RF-MEMS: An enabling technology for reconfigurable radio front-ends

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Abstract

Future handheld wireless communication devices are becoming complex multi-band multi-standard radio's, capable of operating in global cellular standards (like GSM), and in others like GPS, DVB, WLAN and WiMax. To satisfy the constraints on size, battery life, functionality and cost, the radio front-end must be made reconfigurable. RF-MEMS is here discussed as a key enabling technology for reconfigurable radio's.

1. Introduction

The handheld wireless communication device of the future is becoming a complex multi-band multi-mode radio, capable of operating in global cellular standards (like GSM, UMTS, and emerging 4G technologies), and increasingly in others such as global positioning (GPS), digital video and audio broadcast (DVB, DAB), wireless local and body area network (WLAN, WBAN), WiMax for mobile internet access, and, proximity radio (*e.g.*, Bluetooth) for wireless headsets or wireless printing [1-4]. In fact, not only mobile phones support these wireless capabilities, but convergence will mean that other combinations will appear in PDAs, laptop computers and gaming consoles. The device must be capable of receiving wireless transmissions over a total bandwidth of nearly 6GHz.

The consumer has come to expect each new generation of mobile phones/handsets to have improved performance, to maintain long battery life as well as adding new capabilities and functionality, while keeping the handsets small and affordable. Size reduction and increased functionality per unit area has been addressed by continuing chip scaling to the point where off-chip, bulky passive RF components (like high-Q inductors, ceramic filters, SAW filters, varactor diodes and PIN diode switches) have become limiting. It is not expected that the overall size of the phone will shrink any further, but the increased functionality per unit volume necessitates a higher degree of integration of the radio front-end combined with further miniaturization of the components, and, devising novel front-end architectures relying on *reconfigurability* of the radio front-end. Reconfigurable radio (also referred to as softwaredefined radio (SDR)) will allow the same transceiver and modem chain to be re-configured under software control to switch between different frequency bands and different modulation schemes. For instance, in a conventional architecture, for each new band added into a multi-band front-end, the entire front-end architecture is to be duplicated. This is because band-specific filters are needed in both receive and transmit chain. This parallelization, implying increased component count, can be eliminated using reconfigurable switched filter banks or tunable filters. Micro electromechanical system (MEMS) technology is one (perhaps the only) key enabling technology to implement reconfigurable radio's, while at the same time attain higher levels of integration [1-8]. Candidate RF-MEMS components for use in future handsets include switches, bulk acoustic wave (BAW) devices, voltage-tunable capacitors, and micromechanical resonators (and filters). Noteworthy to mention is that the potential and future for RF-MEMS is not so much to be found in a "replacement market", but it is more likely to be situated in the integration capability of RF-MEMS with other passives and active components either in a monolithic way (RF SoC) or in a hybrid fashion (RF SiP). As such, the impact of RF-MEMS technology is propagated from the device level to the system level [7]. For instance, one may think of MEMS-based switched filter banks in modern multi-band, multi-mode wireless systems, in which RF-MEMS switches and (BAW or mechanical) filters are built on the same technology platform. The use of RF-MEMS is further promoted by the improved performance characteristics of some RF-MEMS components, while not compromising on size or cost. For instance, RF-MEMS switching devices offer great potential benefits over GaAs MMICs and PIN diode switches [7]. Prototype RF-MEMS switches have demonstrated low loss, extremely low standby power consumption, excellent linearity and compactness. This makes RF-MEMS switches a very attractive candidate for use in the RF front-end of the handset, to efficiently route signals with minimal loss and distortion that otherwise may impair performance or power consumption.

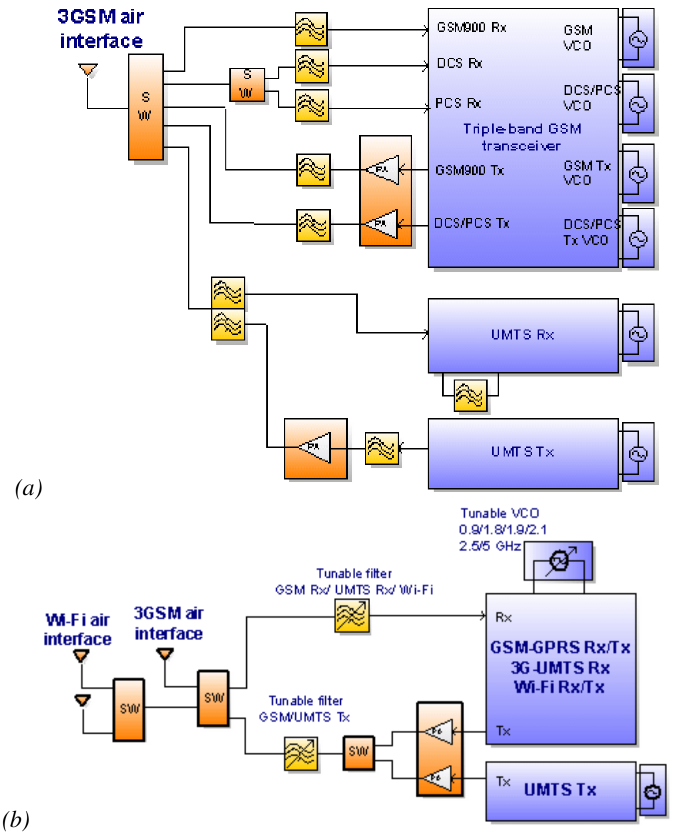

Figure 1: Illustration of a radio front-end of a multi-standard phone after Ionescu [6]. (a) Multi-mode 2.5/3G wireless transceiver architecture, built around fixed filters, clearly highlighting the duplication in the receive and transmit chains. (b) Highly integrated reconfigurable multi-mode 3G/WiFi system implementing tunable filters, thus strongly reducing duplication.

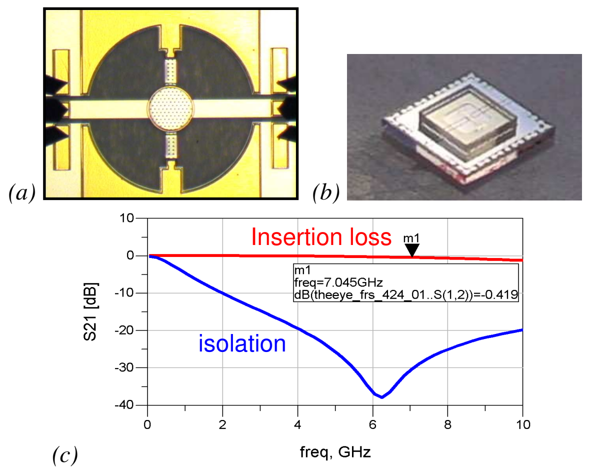

Figure 2: RF-MEMS shunt switch [8]. (a) before packaging; (b) after 0-level packaging and singulation. (c)Measured transmission parameter S_{21}.

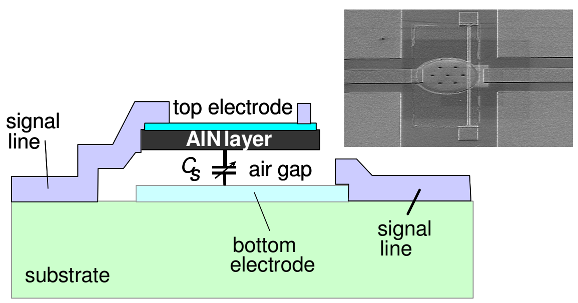

Figure 3: Surface micromachined tunable film bulk acoustic resonator (FBAR), using AlN as the piezoelectric layer [9]. The air-gap serves as acoustic isolation and by changing the gap the frequency is tuned.

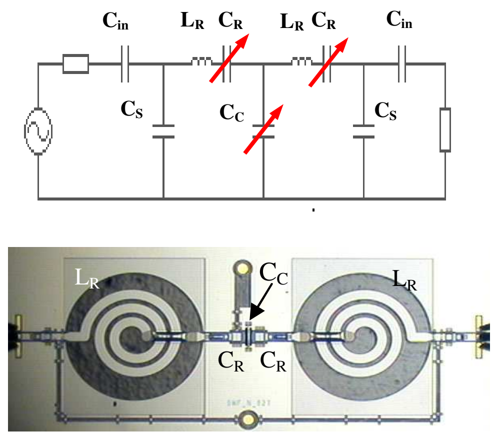

Figure 4: Switchable LC filter [8], e.g., for switching between DCS1800 band the WLAN5.2GHz band. The inductors (L_R) are fixed, while the MEMS caps C_R and C_C are switchable.

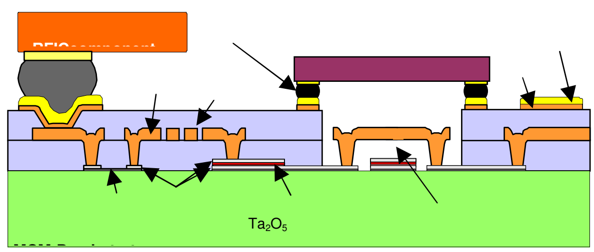

Figure 5: Illustration of IMEC's RF-MEMS-SiP concept [5], in which MEMS components (switches, varicaps, phase shifter) are incorporated (embedded) together with the other (fixed) passives into the carrier substrate.

2. References

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