UCR: An Unclonable Environmentally-Sensitive Chipless RFID Tag

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Motivation

Recently, cost-effective chipless RFID tags that do not contain a microchip in the transponder have been gaining more attention from industry, academia, and government. Existing chipless RFID tags require removing or shorting of some resonators (i.e., spirals or patch slots) on the substrate to encode data, but this incurs a waste of tag area and increases the manufacturing time/cost of chipless RFID tags. In addition, the identifiers (IDs) generated by existing chipless RFID tags are small, deterministic, and clonable. To mitigate these shortcomings, we propose a new unclonable environmental sensitive chipless RFID (UCR) tag that intrinsically generates a unique ID from both manufacturing variations and ambient temperature variation [1].

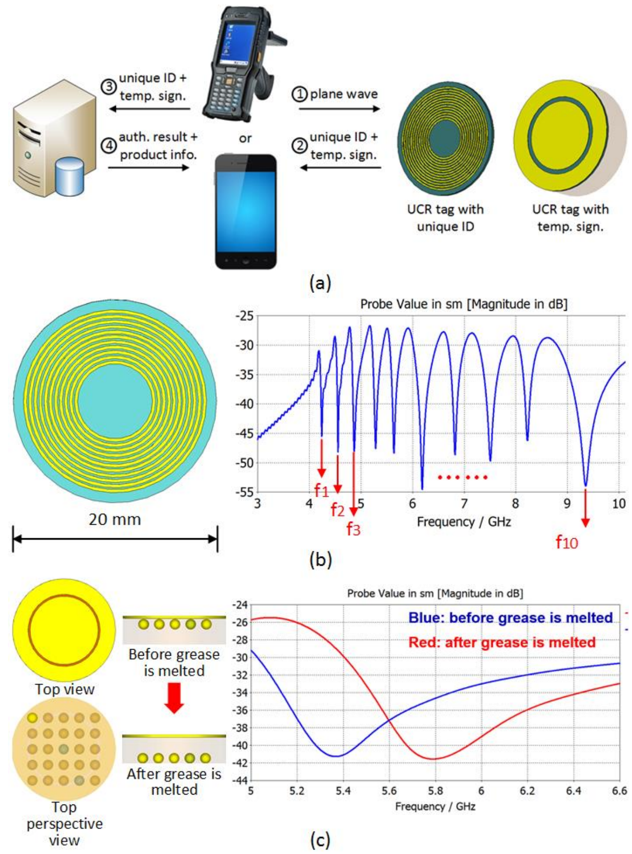

Figure 1: UCR system: (a) communication flow in real scenario, (b) UCR part I, and (c) UCR part II.

UCR

UCR tag consists of two parts: (i) a certain number of concentric ring slot resonators placed on a certain substrate (e.g., TACONIC TLX-0), whose resonance frequencies depend on slot parameters and substrate dielectric constant that are sensitive to manufacturing variations; and (ii) a standalone circular ring slot resonator placed on a particular substrate (e.g., grease) that will be melted at a high temperature, whose resonance frequency depends on slot parameters, substrate dielectric constant, and ambient temperature. When we stimulate the first part of UCR tag with an ultra-wide band (UWB) plane wave, the number of fundamental resonance points in the frequency response spectrum will correspond to the number of slot resonators, as shown in Figure 1(b). These resonance points are independent of each other. Due to process variations during tag fabrication, the slot parameters (i.e., trace width, air gap, substrate thickness, and substrate material dielectric constant) of each resonator will shift away from their design values. Because of the randomness of process variation, the frequency signature of each UCR tag will be unique and different from each other. The vector (f_1, f_2, ..., f_N) will be used as the identifier of each tag, where f_i indicates the resonance frequency of the i*th* slot resonator. The proposed UCR tag is unclonable since the adversaries cannot easily model the uncontrollable process variations during tag fabrication. The resonance frequency of the second part of UCR tag depends on slot parameters, substrate dielectric constant, and ambient temperature. In order to implement temperature tracking, copper balls will be filled into the substrate (made of grease) of the second part of UCR tag. If the UCR tag has ever been exposed to a high temperature, the grease would be melted and the copper balls would fall down to the bottom. The positions of copper balls in the substrate will impact the distribution of electro-magnetic field. Consequently, the resonance point of the second part of UCR tag will shift to a higher frequency after grease is melted, as shown in Figure 1(c). A typical UWB RFID reader or a smart phone that integrates necessary hardware (i.e., antenna, analog front-end, analog-to-digital converter, etc.) will be responsible for providing the UWB plane wave and capturing the frequency response spectrum. Figure 1(a) illustrates the communication flow in real application scenario.

Hardware Demo

Our experimental setup for evaluating UCR performance is shown as in Figure 2(a). Figure 2(b) and Figure 2(c) respectively illustrate the prototypes of UCR part I and UCR part II. A vector network analyzer (VNA) connected to two UWB PCB antenna (one working as transmitter and the other working as receiver) will be responsible for reading the UCR tag attached to a pharmaceutical package. The frequency spectrum of UCR tag will be displayed on the monitor of VNA, as shown in Figure 2(d).

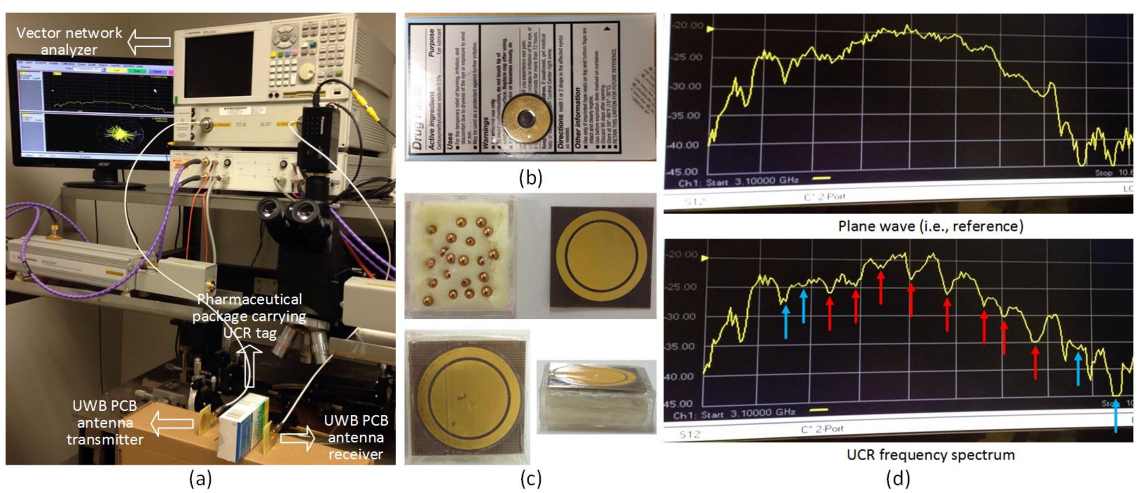

Figure 2: (a) Experimental setup for evaluating UCR performance, (b) UCR part I prototype, (c) UCR part II prototype, and (d) UCR frequency spectrum.

References

[1] Yang, Kun, Domenic Forte, and Mark M. Tehranipoor. "UCR: An unclonable chipless RFID tag." In Hardware Oriented Security and Trust (HOST), 2016 IEEE International Symposium on, pp. 7-12. IEEE, 2016.