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Isolation of High-Q Antennas for Mobile Handsets

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***Abstract*—Isolation, beween the antennas at low frequencies (700 MHz), is one of the major issues in 4th Generation Long Term Evolution. This paper presents a practical method to improve the isolation between the ports of Tx an Rx antennas through narrow-band antennas used in separate transmit and receive mode. Furthermore, a patented feeding technique is applied to feed the antenna, which helps improving the isolation between the antenna ports. An isolation of better than -22dB at 700 MHz, is shown to be possible to achieve, by utilizing this method.**

I. Introduction

Long Term Evolution (LTE) or 4th Generation (4G) LTE mobile network technology is depolyed in order to meet the increased desire for high data rate in mobile terminals. The 4G LTE provides mobile ultra-broadband and low latency internet access, which enables applications that are more demanding on the current mobile data networks, such as online music, film and game. In order to be able to achieve the high data rate, the frequency spectrum for mobile communication has been widened to more than 20 bands, ranging from 700 MHz to 2700 MHz, for use with LTE. The antenna design is in general challenging due to the fundamental limitation of antennas [1]. With LTE, the challenge is enormous for an antenna designer to cover the whole frequency spectrum due to size constraints and very limited available space for antennas in close proximity to other components. Adding an additional antenna on the same Printed Wire Board (PWB), pose even further challenges to the design as well as performance. The already scarce space for an antenna becomes even less and new problems arise due to increased coupling.

Close antenna element spacing inevitably leads to mutual coupling [2], [3]. This coupling means that part of the energy that is fed to an antenna, is not radiated but is instead absorbed by the second antenna port. Sufficient isolation between antennas in mobile terminals is important for several reasons. The coupling between antennas decreases their efficiencies as part of the power that would normally be radiated is captured by the other antenna. This coupling may also cause unwanted interferences between a transmitting radio system and a receiving one, operating at another frequency band. From the radio system design perspective, large antenna isolation is desirable as it enables the use of simpler and hence possibly cheaper and less lossy Radio Frequency (RF) filters.

This paper proposes a method to cover the whole frequency spectrum and at the same time decrease mutual coupling between antenna ports in the mobile handset, by using high Q reconfigurable antennas. High Q antennas have narrow impedance bandwidth characteristic. By adjusting the antenna Q, these reconfigurable antennas can be designed to be very narrowband, since they only need to cover one channel instead of a full band, and tuned to resonate at different channels. The LTE channels vary from 1.4 MHz up to 20 MHz [4]. A tunable antenna has the advantage that it can reuse its entire volume at different operating bands so the physical size of the antenna can be reduced [3]. High Q antennas, because of their low volume, fits the industrial design of smart phones. They are very attractive candidates for the 4G standard, since the volume required for a traditional passive antenna system to cover the wide frequency spectrum, while maintaining a good efficiency, would be too large to fit into many of the present day industrial smart phone designs.

Using Separate Transmit and Receive Method (STRM), mentioned in [5], the Transmit (Tx) and Receive (Rx) narrow-band antennas can be tuned to their respective channels in a certain LTE band. Because of the narrow-band characteristic of the high Q antennas, it is possible to mitigate the mutual coupling, that otherwise is strong when two antennas sharing the same ground plane, are operating at Tx and Rx architecture. In this way, there will be an inherently high isolation between the Tx and Rx ports, leading to a simpler RF front end architecture with lower or no requirements for the duplex filters.

This paper Shows how a very high isolation can be achieved at 700 MHz, by applying narrowband antennas in combination with a patented antenna feeding concept. The paper is organized as follows: Section II introduces the Antenna concept and the patented feeding technique. Section III presents the measured results. Section IV concludes the paper.

II. Antenna Concept

The PWB has the total dimensions of 100x40 mm^2, which is a low-tier platform. An Inverted L Antenna (ILA) is placed

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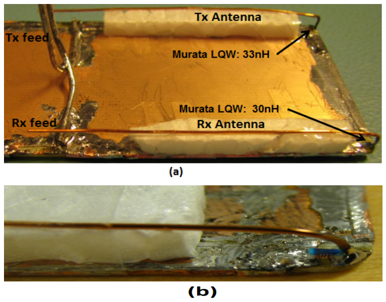

Fig. 1. Geometry of the antennas. (a) PWB with the Tx and Rx antenna elements. (b) Antenna element shorted to ground through inductor. (c) Antenna feed with two matching capacitors.

at each top corner of the PWB (see Figure 1a). The ILA is 60 mm long, placed at 3.5 mm height from the PWB and it is made of thin copper wire. Polystyrene is used as support material between the antenna element and the PWB to make the antenna stable. By placing the antenna elements along the long side of the PWB as shown in Figure 1a, the Q-factor goes high, which is desired in order to get the high isolation between the Tx and Rx antennas.

Figure 1c shows a patented feeding technique [6], which is used to feed the Tx and Rx antennas. One of the many advantages of applying this feeding technique is, that Tx and Rx antennas can be designed to be at high impedance area of each other, leading to better isolation in between the two antenna ports.

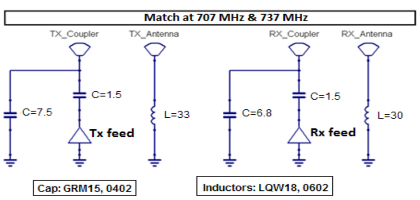

Fig. 2. Circuit diagram of the antennas and matching network.

Figure 2 illustrates the circuit diagram of the proposed antennas together with the matching network. As seen in the Figure, the Tx and Rx antenna elements are shorted to ground trough 33nH and 30nH inductors, respectively (see also Figure 1b). That, in order to force the antenna elements into resonance at their respective frequencies. The two matching capacitors at the feed are used in order to match the antenna impedance into 50 Ω. The investigation is made in LTE band 12 (Tx: 689 - 716 MHz, Rx: 728 - 746 MHz) because this band is the toughest band in terms of loss, and the lower bands are also very challenging in terms of isolation, since the whole PWB acts as a radiator.

III. Measurement results

The antenna impedance is seen in Figure 3, where the abs(S_{11})=-6 dB matched bandwidth for Tx and Rx antenna is 24 MHz, which corresponds to a Q of around 35. This Q is quite high compared to the Q of 3.3, which is required to cover the LTE low band frequency range of 698 - 960 MHz. The worst case isolation achieved between the Tx and Rx antennas, is seen to be around -22dB, which is quite high at these low frequencies. The major contributor to this high isolation is the narrowband characteristic of these high Q antennas, but the feeding technique also helps improving the isolation, since the Tx and Rx antenna impedances are at high impedance area of each other, which will imply more isolation between the ports. The matched impedances of the Tx and Rx antennas, within the Standing Wave Ratio (SWR) of equal to 3 curve, are shown on the smith chart, where it is also visible how the two antenna impedances are at high impedance area of each other.

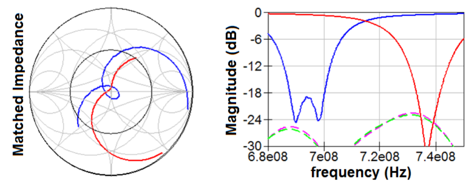

Fig. 3. Measured antenna impedance. (Left) Matched impedance in the smith chart, where blue and red curves correspond to Tx and Rx impedances, respectively. (Rigth) Log magnitude impedance plot, where the dotted pink and green curves correspond to S_{21} and S_{12}, respectively.

IV. Conclusion

In this paper it is shown how good an isolation that can be achieved by using narrowband antennas in combination with a special feeding technique. The high isolation is among others the potential benefit of utilizing narrowband antennas. However, this high isolation is achieved at the expence of higher loss in the antenna system, since high antenna Q implies higher current and field density per area.

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