Chameleon® Self-Tuning

Background

RFID has moved beyond the proof-of-concept stage in a number of application areas, including reusable containers, data center assets and retail apparel. The core technology is proven, key standards are in place, and early adopters have production implementations in operation. However, tag read consistency limits RFID's benefits in many situations, requiring additional system installation cost and/or additional labor in ongoing operation. Many of the consistency issues relate to the fact that tags based on existing RFID chips have a performance level that varies significantly from event to event. Tags can lose performance due a variety of environmental factors that move them out of tune; consequently, tags using conventional chips exhibit reduced read range or missed reads as a result.

RFMicron has developed Chameleon® technology to address tag detuning problems and provide a new level of performance consistency to RFID tags and systems.

Tag Design and Impedance Matching

Passive RFID tags are produced in many different shapes and sizes, but tags all consist of an integrated circuit, or chip, connected to some kind of antenna. There are many different types of antenna structures, all made of some kind of conductive material in a carefully chosen pattern and designed to gather RF (Radio Frequency) signals from RFID readers and to send signals generated by the chip. Tag antennas are designed with a particular chip in mind, and also take into account the expected applications of the tag and the planned operating frequencies.

To maximize the performance of a tag, the transfer of RF power between the chip and the antenna (in both directions) needs to be optimized through a process called impedance matching. The chip and the antenna each have an electrical "impedance" that can be measured at the connection point between them.

Figure 1 below shows a metal-mount tag prototype with a chip in place; a connection is made in manufacturing from the chip to contact pads on the antenna. Figure 2 is a simplified electrical representation of the impedance of the antenna and the chip at the contact point.

Figure 1: Tag antenna with chip attached

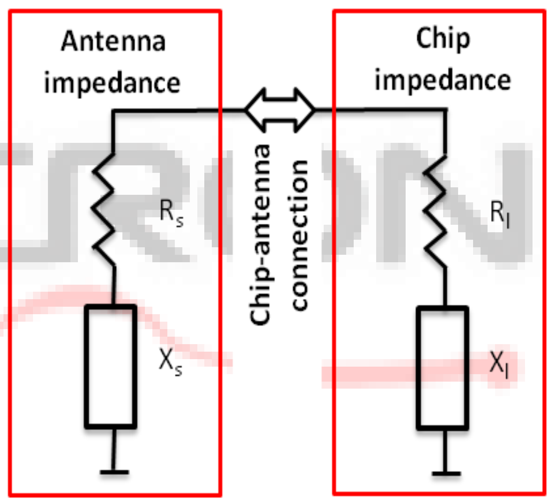

Figure 2: Electrical schematic of chip and antenna impedances

An impedance can be expressed as a combination of resistance (R) and reactance (X). In Figure 2, the antenna is considered the source (hence R_s and X_s) and the chip is considered the load (hence R_l and X_l) for the purpose of this discussion.

A matched impedance that provides optimum performance requires that the chip and antenna impedances be "complex conjugates" of each other. A complex conjugate simply means that $R_s = R_l$ and $X_s = -X_l$.

Conventional RFID tag chips have a single fixed impedance, with their R and X values published on the chip's data sheet. A tag antenna designer can use that information to design an impedance-matched antenna whose impedance is matched to that chip. Unfortunately, the proper match will hold for only a specific frequency and set of environmental conditions.

Tag Detuning

Although the impedance of a conventional tag chip is fixed, the impedance of an antenna is not. Antenna impedances vary with frequency, and are affected by nearby liquids and metals that modify the RF field. When the fixed chip impedance does not match the varying antenna impedance, the tag is said to be "detuned". For example, a tag that is impedance-matched under typical conditions (say at 915 MHz in the US and positioned away from interfering materials) might be severely detuned at 868 MHz in Europe or when placed near a metal beam in a warehouse. So a more accurate representation of the chip-antenna circuit would be as shown in Figure 3. (Note that Rs will also vary, but its variations have less impact on tag performance.)

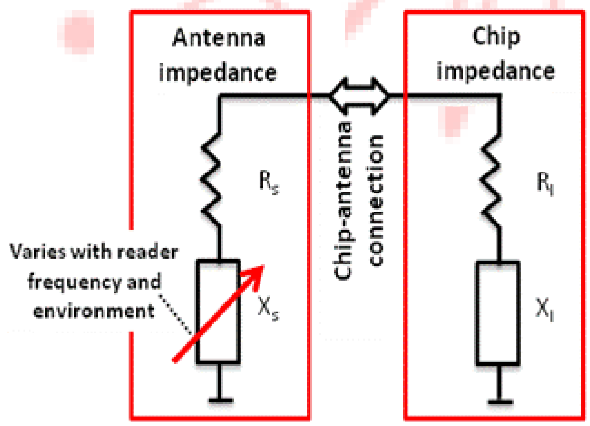

Figure 3: Schematic showing variable antenna impedance with a fixed-impedance chip

Conventional RFID tag chips, with a fixed impedance, cannot provide a good match to a tag antenna over a wide range of frequencies and environments. Tag producers have been able to work around the problem to a degree. For example, broadband (or "global") tags can reduce the effect of frequency changes on antenna impedance, but at the expense of lower performance at all frequencies. And "metal-mount" (or "on-metal") tags can be placed directly on metal objects but can still be detuned by other nearby materials.

The Chameleon® Solution

RFMicron has patented, and proven in silicon, a novel self-tuning mechanism (called Chameleon® technology) that enables tags to remain properly tuned over a wide range of frequencies and environmental conditions. The Chameleon® engine is built into a tag chip and autonomously adjusts the chip's impedance to optimize the match to the antenna for every set of conditions. The chip contains a set of circuit elements (capacitors) that can be switched in or out of the impedance matching network under the control of the Chameleon® engine. The process works as follows:

1. As soon as a signal is received by the tag antenna, the Chameleon® engine wakes up and begins operation. The Chameleon signal processing circuitry requires very little power to operate and can accomplish the self-tuning with much less power than is required for normal chip operation. Operation of the Chameleon circuit is automatic and does not require any reader commands – a Chameleon-based chip will look like any other ISO 18000-6C/EPC Gen 2 chip to the reader. The complete self-tuning process takes less than 120 microseconds, and will be invisible to the rest of the system.
2. The Chameleon® engine starts by assessing the power coming into the chip, and then begins adjusting the matching network to find the setting at which maximum power transfer is achieved. That setting represents the best impedance match with the antenna for the current operating frequency and environmental conditions.
3. Once the tuning is complete and sufficient power is available for full chip operation, the Chameleon circuit

signals the rest of the chip to power up and communicate normally with the reader. The Chameleon engine will self-tune once at the beginning of a communication session with a reader and hold that tuning until the session ends.

With a Chameleon-based chip, the impedance-matching schematic will look like Figure 4, where the chip's impedance is dynamically adjusted to match the changing antenna impedance.

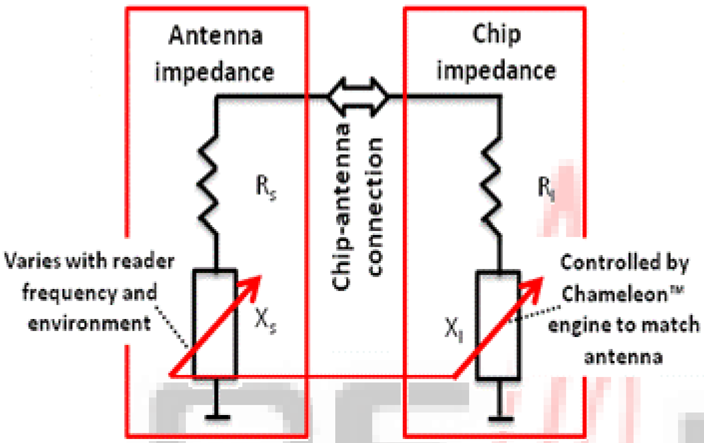

Figure 4: Impedance matching with Chameleon circuit

System Implications

Today's UHF RFID tags offer remarkable performance, considering that they have no internal power source. Under optimum conditions, some tags can be read at 30 meters (100 feet) with modern readers, and at even longer range with specialized multi-element antennas. However, in most applications, the ***maximum*** read range is much less important than the ***minimum*** read range – the range at which the tag will be consistently read under all anticipated operating conditions. An asset tag that can be read at 10 meters in an open field outdoors but reads at only 1 meter on the metal shelving of a cluttered warehouse is less useful than a tag that reads at 5 meters outdoors and 3 meters in the warehouse.

As an example of the variable performance of tags using conventional chips, Figure 5 below shows read range vs. frequency for a family of well-regarded mount-on-metal tags, as published by the manufacturer.

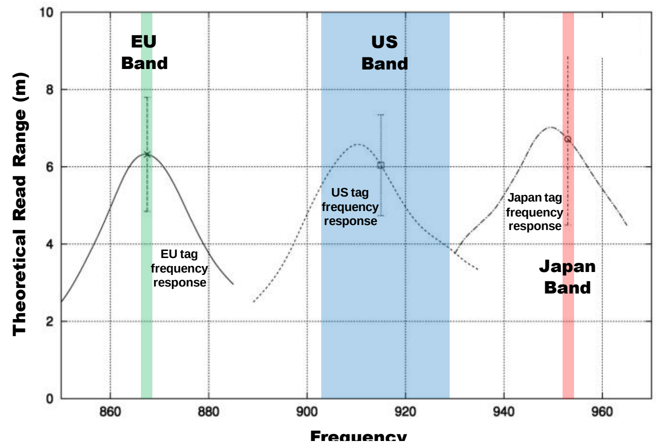

Figure 5: Example performance curves for on-metal tags

In the figure, the three curves show the performance of the three different versions of the tag, each designed for operation in a different regional frequency band. The regulatory EU, US and Japan frequency bands are highlighted in green, blue and red for reference. Two simple conclusions can be drawn from the chart:

- First, none of the tags will be able to provide a meaningful level of performance in a region other than the one targeted by the tag. Further, because of the width of the US band, the US tag will vary in range performance from 4 to 6.5 meters depending on the communication channel randomly selected by the reader. These issues can be addressed to some degree with broadband tag designs, but such designs are relatively difficult for on-metal applications and do entail significant tradeoffs in range to achieve a broadband response.

- Second, it is clear that any kind of detuning that causes a frequency shift in the tag's response will have a major impact on tag performance. It is clear from the curves that a 20 MHz frequency shift from the peak will halve the performance of any of the tags. Such a shift is not at all uncommon –

two examples where such a shift can be seen are:

- Tags on outdoor assets can suffer a 20 MHz shift when wet from rain; and
- Inventory tags on apparel in a retail setting can shift by 20 MHz when stacked closely together in comparison to tags hanging freely at a distance from other tags.

Variations in tag performance can usually be accommodated with careful system design – by adding extra readers and antennas, by carefully tuning reader output power and antenna positioning, or by introducing process changes that constrain how tags are presented to the reader. However, such accommodations come at a cost in terms of added hardware expenses, system integration time and cost, and/or ongoing operating or maintenance expense. Such expenses can be quite high, particularly when a finely-tuned system needs to be recalibrated on a regular basis to maintain consistent performance.

A better approach is to use tags whose performance remains consistent under varying conditions. As mentioned above, the use of broadband ("global") tags can help. Chameleon® technology goes a step further and allows tags to adjust to both frequency and environmental changes to remain in proper tune at all times. Measurements from functional chips have proven both the proper operation of the Chameleon® self-tuning circuit and its impact on tag performance. Figure 6 below shows the frequency response of a prototype metal-mount tag design with and without the Chameleon function engaged.

The antenna design used for the test is pictured above the response curves; for this test, the antenna was held about 1mm from a metal surface to approximate a mount-on-metal situation.

The only difference between the two curves is the use of the Chameleon self-tuning circuit. The red curve shows the response without self-tuning – the response that would be achieved with a conventional fixed-impedance chip. The black curve shows the response of the same tag with self-tuning capability.

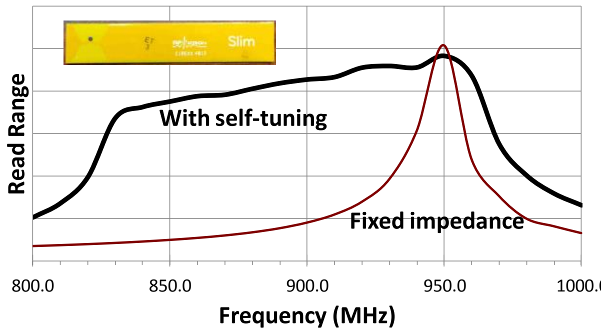

Figure 6: Frequency response of test design with Chameleon on and off

For some users, an RFID system that offers a read rate of 99% - or even 95% - may be perfectly adequate. One large retailer who uses RFID to do frequent sales floor inventory has said just that: the accuracy offered by the RFID system is still a vast improvement over the old system, and they are comfortable that items missed on one inventory count will be caught during the next one.

On the other hand, many applications – especially those involving tagged assets or shipments that are not low-cost disposable items – will realize significant value if read rates can be improved by even small amounts to more closely approach 100%. For those applications, eliminating the cost of even a small number of missed reads and the subsequent exception handling can significantly improve the economics of an RFID deployment.

RFMicron has developed the Chameleon® technology to address the last few percentage points of RFID performance. Through self-tuning, Chameleon-based tags will offer more consistent performance, resulting in fewer missed reads, less exception handling, and simpler, faster and less expensive system design and implementation.

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