RFID Antennas and Sensors
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Topics

Spotlight On

Split ring antennas - A Less Explored Antenna Type in Far Field RFID Tags
Fig. 3

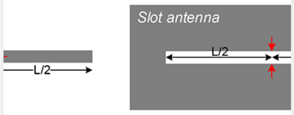

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Fig. 1

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Fig. 2

Editors

1. Split ring antennas

1A. Split ring antennas - A Less Explored Antenna Type in Far Field RFID Tags

By Toni Björninen

Dipole antennas are popular in far field RFID tags. They have an inherently omnidirectional radiation pattern which provides broad spatial coverage for energy harvesting and their single-layer structure is fit for cheap mass manufacturing. Slot antennas share these favorable qualities and exhibit inductive input impedance below the self-resonance frequency of the antenna structure. This facilitates the conjugate impedance matching with capacitive tag ICs. However, the footprints of slot antennas tend to be large in comparison with dipoles. This has perhaps hindered their use in RFID applications. Figure 1 illustrates the geometries of dipole and slot antennas. In the most basic configuration, the main radiating dimension L will be in the order of half of the operating wavelength.

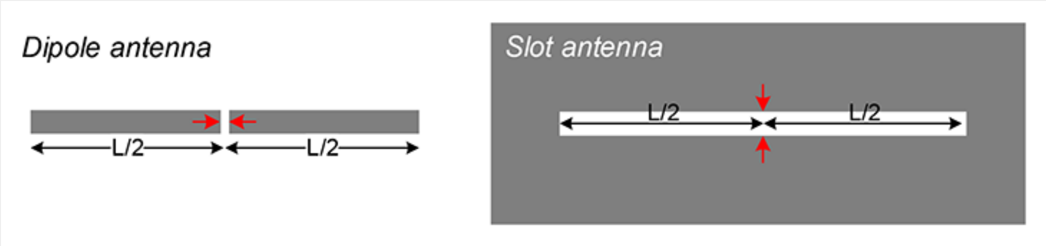

Fig. 1 *Geometries of dipole and slot antennas. Red arrows indicate the antenna terminals.*

A split ring resonator (SRR) can be composed of concentric rings or rectangles with gaps at opposite ends as illustrated in Figure 2. It is an important building block of metamaterials. The magnetic response of periodic arrangements of SRRs have been investigated in detail by Pendry et al. [Pendry et al. 1999]. As shown by Alici and Ozbay [Alici and Ozbay 2007], a monopole loaded with a SRR perpendicular to a ground plane provided a well-performing antenna, where the monopole and SRR occupied a space of only 0.095λ×0.1λ. Later, Sang-Ho Lim et al. [Lim et al. 2008] proposed a split ring resonator antenna to meet the common application specific requirements of an RFID tag antenna: simple single-layer structure, broad spatial coverage and inductive input impedance.

Fig. 2 *Common configurations of split ring resonators based on concentric rings and concentric rectangles.*

In [Lim et al. 2008] the tag IC was mounted over the gap in the inner ring as shown in Figure 3. Hence, the antenna is based solely on a SRR loaded with the tag IC. The diameter of the antenna was 51.6 mm, which is approximately 0.16λ at 915 MHz. In addition to the compact size, the antenna reactance showed a non-monotonic frequency trend in the vicinity of the design frequency of 915 MHz. This can be exploited to implement broadband or dual band impedance matching. Since then, innovative uses of SRRs have been employed in the research on antennas for far field RFID tags. For instance, a meander line dipole antenna based on four split ring resonators in series was proposed by Benjamin B. Braaten [Braaten 2011]. The footprint of the tag was only 0.036λ×0.17λ at 920 MHz. At the same time, Ferran Paredes et al. presented a design procedure [Paredes et al. 2010] for an impedance matching network based on the proximity-coupling of a SRR and transmission line section to provide dual band matching in a slot type tag antenna. They demonstrated the method with a prototype designed for the closely-spaced European and U.S. RFID bands centered at 866.6 MHz and 915 MHz, respectively.

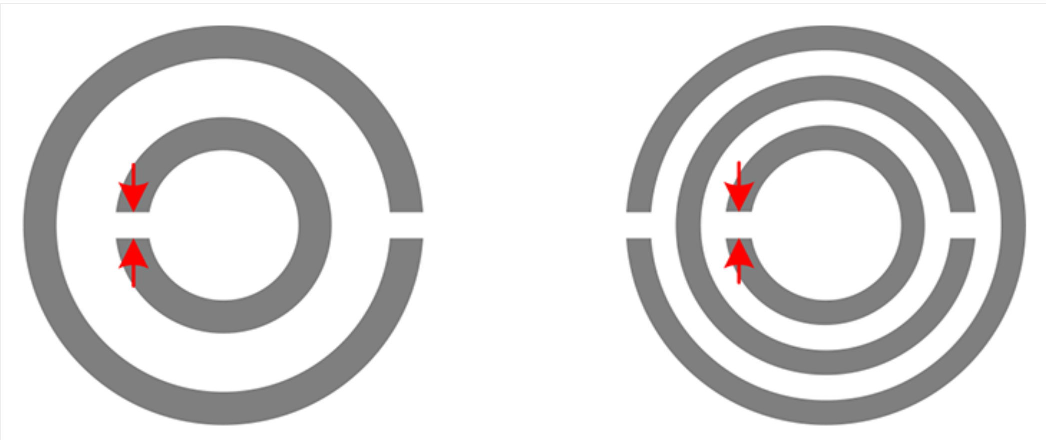

Fig. 3 *Configurations of split ring antennas studied in [Lim et al. 2008] and [Polivka et al. 2013]. Red arrows indicate*

the antenna terminals connected to the tag IC.

In a recent contribution [Polivka et al. 2013] published in 2013 volume of IEEE Antennas and Wireless Propagation Letters, Milan Polivka et al. revisited and extended the concept of a far field RFID tag based solely on a SRR loaded with the tag IC—similar to what was described by Sang-Ho Lim et al. [Lim et al. 2008]. The authors investigated and compared electrically small double and triple split ring configurations, which are both illustrated in Figure 3. The studied antennas achieved compelling size-performance ratios simultaneously with inductive input impedance needed for the antenna-IC impedance matching in RFID tags. The simulation study of a large set of antenna configurations showed that the inclusion of a third concentric ring provided antenna sizes down to the outer ring radius of λ/21 with inductive antenna impedance and radiation efficiency higher than 50%. In terms of miniaturization, this is a very encouraging result for the future antenna research and development of small RFID tags.

2. RFID Sensors

2A. Wireless Battery-free Sensors: IC-Based and SAW-Based Sensing Technology

by Cecilia Occhiuzzi

In the last few years, one of the most common questions asked by RFID Engineers and designers is about the difference between SAW (surface acoustic wave)-based and IC-based RFID sensing technologies and consequently, if there is any appreciable advantage in using one platform versus the other.

Effectively, both SAW and IC-based tags belong to the same technological class: they are both battery-free RFID devices, i.e. devices that exploit Radio frequency (RF) to wirelessly and passively provide their identification (ID) code to a remote transceiver by backscattering a modulating version of the interrogating signal. However, the physics of the backscattered wave is significantly different: the operation of SAW tags is based on piezoelectricity while the functioning of IC tags is only related to a programmable switch, which is able to modulate the impinging field by changing its internal impedance.

Since the mechanical propagation of the wave is affected by the state of the piezoelectric crystal, SAW tags show an inherent sensing capability, and hence in the last 30 years they have been naturally proposed as temperature, mechanical and chemical sensors. On the other hand, from the beginning of their history, IC-based RFID tags have always been considered as labeling devices only, able to give an identity to the objects where they are attached on. However, IC-based RFID technology is rapidly evolving from simple labeling of things to wireless pervasive sensing. The key background is a new paradigm of antenna design that merges together the conventional communication issues with more-specific requirements about sensitivity to time-varying boundary conditions.

A good starting point to better understand the two sensing approaches is given by two reviews recently published by da Cunha [da Cunha 2013] and Occhiuzzi et al [Occhiuzzi, Caizzone and Marrocco 2013]. Apart from the differences in the physical principles and in the measurement techniques exhaustively described in both contributions, three aspects deserve an in-depth analysis: the first one relies on the potential of the two technologies, the second one on their pervasivity and the last one on the applications fields.

While SAW sensors are static devices, whose piezoelectric crystal is designed such that to give a fixed code and to be sensitive to a specific stimulus. IC-RFID tags are tiny computers of increasing performance: data transmitted back to the reader during the interrogation protocol are digitally encoded, but the strength of the backscattered power is governed in an analog manner by the interaction with nearby objects, by the propagation modality, and even by the mutual position and orientation between the reader and the tags. It is hence possible to appoint an inherent and **multi-faced sensing capability** also to those devices, entirely based on the physics governing the antenna function. This fact poses the basis for a different sensing modality, wherein the captured data can even be collected by a “sensor-less” tag (as described in the review, researchers demonstrated that it is possible to use the same RFID IC to monitor the filling level of a beer glass as well as a biological process in evolution inside the human body, provided that both phenomena are able to perturb the tag antenna function). The great limiting aspect of such an approach is the non-specificity of the sensing mechanism, since the sensed data may be only indirectly related to a physical phenomenon under observation. A more effective way to retrieve specific sensing data is to provide the tag with a “real” sensor. This could be either lumped into a device, connected in some part of the tag's antenna, or instead distributed all over the antenna's surface, for instance, as a chemical-receptor painting.

Because the SAW and IC-based devices are wireless, relatively cheap and battery and maintenance free, they have been both proposed as the enabling technologies for the effective boosting of the Internet-of-Things (IoT), however, only IC-based sensors seem up to now ready for such a task. To be suitable in IoT applications a device has to be readable at adequate distance from the reader (~10m) while keeping a miniaturized size such as to be embedded/attached/blended in the “things”, to be cheap enough to be dispersed in the environment, to be robust and with standardized communication protocols in order to be scaled without the necessity of modifying the infrastructure and with high coding features to uniquely label each daily-life object. The read distance in both SAW and IC-based devices is mainly limited respectively by the power losses on the crystal or by the power absorbed by the tag to activate the chip, as well as by the power available from the reader. Since SAW devices operate in the ISM band, the maximum allowed power level from reader is about 10mW, while in the UHF RFID band it is possible to emit approximately up to 4W leading to a read distance of about 5m for SAW and 12m for IC tags. Regarding the power absorbed or lost by the sensor, instead, SAW devices show better performances as they do not require any additional power for the sensing functionality, nor do they have any electronic circuit to be biased. Also "sensor-less" IC-based tags do not need power for the sensing functionality, but they do need to receive enough power to turn the IC on. On the other hand, when a "real" sensor is attached to the IC-based tag, it will also need power, thus increasing the total power consumption. It is however worth specifying that the power consumption of ICs is likely to diminish in the near future, approximately following the well-known Moore's law (in 2010 IC sensitivity was about −15dBm, now it has reached −21dBm).

SAW sensors can be interrogated in three possible dimensions: time, frequency and code. Such versatility is necessary to increase the coding capability of the tags but reveals the lack of a standardized communication protocol and maybe the inappropriateness of such a technology to reach the "things" dimension. Approximately each class of SAW sensor requires a dedicated and customized reader, optimized for reading a limited number of devices at a time and at a maximum distance. That aspect forces the design of ad-hoc solutions for almost any single application, causing higher infrastructural cost compared to IC-tags. The cost of SAW readers is increased also by the necessity to adopt high quality components able to discriminate several distinct signals with extremely low signal-to-noise ratio.

Finally, since IC tags contain a memory and a processor, any information in these tags can be re-written, with undeniable benefits in transforming objects and structures in "smart" devices.

Regarding the application fields instead, probably the most attractive feature of SAW sensors is their capability to operate in harsh environment, characterized by physically and chemically aggressive conditions. Because a SAW device consists only of a piezoelectric crystal and a single layer metal pattern, SAW tags are very robust and can withstand gamma ray sterilization and elevated operating temperatures for long time periods (the review reports application examples in the aerospace sector in which temperatures close to 1000°C have been correctly measured by SAW sensors rotating at approximately 50KHz). In contrast, IC-based tags are very sensitive to such harsh conditions and typically operate only up to 85°C without a proper insulating package.

In conclusion of such a contribution, it appears quite clear that both SAW-based and IC-based RFID sensors can produce great advantages in realizing transparent and distributed sensing platforms. Although there are numerous similarities, the two classes of device represent distinct Worlds and different implementation philosophies, with only partial overlapping. While the former seem to offer better sensing performance especially in hostile environments and in situations where accurate and precise wireless measurements are required, the latter seem to be more ready to effectively realize the "*last meter of IoT*" in all those fields where the lower measurement accuracy is compensated by the advantage of pervasiveness, i.e. the presence of a myriad of sensing points vanishing into things. However, the design of those sensors is not yet a mature discipline, since unified methodologies are still required to efficiently handle multi-physics optimization and data processing. For sure, **their history is only at the beginning** (the first paper has been written only in 2006) and very important updates are expected in the future from both academia and industry.

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