm in size but the production version will be 10mm x 10mm by 3mm.

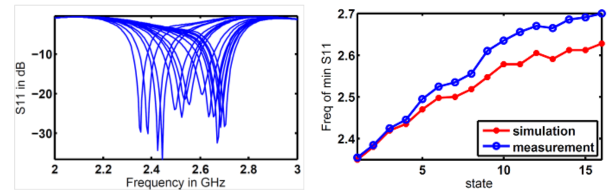


(a) (b)

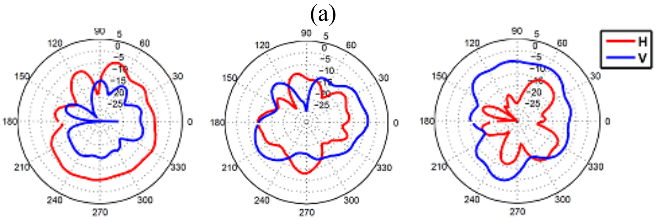
Figure 3: (a) 6-bit and 4-bit versions of the prototype built (view from the side of the ground plane) an (b) close up view of the bare-die switches wire-bonded to the antenna board and the DC control lines.

V. MEASUREMENTS

Only the measurements of the four-bit antenna are given here with a tenability range of 2.3-2.7GHz (6-bit companion tunes from 2.1 to 2.9GHz). Figure 4(a) shows measured S11 for all sixteen logic states of the four shorting pins and the measured frequency of minimum S11 demonstrating tunability across the 2.3-2.7GHz band with good agreement with simulations. Figure 4(b) shows measured gain patterns (dBi) for the 0111 state at 2.591GHz in all three cuts. Peak gain varies between -5.3 and -4dBi across the band.



(a)



(b)

Figure 4: (a) Measured S11 and the measured frequency of minimum S11 for all sixteen logic states, and (b) measured gain patterns (dBi) for the 0111 state at 2.591GHz in all three cuts.

VI. CONCLUSION

Design, manufacturing and measurement of a tunable half-patch antenna are presented for potential use in 4G handsets operating in the 2.3-2.7GHz global roaming band. The work presents a design that is possible to mass produce (wire-bonding bare-die switches) and whose performance can be improved with better switches (lower on-state resistance for higher antenna efficiencies).

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