Antenna Design for UHF RFID Tags: A Review and a Practical Application

K. V. Seshagiri Rao, *Senior Member, IEEE*, Pavel V. Nikitin, *Member, IEEE*, and Sander F. Lam

Abstract—In this paper, an overview of antenna design for passive radio frequency identification (RFID) tags is presented. We discuss various requirements of such designs, outline a generic design process including range measurement techniques and concentrate on one practical application: RFID tag for box tracking in warehouses. A loaded meander antenna design for this application is described and its various practical aspects such as sensitivity to fabrication process and box content are analyzed. Modeling and simulation results are also presented which are in good agreement with measurement data.

Index Terms—Antennas, passive modulated backscatter, radio frequency identification (RFID), tags, transponders.

I. INTRODUCTION

RADIO FREQUENCY identification (RFID) is a rapidly developing technology which uses RF signals for automatic identification of objects. Although the first paper on modulated backscatter (basic principle of passive RFID) was published in 1948 [1] it took considerable amount of time before the technology advanced to current level [2]. Now RFID finds many applications in various areas such as electronic toll collection, asset identification, retail item management, access control, animal tracking, and vehicle security [3]. Several standards of RFID systems are currently in use (ISO, Class 0, Class 1, and Gen 2).

Globally, each country has its own frequency allocation for RFID. For example, RFID UHF bands are: 866–869 MHz in Europe, 902–928 MHz in North and South America, and 950–956 MHz in Japan and some Asian countries. A typical passive RFID transponder often called "tag" consists of an antenna and an application specific integrated circuit (ASIC) chip. RFID tags can be active (with batteries) or passive (batteryless).

A passive back-scattered RFID system operates in the following way. A base station (reader) transmits a modulated signal with periods of unmodulated carrier, which is received by the tag antenna. The RF voltage developed on antenna terminals during unmodulated period is converted to dc. This voltage powers up the chip, which sends back the information by varying its front end complex RF input impedance. The impedance typically toggles between two different states, between conjugate match and some other impedance, effectively modulating the back-scattered signal. Fig. 1 illustrates a passive RFID system operation.

Proper impedance match between the antenna and the chip is of paramount importance in RFID. Since new IC design and manufacturing is a big and costly venture, RFID tag antennas are designed for a specific ASIC available in the market. Adding an external matching network with lumped elements is usually prohibitive in RFID tags due to cost and fabrication issues. To overcome this situation, antenna can be directly matched to the ASIC which has complex impedance varying with the frequency and the input power applied to the chip.

Several papers have been published on RFID antennas for both passive and active tags, including covered slot antenna design [4], circular patch antenna analysis [5], meander antenna optimization [6], planar inverted F-antenna [7], folded dipole antenna [8], etc. However, very few papers [9] provided an overview of criteria for RFID tag antenna design and an analysis of practical application aspects. At the same time, there exist many papers on practical analysis and design of particular classes of antennas used for other applications [10]–[12].

In the current article, we attempted to fill the existing gap. We reviewed design requirements for passive UHF RFID tag antennas, outlined the design process, described range measurement techniques, and proposed a performance chart for tag analysis. We also presented a specific application example: a passive UHF tag design for a RFID tag placed on a cardboard box that is being tracked in standard supply chain. The design is a versatile loaded meander antenna which can be easily tuned for boxes with various content like dry goods or plastics. This example is supplemented with modeling and simulation results which are in close agreement with measured data.

II. ANTENNA DESIGN

A. Performance Criteria

The most important tag performance characteristic is read range—the maximum distance at which RFID reader can detect the backscattered signal from the tag. Because reader sensitivity is typically high in comparison with tag, the read range is defined by the tag response threshold. Read range is also sensitive to the tag orientation, the material the tag is placed on, and to the propagation environment.

The read range r can be calculated using Friis free-space formula as

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r \tau}{P_{th}}} \qquad (1)$$

where λ is the wavelength, P_t is the power transmitted by the reader, G_t is the gain of the transmitting antenna, G_r is the gain of the receiving tag antenna, P_{th} is the minimum threshold
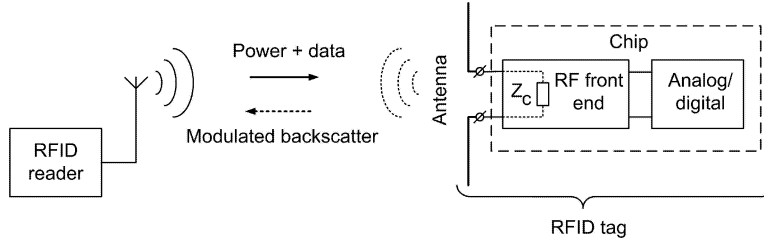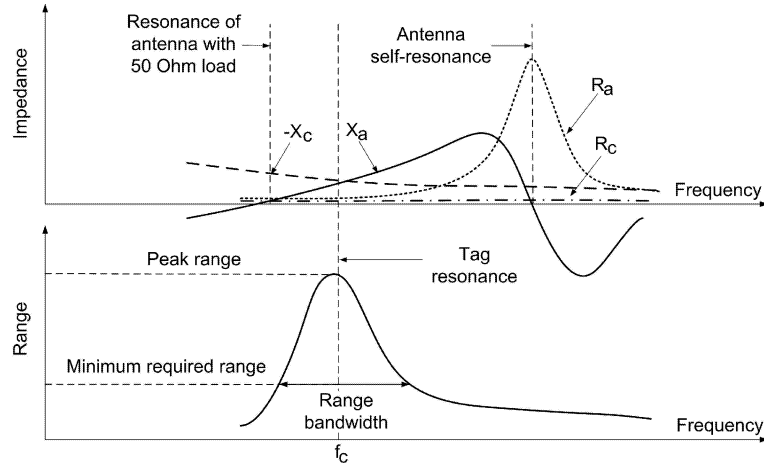
Fig. 1. RFID system operation. The backscattered signal is modulated by changes in chip impedance Z_c.

Fig. 2. Antenna impedance, chip impedance, and range as functions of frequency for a typical RFID tag.

power necessary to provide enough power to the RFID tag chip, and τ is the power transmission coefficient given by

$$\tau = \frac{4R_cR_a}{|Z_c + Z_a|^2}, \quad 0 \le \tau \le 1 \quad (2)$$

where $Z_c = R_c + jX_c$ is chip impedance and $Z_a = R_a + jX_a$ is antenna impedance.

Qualitative behavior of antenna impedance, chip impedance, and read range as functions of frequency for a typical RFID tag is illustrated in Fig. 2. The frequency of the peak range is referred as the tag resonance. The tag range bandwidth can be defined as the frequency band in which the tag offers an acceptable minimum read range over that band. From (1) one can see that read range is determined by the product P_tG_t of the reader (transmitter EIRP), tag antenna gain G_r, and transmission coefficient τ. Typically τ is dominant in frequency dependence and primarily determines the tag resonance which happens at the frequency of the best impedance match between chip and antenna. This frequency is different from the resonant frequency of antenna loaded with 50 Ohm and the antenna self-resonance.

The range in (1) can be normalized with a factor $r_o = (\lambda/4\pi)\sqrt{P_tG_t/P_{th}}$. This factor is the range of the tag with 0 dBi antenna perfectly matched ($\tau = 1$) to the chip impedance at a fixed frequency. Contours of constant range from (1) can be plotted on gain-transmission coefficient plane as shown in Fig. 3 where they are labeled with their values normalized to r_o. The chart in Fig. 3 can be used as a common reference frame to present the performance of any RFID tag antenna similar to impedance presentation of a circuit
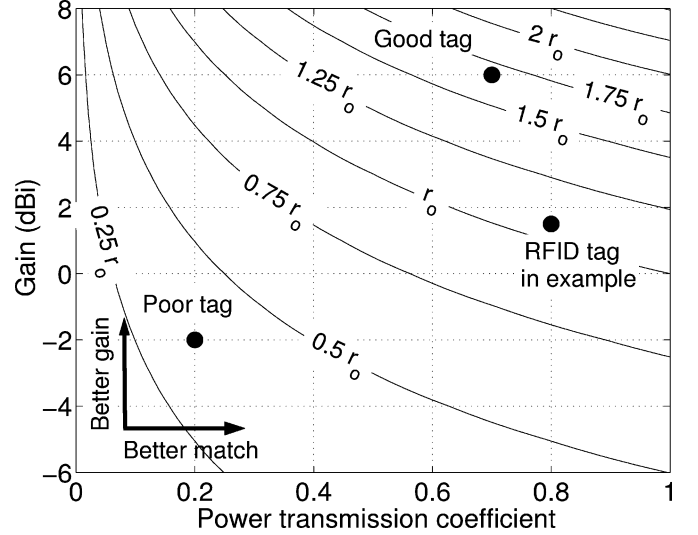
Fig. 3. Tag antenna performance chart: contours of constant normalized range in gain-transmission coefficient plane where the range multiplier is $r_o = (\lambda/4\pi)\sqrt{P_tG_t/P_{th}}$. Peak free-space performance of RFID tag in example given in this article is also shown.

on a Smith chart. The same range can correspond to several gain-transmission coefficient combinations.

The RFID tag antenna design process involves inevitable tradeoffs between antenna gain, impedance, and bandwidth. The performance chart in Fig. 3 helps the designer to estimate the range tradeoff between the impedance matching and the gain. The normalization factor for this performance chart can be easily calculated for any case of EIRP and threshold power of the chip for a given frequency.

B. Design Requirements

Several general RFID tag design requirements whose relative importance depends on tag application are discussed in the following paragraph. These requirements largely determine the criteria for selecting an RFID tag antenna.

1) **Frequency band.** Desired frequency band of operation depends on the regulations of the country where tag will be used.

2) **Size and form.** Tag form and size must be such that it can be embedded or attached to the required objects (cardboard boxes, airline baggage strips, identification cards, etc.) or fit inside a printed label.

3) **Read range.** Minimum required read range is usually specified for different:
   - **EIRP.** EIRP is determined by local country regulations.
   - **Objects.** Tag performance changes when it is placed on different objects (e.g. cardboard boxes with various content), or when other objects are present in the vicinity of the tagged object. Tag antenna can be designed or tuned for optimum performance on a particular object or designed to be less sensitive to the content on which the tag is placed.
   - **Orientation.** Read range depends on antenna orientation. Some applications require a tag to have a specific directivity pattern such as omnidirectional or hemispherical coverage.

4) **Applications with mobility.** RFID tag may be used in situations where tagged objects like pallets or boxes travel on a conveyor belt at speeds up to either 600 ft/min or 10 mph. The Doppler shift in this case is less than 30 Hz at 915 MHz and does not affect RFID operation. However, the tag spends less time in the read field of RFID reader, demanding high read rate capability. In such cases, RFID system must be carefully planned to ensure reliable tag identification.

5) **Cost.** RFID tag must be a low-cost device. This imposes restrictions both on antenna structure and on the choice of materials for its construction including the ASIC used. Typical conductors used in tags are copper, aluminum, and silver ink. The dielectrics include a flexible polyester and rigid PCB substrates like FR4.

6) **Reliability.** RFID tag must be a reliable device that can sustain variations due to temperature, humidity, stress, and survive such processes as label insertion, printing and lamination.

C. Design Process

RFID tag antenna performance strongly depends on the frequency-dependent complex impedance presented by the chip. Tag read range must be closely monitored in the design process in order to satisfy design requirements. Since antenna size and frequency of operation impose limitations on maximum attainable gain and bandwidth [13], [14] compromises have to be made to obtain optimum tag performance to satisfy design requirements. Often a tunable antenna design is preferable to provide tolerance for tag fabrication variations and for optimizing antenna performance on different materials in different frequency bands.
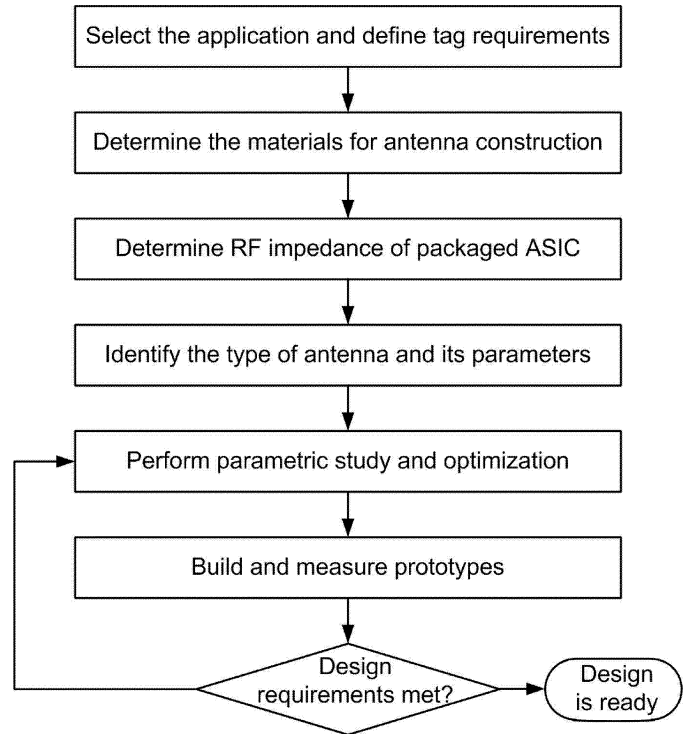

Fig. 4.   RFID tag antenna design process.

RFID tag antenna design process is illustrated on a flow chart shown in Fig. 4. Once the RFID application is selected, system requirements can be translated into tag requirements. These requirements determine the materials for tag antenna construction and ASIC packaging. The impedance of the selected ASIC in a chosen RF package (like flip-chip, etc.) to which antenna will be matched can be measured with a network analyzer.

Antenna parametric study and optimization is performed until design requirements are met in simulation. Like most antennas, RFID tag antennas tend to be too complicated for analytical solution as they can be used in complex environment. Tag antennas are usually analyzed with electromagnetic modeling and simulation tools, typically with method of moments (MoM) for planar designs (e.g. thin flexible tags) and with finite-element method (FEM) or finite-difference time-domain method (FDTD) for more complicated three-dimensional designs (e.g. thick metal mounted tags). Fast EM analysis tools are crucial for efficient tag design. In a typical design process, modeling and simulation tools can be benchmarked against measurements. Read range calculation can be implemented directly in EM software. Tag antenna is first modeled, simulated, and optimized on a computer by monitoring the tag range, antenna gain, and impedance which give to a designer a good understanding of the antenna behavior.

In the last step of the design process, prototypes are built and their performance is measured extensively. If design requirements are satisfied, the antenna design is ready. Otherwise, the design is further modified and optimized until requirements are met.

D. Range Measurement

Accurate tag range measurement can be conducted in a controlled environment, such as anechoic chamber or transverse electromagnetic (TEM) cell. In both methods tag position can be fixed and transmitter output power can be varied by controlled
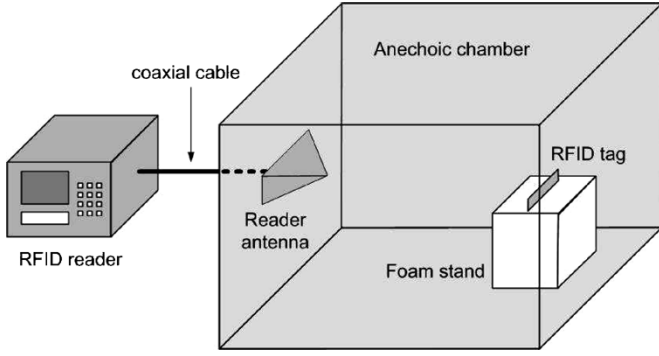
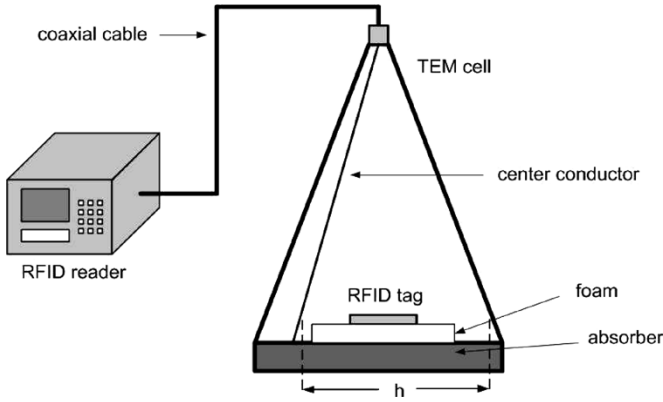Fig. 5.   RFID tag range measurement using anechoic chamber.

Fig. 6.   RFID tag range measurement using TEM cell.

attenuation. This allows one to carry accurate tag range characterization and avoid using large and prohibitively expensive chambers or cells. Compact TEM cell is a convenient tool for measuring small tags while larger anechoic chamber can be used to measure tag performance on various objects.

In anechoic chamber, the tag is placed at a fixed distance from the reader antenna as illustrated in Fig. 5.

At each frequency, the minimum power $P_{\min}$ required to communicate with the tag is recorded. Since the loss L of the connecting cable, the gain G_t of the transmitting antenna and the distance d to the tag are known, the tag range for any transmitter EIRP of interest can be determined from (1) as

$$r = d\sqrt{\frac{\text{EIRP}}{P_{\min}LG_t}}. \tag{3}$$

The general guidelines for selecting the tag position in anechoic chamber are the following: i) the distance must be such that the tag will respond and will be in far field and ii) the tag must be placed in a quiet zone of the anechoic chamber where multipath is minimal.

In TEM cell, the tag is placed inside, and the cell is connected to RFID reader with variable output power as illustrated in Fig. 6.

At each frequency, the minimum power $P_{\min}$ at the input of TEM cell required to communicate with the tag is measured. Tag range can be calculated from known expressions for the field inside TEM cell [15] as

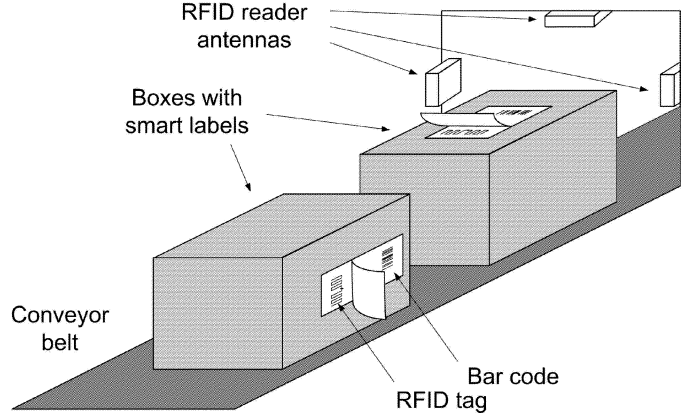$$r = h\sqrt{\frac{30\,\text{EIRP}}{P_{\min}LZ}} \tag{4}$$

Fig. 7.   RFID conveyor belt application. Boxes are equipped with smart labels and being tracked.

where h is the height of the TEM cell at the cross-section where RFID tag is placed and Z is TEM cell input impedance.

In our measurements, we used an anechoic chamber with 3 ft (0.91 m) distance to the tag and 6.2 dBi linearly polarized reader antenna. The TEM cell had parameters $h = 220$ mm and $Z = 50$ Ohm. Cable loss was -0.5 dB in both cases.

III. RFID Example

A. Application

Consider a specific application: a smart label for cardboard box labeling in warehouse environment worldwide. Such a label with a bar code printed on it and an RFID tag embedded underneath can be placed on cardboard boxes with various contents. Boxes may travel on a conveyor belt as shown in Fig. 7 or may be moved through large portals by forklifts equipped with RFID readers. Requirements to the tag design are the following:

- Tag should be easily tunable to any frequency in 860–960 MHz range for various contents in the final assembly when the tag is inserted into a label and placed on a cardboard box.
- Tag should have at least 2.5 m range with 4 W EIRP in 915 MHz band (902–928 MHz frequencies, US) and at least 2.2 m range with 2 W ERP (3.3 W EIRP) in 868 MHz band (866–869 MHz frequencies, Europe) to meet worst case application requirements.
- Tag should fit into a standard 6 × 4 inch label. It is desirable to have as small footprint as possible to fit into 4 × 2 inch and 4 × 1 inch labels for other potential applications.
- It is preferred to have omni-like read range performance for a tag.

B. Antenna Design

The process of antenna design is briefly described below.

- **Materials.** Because of cost and application considerations, it was decided to use for the antenna a thin flexible polyester substrate with a dielectric permittivity of 3.5 and a thickness t_s of 2 mil (0.051 mm). Top antenna trace was made of copper and had a thickness t_a of 0.7 mil (0.018 mm).

TABLE I
PARAMETERS OF THE LOADED MEANDER TAG ANTENNA (mm)

Parameters	l	w	s	d	a	b	t_s	t_a
Values	96	0.7	0.7	9	6	14	0.051	0.018

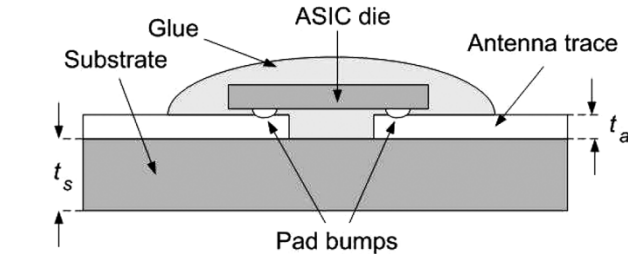Fig. 8. RFID chip affixed to antenna terminals using flip-chip packaging.
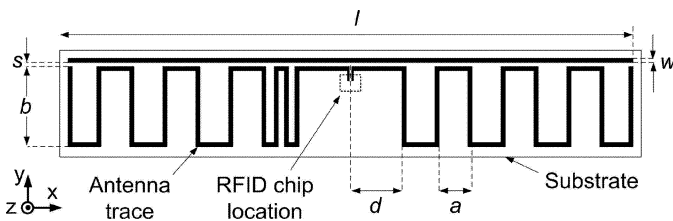
Fig. 9. Geometry of the loaded meander tag antenna.
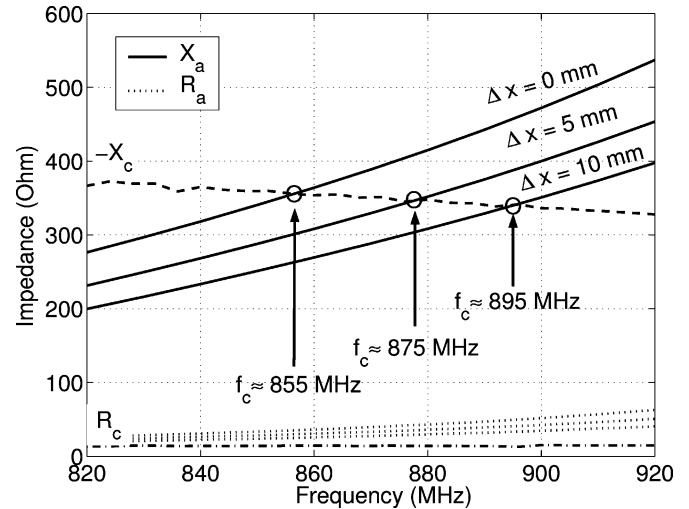

Fig. 10. Impedance of the loaded meander tag antenna (R_a, X_a) as a function of meander trace length trimming Δx. Tag resonance is determined by the best match with the chip impedance (R_c, X_c).

- **ASIC.** For this smart label application, we used Philips EPC 1.19 G2 RFID ASIC chip [16] mounted on antenna terminals as shown in Fig. 8 using flip-chip packaging [17] which has been widely established as a popular low-cost technique.

  The input impedance of the packaged chip was measured in the frequency domain with the network analyzer for different power levels. It was determined with RFID reader that the minimum power needed by the chip to turn on is −10 dBm, which agreed with manufacturer specifications.

- **Antenna type.** The antenna geometry is shown in Fig. 9. Because of the size and tunability requirements, meandered dipole antenna was a natural choice. Meandering allowed the antenna to be compact and to provide omnidirectional performance in the plane perpendicular to the axis of the meander. To have a better control over the antenna resistance, we added one loading bar with the same width as the meander trace. To provide a better match for the chip capacitive impedance, one meandered section was further meandered to obtain additional inductance. This antenna can be easily tuned by trimming. Lengths of meander trace and loading bar can be varied to obtain optimum reactance and resistance matching. The trimming is realized by punching holes through the antenna trace at defined locations. Such tunable design is desirable where it is often needed to provide a solution for a particular application with a minimum lead time.

- **Parametric study and optimization.** The loaded meander antenna has several key parameters: loading bar width w, distance d, spacing s, meander step width a, and meander step height b. Maximum allowed antenna length l is dictated by the size requirements. The parameters mentioned above influence antenna gain and impedance which determine tag resonance, peak range, and bandwidth. This thin planar antenna was optimized using Ansoft Designer. Tag range was computed from (1) using simulated values for gain G_r and impedance Z_a and measured values for chip impedance Z_c at the threshold power. Although Ansoft software had a powerful parametrics and optimization engine, its post-processing capabilities were not sufficient to create an adequate cost function for our design requirements. The optimal realizable combinations of tag antenna parameters were identified by plotting and examining the families of curves. After optimization, we arrived to the final parameter values for tag antenna given in Table I.

  Antenna reactance and resistance can be controlled by trimming as it is illustrated in Fig. 10. For example, trimming the meander trace by $\Delta x = 5$ mm moves the resonant frequency up by 20 MHz. The gain is not significantly affected by trimming as it is shown in Fig. 11. The performance of the untrimmed tag is also shown on the chart in Fig. 3.

- **Prototyping and validation.** Several tag prototypes similar to the one shown in Fig. 12 were fabricated and tested in both anechoic chamber and TEM cell range measurement setups.

  Fig. 13 presents a comparison between theoretical and experimentally measured read range for one of the tags tuned to 915 MHz band in free space. It can be seen that theoretical curve and experimental data are in close agreement. Differences between TEM cell data and anechoic chamber data are due partially to imperfections of anechoic chamber and partially to electric field nonuniformities inside TEM cell.
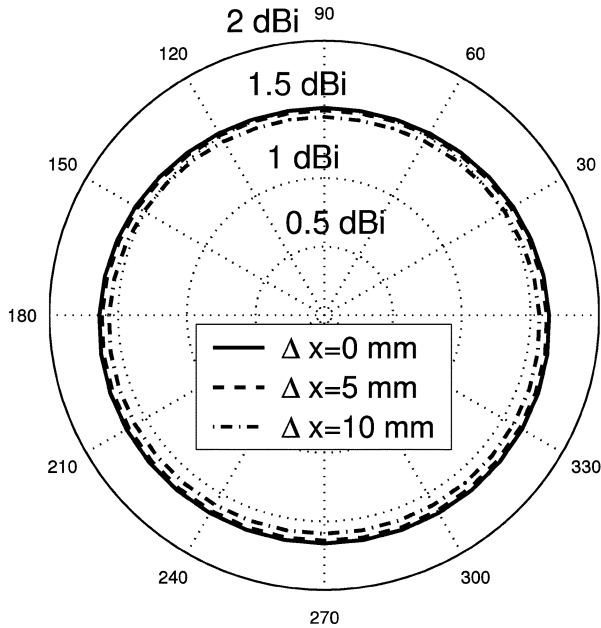
Fig. 11. Gain of the loaded meander tag antenna in yz-plane at 900 MHz as a function of meander trace length trimming Δx.
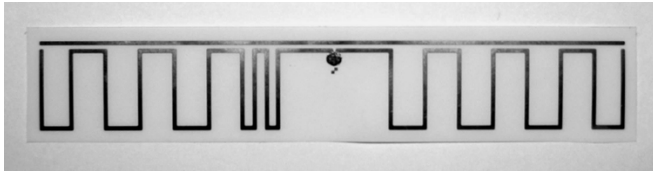

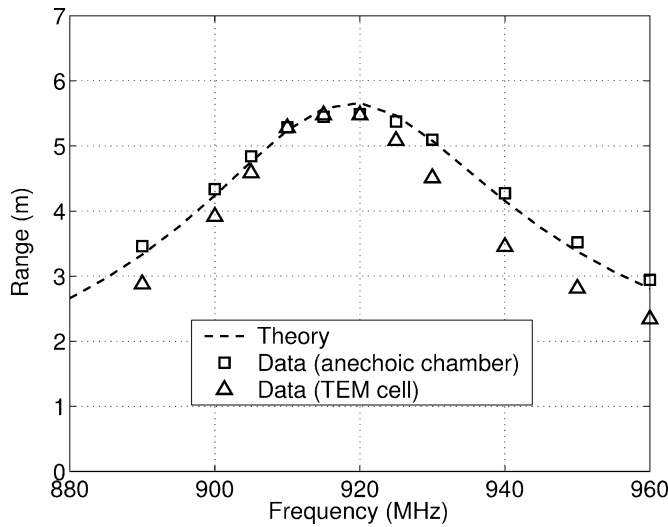Fig. 12. Prototype of RFID tag with loaded meander antenna.

Fig. 13. Theoretical and experimental read ranges for loaded meander RFID tag in free-space (EIRP = 4 W).

- **Sensitivity to chip variations.** Tag design must meet range requirements in spite of variations in ASIC assembly and packaging process. Because all fabrication details may not be known in advance, the tag resonant frequency after fabrication may differ significantly from the expected value.

  To provide sufficient tolerance for tag resonant frequency, our meander antenna is designed to resonate in free-space with a typical chip impedance shown in
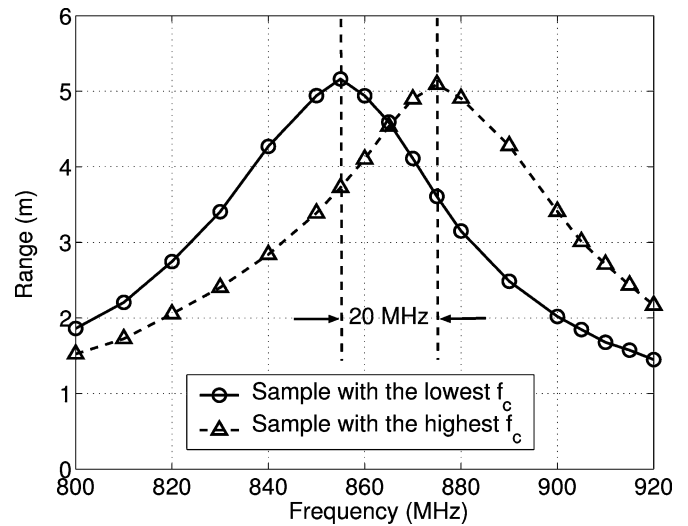

Fig. 14. Variations of RFID tag range versus frequency for different samples due to ASIC packaging process variations (ERP = 2 W).
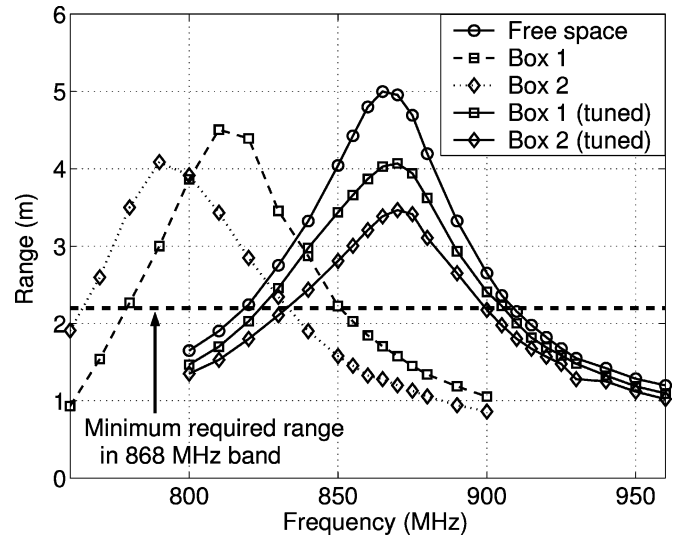

Fig. 15. Variations of RFID tag range versus frequency for different tagged objects (ERP = 2 W). Box 1 is empty cardboard box and box 2 is cardboard box with plastic material ($\epsilon = 2.87$) inside.

Fig. 10 at about 855 MHz. This ensures that when the tag is placed on the box, it covers the lowest RFID band (866–869 MHz) even if fabrication process causes significant resonant frequency deviation. The tag antenna can always be trimmed to a shorter length whereas extending its length after the fabrication is not easy.

After the prototypes were fabricated, it was found that the spread of the tag resonant frequency f_c is about 20 MHz as shown in Fig. 14. This spread was caused by the flip-chip attachment process which affected the package parasitics and added variations to the imaginary part of the packaged chip impedance.

- **Sensitivity to box content.** When the tag is placed on a cardboard box with some content, its resonance frequency shifts down but the tag can be trimmed and tuned to the proper frequency and range performance as shown in Fig. 15. The corresponding trimming of the meander trace and the loading bar is shown in Fig. 16.
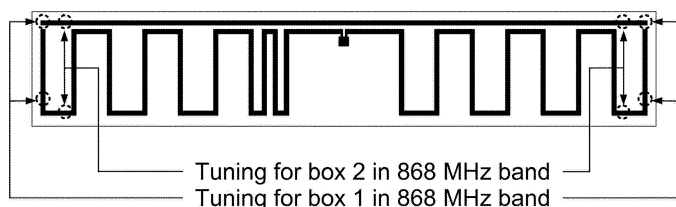
Fig. 16.   Meander tuning for various box content in 868 MHz band.

Once the tuning is determined, it can be applied to all tags destined to work for specific box content in specific frequency band. The presented tag design meets the desired range requirements for various box contents in both 868 MHz and 915 MHz frequency bands.

IV. CONCLUSION

Radio frequency identification is a rapidly developing technology for automatic identification of objects. In this paper, we presented an overview of antenna design for passive UHF RFID tags. We discussed various requirements to such designs, outlined a generic design process including range measurement techniques, and concentrated on one practical application, RFID tag for box tracking in warehouse. We presented a loaded meander antenna design for this application and analyzed various practical aspects such as its sensitivity to fabrication process and box content. We also presented modeling and simulation results which were in good agreement with measurement data. The analysis presented here can also be applied to active tags and tags operating at other frequencies.

ACKNOWLEDGMENT

REFERENCES

[1] H. Stockman, "Communication by means of reflected power," *Proc. IRE*, pp. 1196–1204, Oct. 1948.

[2] K. Finkenzeller, *RFID Handbook: Radio-Frequency Identi cation Fundamentals and Applications*, 2nd ed: Wiley, 2004.

[3] R. Bansal, "Coming soon to a Wal-Mart near you," *IEEE Antennas Propag. Mag.*, vol. 45, pp. 105–106, Dec. 2003.

[4] S.-Y. Chen and P. Hsu, "CPW-fed folded-slot antenna for 5.8 GHz RFID tags," *Electron. Lett.*, vol. 24, pp. 1516–1517, Nov. 2004.

[5] S. K. Padhi, N. C. Karmakar, C. L. Law, and S. Aditya, "A dual polarized aperture coupled circular patch antenna using a C-shaped coupling slot," *IEEE Trans. Antennas Propag.*, vol. 51, no. 12, pp. 3295–3298, Dec. 2003.

[6] G. Marrocco, "Gain-optimized self-resonant meander line antennas for RFID applications," *Antennas Wireless Propag. Lett.*, vol. 2, no. 21, pp. 302–305, 2003.

[7] M. Hirvonen, P. Pursula, K. Jaakkola, and K. Laukkanen, "Planar inverted-F antenna for radio frequency identication," *Electron. Lett.*, vol. 40, pp. 848–850, Jul. 2004.

[8] Q. Xianming and Y. Ning, "A folded dipole antenna for RFID," in *Proc. IEEE Antennas and Propagation Soc. Int. Symp.*, vol. 1, Jun. 2004, pp. 97–100.

[9] P. R. Foster and R. A. Burberry, "Antenna problems in RFID systems," in *Proc. Inst. Elect. Eng. Colloquium RFID Technology*, Oct. 1999, pp. 3/1–3/5.

[10] C. Peixeiro, "Design of log-periodic dipole antennas," *Proc. Inst. Elect. Eng. Microwaves, Antennas and Propagation*, vol. 135, pp. 98–102, Apr. 1988.

[11] S. Weigand, G. H. Hu, K. H. Pan, and J. T. Bernhard, "Analysis and design of broad-band single-layer rectangular U-slot microstrip patch antennas," *IEEE Trans. Antennas Propag.*, vol. 51, no. 3, pp. 457–468, Mar. 2003.

[12] S. Brebels, J. Ryckaert, B. Come, S. Donnay, W. D. Raedt, E. Beyne, and R. P. Mertens, "SOP integration and codesign of antennas," *IEEE Trans. Adv. Packag.*, vol. 27, pp. 341–351, May 2004.

[13] R. F. Harrington, "Effect of antenna size on gain, bandwidth, and eciency," *J. Res. Nat. Bureau Standards*, vol. 64D, pp. 1–12, Jan.-Feb. 1960.

[14] H. A. Wheeler, "Small antennas," *IEEE Trans. Antennas Propag.*, vol. AP-23, no. 4, pp. 462–469, Jul. 1975.

[15] P. Hui, "Small antenna measurements using a GTEM cell," in *Proc. IEEE Antennas and Propagation Soc. Int. Symp.*, vol. 1, Jun. 2003, pp. 715–718.

[16] http://www.semiconductors.philips.com.

[17] R. Tummala and E. Rymaszewski, *Microelectronics Packaging Handbook*. New York: Van Nostrand Reinold, 1989.

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Since 1982, he has been involved with various RF communication hardware design. He was involved in the research and development of single-conversion TVRO and CATV headend equipment with Triple Crown Electronics Inc., Mississauga, ON, Canada. In 1989, he joined U.S.-based Auget Communication Products Inc., where he was the lead RF Designer involved with CATV two-way broad-band trunk distribution amplifiers. In 1997, he joined the Intermec Technologies Corporation, Everett, WA, where he is currently the Senior RF Engineer. His interests include various RF communication hardware design and RFID tag development.

射 频 和 天 线 设 计 培 训 课 程 推 荐

易迪拓培训(www.edatop.com)由数名来自于研发第一线的资深工程师发起成立，致力并专注于微波、射频、天线设计研发人才的培养；我们于 2006 年整合合并微波 EDA 网(www.mweda.com)，现已发展成为国内最大的微波射频和天线设计人才培养基地，成功推出多套微波射频以及天线设计经典培训课程和 ADS、HFSS 等专业软件使用培训课程，广受客户好评；并先后与人民邮电出版社、电子工业出版社合作出版了多本专业图书，帮助数万名工程师提升了专业技术能力。客户遍布中兴通讯、研通高频、埃威航电、国人通信等多家国内知名公司，以及台湾工业技术研究院、永业科技、全一电子等多家台湾地区企业。

易迪拓培训课程列表：http://www.edatop.com/peixun/rfe/129.html

射频工程师养成培训课程套装

该套装精选了射频专业基础培训课程、射频仿真设计培训课程和射频电路测量培训课程三个类别共 30 门视频培训课程和 3 本图书教材；旨在引领学员全面学习一个射频工程师需要熟悉、理解和掌握的专业知识和研发设计能力。通过套装的学习，能够让学员完全达到和胜任一个合格的射频工程师的要求…

课程网址：http://www.edatop.com/peixun/rfe/110.html

ADS 学习培训课程套装

该套装是迄今国内最全面、最权威的 ADS 培训教程，共包含 10 门 ADS 学习培训课程。课程是由具有多年 ADS 使用经验的微波射频与通信系统设计领域资深专家讲解，并多结合设计实例，由浅入深、详细而又全面地讲解了 ADS 在微波射频电路设计、通信系统设计和电磁仿真设计方面的内容。能让您在最短的时间内学会使用 ADS，迅速提升个人技术能力，把 ADS 真正应用到实际研发工作中去，成为 ADS 设计专家…

课程网址：　http://www.edatop.com/peixun/ads/13.html

HFSS 学习培训课程套装

该套课程套装包含了本站全部 HFSS 培训课程，是迄今国内最全面、最专业的 HFSS 培训教程套装，可以帮助您从零开始，全面深入学习 HFSS 的各项功能和在多个方面的工程应用。购买套装，更可超值赠送 3 个月免费学习答疑，随时解答您学习过程中遇到的棘手问题，让您的 HFSS 学习更加轻松顺畅…

课程网址：http://www.edatop.com/peixun/hfss/11.html

CST 学习培训课程套装

该培训套装由易迪拓培训联合微波 EDA 网共同推出，是最全面、系统、专业的 CST 微波工作室培训课程套装，所有课程都由经验丰富的专家授课，视频教学，可以帮助您从零开始，全面系统地学习 CST 微波工作的各项功能及其在微波射频、天线设计等领域的设计应用。且购买该套装，还可超值赠送 3 个月免费学习答疑…

课程网址：http://www.edatop.com/peixun/cst/24.html

HFSS 天线设计培训课程套装

套装包含 6 门视频课程和 1 本图书，课程从基础讲起，内容由浅入深，理论介绍和实际操作讲解相结合，全面系统的讲解了 HFSS 天线设计的全过程。是国内最全面、最专业的 HFSS 天线设计课程，可以帮助您快速学习掌握如何使用 HFSS 设计天线，让天线设计不再难…

课程网址：http://www.edatop.com/peixun/hfss/122.html

13.56MHz NFC/RFID 线圈天线设计培训课程套装

套装包含 4 门视频培训课程，培训将 13.56MHz 线圈天线设计原理和仿真设计实践相结合，全面系统地讲解了 13.56MHz 线圈天线的工作原理、设计方法、设计考量以及使用 HFSS 和 CST 仿真分析线圈天线的具体操作，同时还介绍了 13.56MHz 线圈天线匹配电路的设计和调试。通过该套课程的学习，可以帮助您快速学习掌握 13.56MHz 线圈天线及其匹配电路的原理、设计和调试…

详情浏览：http://www.edatop.com/peixun/antenna/116.html

我们的课程优势：

※ 成立于 2004 年，10 多年丰富的行业经验，

※ 一直致力并专注于微波射频和天线设计工程师的培养，更了解该行业对人才的要求

※ 经验丰富的一线资深工程师讲授，结合实际工程案例，直观、实用、易学

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