

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HID GLOBAL CORPORATION,
Petitioner,

v.

DATAMARS SA,
Patent Owner.

Case IPR2023-01445
Patent No. 11,128,027

**PETITION FOR *INTER PARTES REVIEW*
OF U.S. PATENT NO. 11,128,027**

Declaration of Kelley M. Hayes Greenhill Regarding Exhibit 1015 (“*Moradi*”)

I, Kelley M. Hayes Greenhill, state and declare as follows:

I. Introduction

1. I have prepared this Declaration in connection with the Petition for *Inter Partes* Review of U.S. Patent No. 11,128,027, which I understand will be filed concurrently with this Declaration.

2. I am currently a Senior Manager with the Research & Information Services team at Finnegan, Henderson, Farabow, Garrett & Dunner, LLP, located at 901 New York Avenue, NW, Washington, DC 20001-4413.

3. I am over eighteen years of age, and I am competent to make this Declaration. I make this Declaration based on my own personal knowledge, and my knowledge of library science practices.

4. I earned a Master of Science in Library Science from the Catholic University of America in 1995, and a Bachelor of Arts in Political Science from Duquesne University in 1989. I have work as a librarian for over twenty-five years. I have been employed at Finnegan, Henderson, Farabow, Garrett & Dunner, LLP since 2019. Before that, from 1995–2015, I was employed in the Library Department of Sterne, Kessler, Goldstein & Fox, PLLC. And from 2015–2019, I was employed in the Knowledge and Research Service Group (formerly, Information Research Service) at Northrop Grumman Corporation.

5. I am a member of the American Association of Law Libraries.

II. Standard Library Practices for Receiving, Cataloging, and Making Materials, Including Serial Publications, Publicly Available

6. I have knowledge of and experience with standard library practices regarding the receipt, cataloging, shelving, and making materials, including serial publications, available to the public. I have knowledge of and experience with the Machine-Readable Cataloging (MARC) system, an industry-wide standard that libraries use to catalog materials.

7. The MARC system was developed during the 1960s to standardize bibliographic records so they could be read by computers and shared among libraries. By the mid-1970s, MARC had become the international standards for bibliographic data and cataloguing. It still used today. Many libraries provide public access to their MARC records via the Internet and/or their electronic cataloging systems at the library.

III. MARC Records

5. The MARC record system uses a specific three-digit numeric code (from 001-999) to identify each field in a catalog record. For example, field tag 008 provides the six-digit date the item was catalogued (*Date entered on file*). The first six characters of field tag 008 are always in the “**YYMMDD**” format. Descriptions and definitions of all of the character positions of field tag 008 are outlined here: <https://www.loc.gov/marc/bibliographic/bd008a.html>

8. As is relevant to this Declaration, MARC field tag 245 identifies the full title statement for the work; field tag 264 identifies the place of publication, name of publisher, and copyright date of the publication; and field tag 310 denotes the current frequency of the publication. Finally, field tag 588 includes general and specific source of description notes that are especially of interest to other catalogers.

9. Based on standard library practice, when a library receives an item, including a serial, it generally stamps (and/or labels) the item with the library name, barcode, often with a date that is within a few days or weeks of receipt. Next, the library will catalog the item within a matter of a few days or weeks of receiving it. As a general practice, cataloguing is centralized and performed by a cataloguing department within a library or university setting. In certain circumstances the catalogued item may be subsequently sent to a library location within the library or university setting where it may be stamped and/or labeled after it has been catalogued.

10. Generally, after an item is cataloged, the public may access the item by searching a catalog, browsing the library shelves, and either requesting or electronically accessing the item from the library. Standard library practice is to make the item available to the public within a few days or weeks of cataloging it.

IV. Serial Publications

11. A serial publication, often known as a “journal,” is a resource that is issued in successive parts and has no predetermined conclusion. These successive parts are commonly referred to as “issues,” and each issue is usually chronologically numbered and dated. The presence of enumeration, years of coverage, and/or other chronological information also indicates a serial publication.

12. There are significant differences between cataloging finite resources (books/monographs) and continuing resources (serials). For serials, the catalog record provides information about the serial as a whole, including the first or earliest available issue. It also provides information as to holdings – the volumes and issues, with dates, received by the library and made available to the public. In serials cataloging, there are identifying characteristics unique to serials that are slightly different from monographs (books). The issue date for a print serial publication, for example, generally appears on the cover (front or back), the masthead page, the title page (if any), the table of contents page(s), or on the pages of the individual articles contained in the issue. More information regarding the unique aspects of cataloguing serials can be found at this link:

<https://www.loc.gov/aba/pcc/conser/scctppt/Basic-2014/Basic-Trainee-Mannual.pdf>.

V. Cataloguing of Conference Proceedings (Monographs v. Serial Treatment)

13. Conference proceedings often consist of collections of papers presented at a meeting, program, symposium or conference held during a specific time-period in a designated geographic place. Bibliographic control of conference proceedings to promote public discovery and access has long been a priority of catalogers. Although some ongoing conference publications are catalogued as serials (if a conference publication exhibits continuity, regularity, and evidence of seriality), cataloguing a conference publication as a monograph is preferred for public retrieval purposes. Cataloguing a conference publication as a monograph is an optimal way for the public to easily access the conference resource, and its papers, by searching for a unique title and other descriptive data elements added by the cataloger. Monographs are efficient for public searching and offer the public an easier way to discover what an institution holds, while changes to the record (unlike serials) are not an issue. However, sometimes conference proceeding cataloging is done serially, and the MARC record will be updated after each serial publication is received.

VI. Copyright Office Record

14. The United States Copyright Office, a part of the Library of Congress, is the official U.S. government body that maintains records of copyright registrations in the United States, including providing public access to an online

Copyright Catalog. The records contained in this catalog are publicly accessible and are routinely used by copyright title researchers who are attempting to clear a chain of title for copyrighted works.

VII. IEEE Xplore

15. The IEEE *Xplore* digital library is a powerful resource for discovery of scientific and technical content published by the Institute of Electrical and Electronics Engineers (IEEE) and its publishing partners. IEEE *Xplore* provides web access to more than 6 million full-text documents from some of the world's most highly cited publications in electrical engineering, computer science and electronics. Approximately 25,000 new documents are added to IEEE *Xplore* each month. Access to full-text documents in IEEE *Xplore* can be obtained from: institutional subscriptions, exclusive subscription available to IEEE member and IEEE society members, and online purchase of individual documents.

16. The date of publication for journals and standards on IEEE *Xplore* represents the very first instance of dissemination. IEEE *Xplore* previously made distinctions between the online publication date, print publication date, etc. This was simplified to reflect a single publication date of record as defined above.

17. IEEE publishes more than 1,700 leading-edge conference proceedings every year, which are recognized by academia and industry worldwide as the most

vital collection of consolidate publisher papers in electrical engineering, computer science and related fields.

18. Conference publications appear in IEEE *Xplore* about 30–60 days following IEEE’s receipt of the printed conference proceedings. It is worth noting that conference proceedings often arrive at IEEE several weeks after the conference date.

19. Conference proceedings in IEE *Xplore* show “Date of Conference” which is the date of the event, and “Date Added to IEEE *Xplore*” which is the date proceedings were first published.

VIII. Public Availability of *Moradi* (Exhibit 1015)

20. This Declaration relates to the dates of receipt and public availability of the following reference: Elham Moradi, Toni Bjorninen, Leena Ukkonen and Yahya Rahmat-Samii, "Characterization of embroidered dipole-type RFID tag antennas," (“*Moradi*”) found within the 2012 IEEE International Conference on RFID-Technologies and Applications (RFID-TA), Nice, France, 2012, pp. 248–253. I understand that *Moradi* has been submitted as Exhibit 1015 in this proceeding. That same reference is appended to my Declaration as **Appendix A**.

6. As detailed below, I have reviewed the reference, public holdings information and Library of Congress MARC record for *Moradi* to determine the date of public availability for this reference.

7. **Appendix A** to this declaration is a true and accurate copy of the cover page (including binding), title page, front matter, table of contents for the copy of the *IEEE International Conference on RFID-Technologies and Applications* containing *Moradi* held by the Library of Congress. **Appendix A** also include pages 248 – 253, which comprises the publication, “Characterization of embroidered dipole-type RFID tag antennas,” *i.e. Moradi*.

21. The Library of Congress public catalog record (**Appendix B**) sets forth the public holdings and onsite location information for members of the public seeking a physical copy of *IEEE International Conference on RFID-Technologies and Applications* containing *Moradi*. The public catalog record indicates it is a “periodical or newspaper” record and, specifically, identifies the serial title name as “*IEEE International Conference on RFID-Technologies and Applications*,” and the main title as “*IEEE International Conference on RFID-Technologies and Applications*.” The public catalog record notes that the publications associated with the record are published annually and should be requested in the Jefferson or Adams Building Reading Rooms at Call Number TK6570. I34a. This information indicates serial cataloging, as discussed above.

The public catalog record also notes a publication location in Piscataway, NJ, and IEEE as the publisher. Based on my experience as a librarian, the information provided in the public catalog record (**Appendix B**) indicates that the record references multiple publications. Further, based on my experience as a librarian, the public catalog record (**Appendix B**) references the *IEEE International Conference on RFID-Technologies and Applications* that containing *Moradi* (**Appendix A**).

22. **Appendix C** to this declaration is a true and correct copy of the Library of Congress public catalog and MARC for its copy of the publication *IEEE International Conference on RFID-Technologies and Applications*, containing *Moradi*, which was downloaded from: <https://lccn.loc.gov/2014205227>.

23. The Library of Congress MARC record for *Moradi* identifies the fixed data elements of MARC field tag 008 as 140414c20uu9999n | a0eng. This indicates that the record for *IEEE International Conference on RFID-Technologies and Applications* was last catalogued by the Library of Congress on April 14, 2014. The publication status code “c” appearing in MARC field tag 008 refers to “continuing resource and currently published” indicating that this item continues to be published and received by the Library of Congress. Based on this MARC record, and the continuous receipt and processing of *IEEE International*

Conference on RFID-Technologies and Applications by the Library of Congress, *Moradi* would have been catalogued and made available to the public.

24. The Library of Congress MARC record for *IEEE International Conference on RFID-Technologies and Applications* containing *Moradi* includes field tag 245, which denotes the title and statement of responsibility for the work as “IEEE International Conference on RFID-Technologies and Applications.”

25. In the Library of Congress MARC record, field tag 264 denotes information relating to the place of publication, name of publisher, and date of publication of IEEE International Conference on RFID-Technologies and Applications as “.| Piscataway, NJ b. IEEE and a. Red Hook, NY b. Available [sic] from Curran Associates.” Subfield code “a” refers to the place of publication. Subfield code “b” refers to the name of the publisher.

26. In the Library of Congress MARC record, field tag 310 indicates that *IEEE International Conference on RFID-Technologies and Applications* is an annual publication.

27. In the Library of Congress MAR record, field tag 588 includes general and specific source of description notes, indicates the “Description based on: 2012; title from title page and latest issue consulted: 2012.”

28. Based on the information in **Appendices B and C**, it is clear that the MARC record (**Appendix C**) references *IEEE International Conference on RFID-Technologies and Applications* containing *Moradi*.

29. **Appendix D** to this declaration is a true and accurate copy of the U.S Copyright Office record for it copy of the *IEEE International Conference on RFID-Technologies and Applications* containing *Moradi* which was retrieved from <https://cocatalog.loc.gov/cgi-bin/Pwebrecon.cgi?v1=2&ti=1,2&Search%5FArg=2012%20IEEE%20International%20Conference%20on%20RFID&Search%5FCode=TALL&CNT=25&PID=hCuAKW6jCcKqFFC9wSRLd8Eu&SEQ=20230920145120&SID=1>

30. This record indicates a title of *IEEE International Conference on RFID-Technologies and Applications (RFID-TA) (12EX7672)* which is the same title as found in *Moradi*. The record denotes the publication date for *IEEE International Conference on RFID-Technologies and Applications* as December 17, 2012.

31. Based on the information in this **Appendix D** the issue *IEEE International Conference on RFID-Technologies and Applications (RFID-TA) (12EX7672)*, containing *Moradi* would have been publicly available within a few days or weeks of December 17, 2012.

32. **Appendix E** to this declaration is a true and accurate copy of the IEEE *Xplore* record for *Moradi*. This record indicates the article entitled “*Characterization of embroidered dipole-type RFID tag antennas*” was published in *IEEE International Conference on RFID-Technologies and Applications (RFID-TA)*. Further, this record indicates Date of Conference: 05-07 November 2012 and Date Added to IEEE *Xplore*: 10 January 2013.

33. Based on the information in **Appendix E**, it is clear that the issue of *IEEE International Conference on RFID-Technologies and Applications (RFID-TA)* containing *Moradi* was published by IEEE *Xplore* on January 10, 2013. *Moradi* would have been available to the public within a matter of a few days or weeks of receipt of January 10, 2013.

IX. Conclusion

34. In signing this Declaration, I understand it will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I understand I may be subject to cross-examination in this case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

35. I declare that all statements made herein of my knowledge are true, that all statements made on information and belief are believed to be true, and that

these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed on September 28, 2023, in Washington, DC.


Kelley M. Hayes Greenhill

APPENDIX A

LIBRARY OF CONGRESS



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IEEE INTERNATIONAL CONFERENCE ON RFID-TECHNOLOGIES AND APPLICATIONS

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2012 IEEE International Conference on RFID-Technologies and Applications

(RFID-TA 2012)

Nice, France

5 – 7 November 2012



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ISBN: 978-1-4673-4656-6

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**Nice, France
5 – 7 November 2012**



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Characterization of Embroidered Dipole-type RFID Tag Antennas

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Abstract—Wearable RFID tags and wireless sensors can be used for on-body and human monitoring applications. Embroidery with conductive thread provides compelling means for the fabrication of seamlessly garment-integrable antennas for wearable tags and wireless sensors. In this paper, we present the fabrication of fully assembled tags based on embroidered dipole-type antennas. The prototype tags achieve 5.5-to-7 meters read range. Moreover, we present a method for estimating the effective conductivity of the embroidery pattern, which depends on the sewing pattern and the stitch density. This will enable the judicious optimization of embroidered tag antennas using electromagnetic simulation tools.

Keywords— *conductive thread; embroidered RFID antenna; UHF RFID; sewing machine; wearable RFID tag*

I. INTRODUCTION

Radio Frequency Identification (RFID) system consists of a reader, and a remote transponder, denoted as a tag, which is attached to a labelled object. The tag is made of an antenna and a microchip containing the identification code related to the object. Passive tags provide the required energy to drive the microchip from the radio frequency wave transmitted by the reader antenna. In a passive RFID system, communication happens through backscattering modulation. Reader sends carrier wave to activate the tag and a command to backscatter the identification data. When the tag receives the command signal, the microchip switches its impedance between two values in a coded manner corresponding to the stored data during the reader's carrier signal phase. Thus, the tag scatters a modulated signal back to the reader. The reader then demodulates and decodes the signal and gives the data stored in the tag as output [1].

Wearable tags can be applied for youngsters, the aged, athletes and patients for the purpose of monitoring. Like all wearable antennas, they should be light weight, low cost, flexible, maintenance-free, and seamlessly integrated with clothing [2], [3]. Thus, embroidery with conductive threads is a compelling approach for the fabrication of such antennas.

Several flexible conductive materials have been introduced in literature, including fibers having polymer cores and metallic coatings (E-fibers) [4], [5], yarns bundled with thin metal filaments, yarns/fabrics embedded with carbon nanotubes [6],

and fabrics embedded with metal filaments [7]. In the referenced articles elastic polymers and fabrics have been used as the flexible substrate.

Tag antenna has a major role in the overall RFID system performance, such as the read range, and the compatibility with tagged objects. Wearable RFID tags have been designed and explored in [8]-[10]. Authors of these articles have sewed the geometry of the tag antenna on textile with a computer aided sewing machine using conductive threads. These articles explore the performance of sewed tag antennas, and investigate the factors affecting the conductivity of the sewed antennas. According to the measurement results of these articles the conductivity of sewed antenna improves by using highly conductive threads, increasing stitch and thread density, and also by choosing a sewing pattern that consists of sewed lines along the direction of current flow.

In this paper, we show that when designing an embroidery tag antenna, with electromagnetic simulators we can treat the complex embroidery pattern as a uniform conductive material layer when the pattern is sewed densely. Hence, it is the conductivity of an embroidery pattern that is the decisive factor in the simulation model of an embroidery antenna. This paper focuses on wearable embroidered dipole-type ultra high frequency (UHF) RFID tag antennas. The objective of this paper is to explain an estimation technique for the conductivity of sewed RFID tag antennas, and also to further investigate the factors affecting the conductivity and the performance of sewed dipole-type tag antennas. In this study the effects of human body and moisture in the cotton are not considered.

The rest of the paper is organized as follows. Section 2 explains the properties of the used materials, their effects on the performance of the antenna, and the fabricated prototypes. Section 3 discusses the measurement of the prototypes. Section 4 illustrates a modeling technique for the sewed dipole-type tag antennas. Finally, conclusions are drawn in Section 5.

II. DESIGN AND FABRICATION OF EMBROIDERED ANTENNAS

In this article, we investigate the operation of dipole-type embroidery tag antennas, sewed on cotton, which is used as the substrate. Essential factors that define the operation of a planar

antenna are the electrical properties of the substrate, electrical properties of the radiating element, and antenna geometry. The conductive thread used in the sewing of the antennas is Shieldex 110f34 dtex 2-ply HC [11].

At the beginning of this study, relative permittivity and loss tangent of cotton were unknown. Hence, the electrical properties of cotton are measured using the resonance method [12]. The measured relative permittivity and loss tangent of cotton (in dry condition) are 1.8 and 0.018, respectively.

The embroidery antennas are sewed with Husqvarna VIKING computer aided sewing machine, using conductive thread [11]. The thread has a weight of 110 dtex (dtex = g/10000m) raw yarn twisted with a second 110 dtex raw yarn to make a yarn of 220 dtex. Then the yarn is plated with silver to gain a weight of 275 dtex. The DC lineal resistivity of the thread is $500 \pm 100 \Omega/\text{m}$, and the diameter is approximately 0.16 mm. The thread consists of 34 filaments in a yarn.

A. Electrical Properties of the Conductive Thread

Conduction losses of the radiating element of an antenna cause the antenna loss resistance to depend on the frequency. The high-frequency resistance of a metal structure is not the same as the DC resistance [13]. The DC resistance of a uniform metal rod with length l and cross-sectional area A is given by

$$R_{dc} = \frac{1}{\sigma} \frac{l}{A}, \quad (1)$$

where σ is the conductivity of the metal (S/m). When the frequency increases, the skin depth δ ($\delta = \sqrt{2/(\omega\mu\sigma)}$) becomes much smaller than the conductor radius and the current confines to a thin layer near the conductor surface. Hence, the high-frequency resistance, based on a uniform current distribution along the length of the rod, is given as [13]

$$R_{hf} = \frac{l}{P} R_s = \frac{l}{P} \sqrt{\frac{\omega\mu_0}{2\sigma}}, \quad (2)$$

where P is the perimeter of the cross section of the rod ($P=2\pi b$ for a circular wire of radius b), R_s is the conductor surface resistance (Ω), ω is the angular frequency (rad/s), μ_0 is the permeability of free-space (H/m), and σ is the conductivity of the metal (S/m).

Equations (1) and (2) are defined for a uniform metal rod with a uniform current distribution. Conductive threads, however, do not have a uniform metal structure, and they consist of many filaments which are silver plated nylons. Thus, Equations (1) and (2) cannot be used to characterize the conductive threads. However, it is obvious that the conductivity of the conductive thread is higher the higher the weight of the metal part of the thread is. The weight of silver in the thread we have used is 55g/10000m (dtex), which provides a good conductivity.

In addition to the conductivity of the electric-thread, conductivity of the embroidery antennas depends also on the sewing pattern and the stitch density [8], [10]. Hence, at the first level, it is sufficient that the dtex value of the electric-

thread is high enough while the exact conductivity of the thread alone is less important for the antenna design.

B. Copper-based Reference Antenna

Conductivity of the radiating element of an antenna does not affect the operation frequency of the antenna directly, but it affects the quality factor (Q) of the antenna: the higher the conductivity, the lower the Q . On the other hand, the relation between Q and the obtainable frequency bandwidth is defined as

$$\frac{\Delta f}{f_0} = \frac{1}{Q}, \quad (3)$$

where Δf is the frequency bandwidth and f_0 is the center frequency. Thus, a decrease in the quality factor increases the obtainable frequency bandwidth of the antenna. Taking into account that copper has high conductivity, the copper-based reference antenna is likely to exhibit a narrower bandwidth compared with the embroidered antennas discussed in Section II.C.

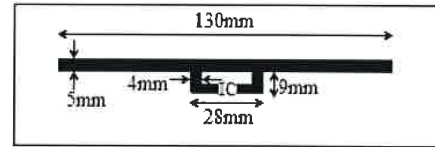


Figure 1. Geometry of the designed copper dipole-type tag antenna.

The dominant difference between a copper tag antenna and an embroidery tag antenna is their conductivities. Hence, in order to define an optimum geometry for a dipole-type tag antenna working in UHF region, we have designed a tag antenna consisting of copper as the radiating element, and cotton as the substrate. The geometry of the designed dipole is shown in Fig. 1. The thickness of the copper is 0.05 mm, and the dipole is designed for the chip, Alien Higgs-3 UHF RFID IC [14], which has a sensitivity of -18 dBm. The chip has an equivalent input parallel resistance of 1500Ω , and an equivalent input parallel capacitance of 0.85 pF. The chip is attached to the fabricated antenna with conductive epoxy [15].

C. Embroidered Antennas

The geometry of the designed copper dipole is sewed on cotton using the embroidery machine Husqvarna Viking. First the image of the antenna is exported from the HFSS software and transferred to the 5D Embroidery System software. Using this software we have created the sewing pattern for the antenna. The software enables to control the stitching techniques and the stitching density when creating the sewing pattern. The file containing the created pattern is then transferred to the embroidery machine to be sewed on cotton automatically. The created sewing pattern consists of a horizontal line along the length of the dipole, and zigzags sewed vertically on it.

Effect of the stitch and zigzag density on the performance of the antenna is investigated by sewing six dipoles with different zigzag densities and measuring them in an anechoic chamber. The fully assembled tags are shown in Fig. 2 with the amount of stitches of each sewed tag written on top of it. The dipole with 2550 stitches has the highest zigzag density, and the dipole with 225 stitches has the lowest zigzag density. The right-most tag is the copper-based reference.

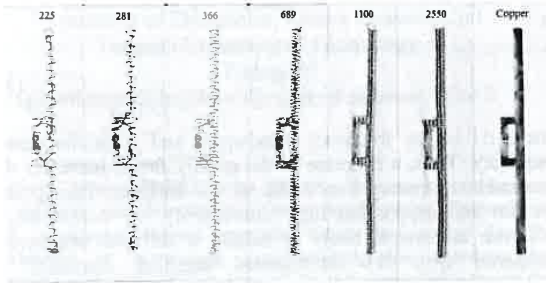


Figure 2. Sewed tags with different stitch densities.

III. PERFORMANCE OF THE EMBROIDERED ANTENNAS

According to the articles [8] and [10], conductivity of an embroidery antenna increases as the thread and stitch densities increase. In our case, this means that increasing the zigzag density should increase the conductivity of the antenna.

To characterize the performance of the sewed dipoles, we have measured the achievable read range (r_{max}) of the fully-assembled tags using RFID measurement system [16]. In practice the read range r_{max} is attained when the tag is located in the main beam of a reader antenna, which has its polarization perfectly aligned with the tag and is transmitting the maximum power allowed by the regulations. In our measurement configuration, the achievable read range is calculated as

$$r_{max} = \frac{\lambda}{4\pi} \sqrt{\frac{EIRP}{L_{fwd} P_{th}}}, \quad (4)$$

where λ is wavelength, L_{fwd} is the measured linkloss factor from the output port of the generator to the input of a hypothetical isotropic radiator placed at the tag's location, P_{th} is the minimum transmitted power required to turn the tag IC on, and $EIRP$ is the regulated effective isotropic radiated power (EIRP). By definition, $EIRP$ is the amount of power that would be needed to put into an isotropic antenna to produce the same power density in the radiation field as we get in the main beam of the directional antenna. In the European RFID band (865.7-867.6 MHz) $EIRP = 3.28$ W.

Figure 3 shows the measured read ranges of the tags shown in Fig. 2. Comparing the read range graphs of the copper dipole with the corresponding graphs of sewed dipoles, we can observe that in the case of sewed dipoles the frequency bandwidth is greatly increased. This is mainly due to the reduction of conductivity and quality factor of the sewed antennas. The achieved read ranges of the sewed tags range

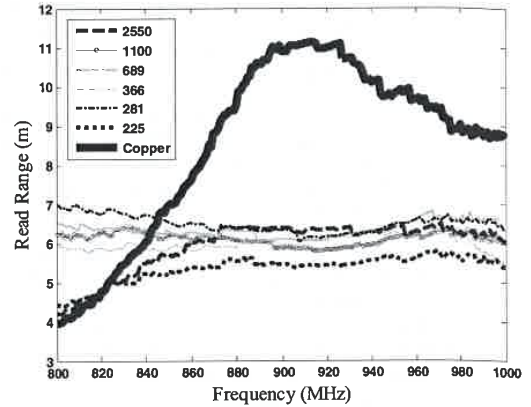


Figure 3. Measured forward read range graphs of sewed dipoles with different stitch densities

from 5.5 m to 7 m. This achievement is better than the results reported in [8]-[10] and without a doubt sufficient in many applications.

According to Fig. 3, performance of the sewed tags with this sewing pattern is fairly similar regardless of the zigzag density and only when the amount of stitches is as low as 225 the performance starts to change noticeably. Thus, it can be deduced that we can sew antennas with this sewing pattern sparsely to save materials and still achieve nearly as good performance as with antennas sewed with a high stitch and zigzag density. However, adding sewed lines along the direction of current flow might affect the conductivity of the antenna. But in this case, the sewing pattern will change significantly, and the resulting pattern might have even lower effective conductivity.

IV. SIMULATION MODEL FOR THE EMBROIDERED ANTENNAS

For modelling the embroidery tag antennas, the effective conductivity of the embroidery pattern needs to be known. In this way the antenna can be modelled as a uniform conductor layer and its performance can be optimized in an appropriate manner. This section presents a technique to evaluate the conductivity of sewed antennas based on the comparison between simulation and measurement results. This enables the design of antennas optimized for a given stitch pattern.

A. Conductivity of Sewed Tag Antennas

One of the most important antenna parameters is realized gain of an antenna. Theoretically, realized gain is a parameter that beside the directivity and the efficiency of the antenna, accounts for the impedance matching between the antenna and the IC. Thus, the simulator calculates realized gain as

$$G_{r,s} = \tau G = \frac{4R_{IC} R_{ant}}{|Z_{ant} + Z_{IC}|^2} \times G, \quad (5)$$

where τ is power transfer coefficient, R_{ant} is resistance of the tag antenna at its terminals, Z_{ant} is impedance of the tag antenna

at its terminals, R_{IC} is input resistance of the IC, Z_{IC} is the input impedance of the IC, and G is gain of the antenna. On the other hand, in empty-space measurement conditions, realized gain is defined as

$$G_{r,m} = \frac{P_{IC,sens}}{L_{fwd} P_{th}}, \quad (6)$$

where $P_{IC,sens}$ is the sensitivity of the IC.

In order to find the conductivity of the sewed antennas, the measured realized gain graphs of the sewed antennas are compared with simulation results of the dipole with different conductivity values and thicknesses. In other words, measured realized gain $G_{r,m}$ is compared with simulated realized gain $G_{r,s}$.

The thickness of embroidered antennas changes as a function of stitch density. When the amount of stitches and the thread density are high enough, in a sense that the sewed structure resembles a flat pattern, we can talk about the thickness of the sewed structure. But, when the sewed pattern is sparse, it is not convenient to talk about the thickness of it, because the sewed structure is not flat and solid. Still, in simulator we may to define a thickness for the antenna material. Thus, the thickness of the sewed structure on the upper face of each tag is measured, and it is defined as the thickness of the conductive part of the antenna in ANSYS HFSS simulator. The measured thicknesses of the sewed planar dipoles are listed in Table 1.

TABLE I. THICKNESS OF THE SEWED ANTENNA ON THE UPPER FACE OF EACH TAG

Number of stitches	2550	1100, 689	366, 281, 225
Thickness (mm)	0.425	0.2	0.1

As illustrated in Fig. 3, the read range graphs of sewed dipoles are located closely to each other. This might lead to a conclusion that the conductivities of sewed antennas are almost the same too. However, when we consider the thickness of the sewed structure, we end up with different effective conductivity values for each of them.

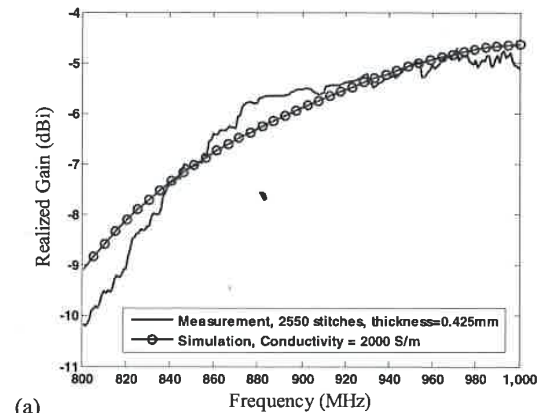
Conductivity of antenna affects the loss resistance of the antenna (3), which in turn affects the power transfer coefficient and the efficiency of the antenna. On the other hand, in equation (4), P_{th} is a function of the impedance mismatch between the antenna and the IC, and the conductivity of the antenna. Here, we model the sewed antennas, using the hypothesis that an antenna with a measured realized gain of $G_{r,m}$ has the same conductivity as corresponding simulated antenna with a realized gain of $G_{r,s}$, when $G_{r,s}$ is equal to $G_{r,m}$.

In this study, the only differences between the copper-fabricated and embroidered tags were the conductivity and thickness of the antenna conductor. Both of these parameters affect the antenna input impedance, but since the studied

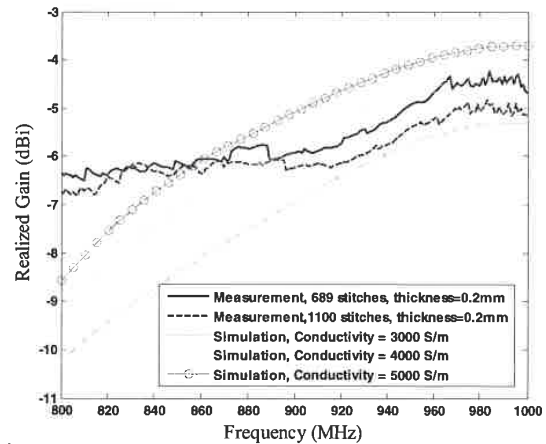
antennas are otherwise identical, the possible variations in the input impedance can be modelled by varying only the conductivity and the thickness of the antenna conductor in the simulations. Therefore this effect is fully included in the realized gains analyzed in this study.

As it is shown in Fig. 4(a), the simulated realized gain of the dipole with a thickness of 0.425 mm and a conductivity of 2000 S/m matches with the measured realized gain of the sewed dipole with 2550 stitches. Thus, we can deduce that the conductivity of this sewed dipole is 2000 S/m.

Similarly, Fig. 4 (b) shows simulated realized gain of the dipole with different conductivities, and measured realized gain of sewed dipoles with 1100 and 689 stitches. In this case, in simulations the thickness of the dipoles is set to 0.2 mm. According to the Fig. 4 (b), the conductivity of sewed dipoles with 1100 and 689 stitches varies from 3000 S/m to 5000 S/m. Figure 4 (c) shows simulation results and measurement results of sewed tag antennas with 366, 281 and 225 stitches. In this case, in HFSS model the thickness of the dipole is 0.1 mm, which results in higher conductivity values. According to this figure the conductivity of these tag antennas varies from 6000 S/m to 10000 S/m.



(a)



(b)

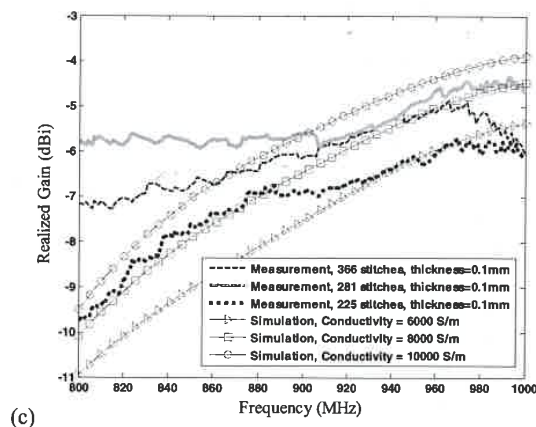


Figure 4. Measured realized gain graphs of sewed dipoles and simulated realized gains.

According to the presented results, the effective conductivity of the sewed dipoles decreases as the thread density and the thickness of the sewed pattern increases. There is little performance deviation between the sewed dipoles with 281-2550 stitches, while they have different thicknesses. Thus, the thicker and more densely sewed pattern (or conductive layer) must have smaller effective conductivity in order to have losses at the same level as the thinner one. In the densely sewed patterns, a larger amount of vertically sewed conductive threads are very close to each other and their interaction may cause unexpected losses compared to less dense sewing patterns.

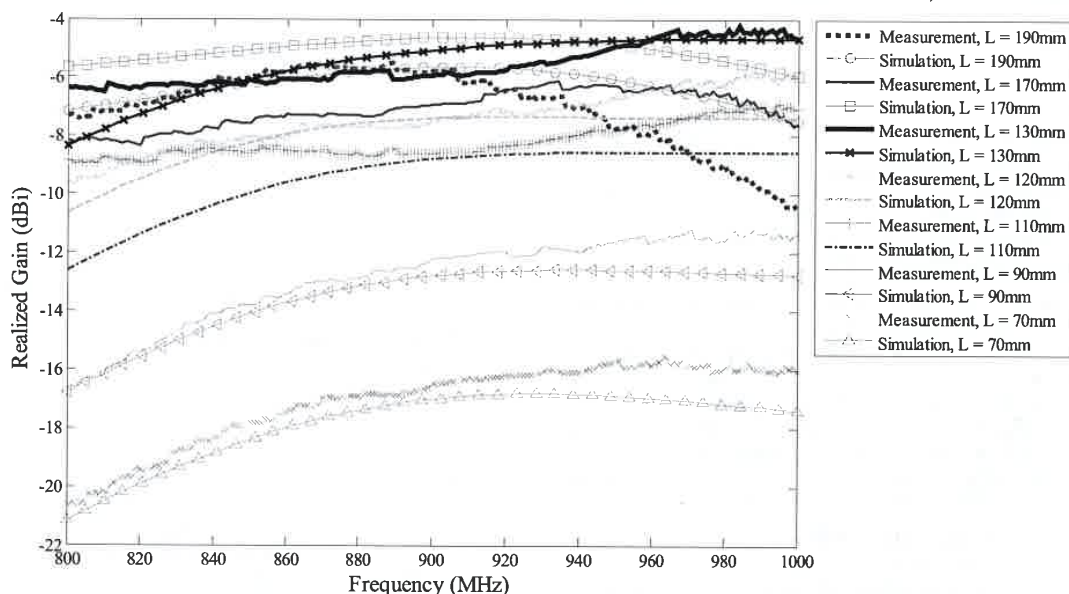


Figure 6. Measurement and simulation results of sewed dipoles with different lengths.

B. Verifying the Simulation Model

In order to verify the proposed simulation model, six dipoles with six different lengths are sewed and measured. The sewed dipoles have the same zigzag density as the 130 mm long dipole with 689 stitches. Thus, the thickness and conductivity of all of them are 0.2 mm and 4000 S/m respectively (Fig. 4(b)). Figure 5 shows the picture of the sewed tag antennas.

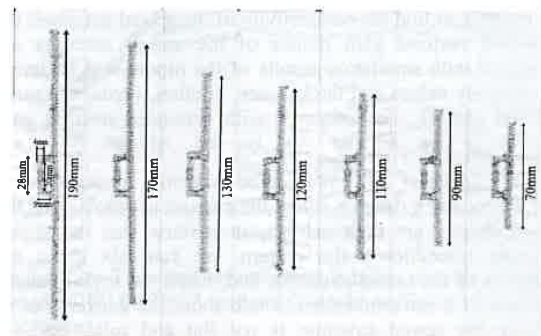


Figure 5. Sewed antennas with the same T-match geometry as before, but with different lengths.

The in-air measurement results of the sewed dipoles are then compared with the simulation results of them. As Fig. 6 shows, the measurement and simulation results of most of sewed dipoles match quite well. According to the datasheet of the IC [14], sensitivity of the IC is -18 dBm at frequencies 860-960 MHz, but the simulator use this value in its calculations in the whole frequency area (800-1000 MHz). In addition, the simulator uses a circuit model for the IC, which is also defined

for the frequencies 860-960 MHz. Thus, the reason for the slight difference in simulation and measurement results outside this frequency area could be the possible change of the sensitivity of the IC, and the imperfectness of the circuit model at lower frequencies than 860 MHz and higher frequencies than 960 MHz. Another reason for the slight difference is that sewed antennas are not made of homogeneous conductive material as they are modelled in the simulator.

Figure 6 proves the validity of the hypothesis and the modelling method explained in the previous subsection. This method is applicable in designing T-matched dipole-type embroidery tag antennas.

V. CONCLUSIONS

Embroidered RFID tag antennas have been designed for UHF RFID applications. The designed dipoles are embroidered on cotton with different stitch densities. The sewing pattern consists of a sewed line along the length of the dipole, and zigzags sewed on it. The sewed dipoles are measured in anechoic chamber, when the cotton was dry. The measured read ranges of the sewed dipoles vary from 5.5 m to 7 m, offering excellent performance for many practical applications.

Conductivity of the sewed dipoles is estimated as a function of the thickness of the sewed structure. The evaluated conductivity values vary from 2000 S/m to 10000 S/m. According to the modelling technique presented in this paper, the overall conductivity of sewed antennas decreases as the thread density and the thickness of sewed structure increases. In the densely sewed patterns, a larger amount of vertically sewed conductive threads are very close to each other and their interaction may cause unexpected losses compared to less dense sewing patterns.

The evaluated conductivities of the sewed dipoles and the presented modelling technique can be used in future for optimization of the sewed antennas to operate in the vicinity of body.

According to the presented results, in the case of the sewing pattern presented in this paper, it is not necessary to sew T-matched dipole-type tag antennas with a high stitch and thread density. We can achieve high read range values even from very sparsely sewed T-matched dipoles, and thus achieving cost-savings by using less conductive threads and reducing the time spent on sewing.

In the future, it is important to further investigate the effect of the structure of the sewing pattern along with the geometry of the antenna on the conductivity of embroidery antennas. Conductivity of a sewing pattern might be higher for distinct antenna geometries, and lower for some other antenna types. So, it is preferable to study more the relation between the sewing pattern and the antenna type or geometry. In the future, also the operation of sewed tag antennas can be explored more precisely by studying the effect of relative positioning of electric threads in a sewing pattern on the input impedance of the tag antenna. This could be done by comparing the measured input impedance of tag antennas, when they are sewed with different kinds of sewing patterns.

REFERENCES

- [1] D. M. Dobkin, *RF in RFID - Passive UHF RFID in practice*, Elsevier, USA, 2008.
- [2] L. Yang, R. Vyas, A. Rida, J. Pan, M. Tentzeris, "Wearable RFID-enabled sensor nodes for biomedical applications", *Proceeding of Electronic Components and Technology Conference*, 27-30 May 2008, Lake Buena Vista, Florida.
- [3] P. Salonen, Y. Rahmat-Samii, "Wearable antennas: Advances in the design, characterization and application", in *Antennas and Propagation for body-centric wireless communications*, edited by P. Hall and Y. Hao, pp. 151-188, Artech House, Inc. MA, 2006.
- [4] J. L. Volakis, Z. Lanlin, W. Zheyu, Y. Bayram, "Embroidered flexible RF electronics", *IEEE International Workshop on Antenna Technology (iWAT)*, 5-7 March 2012, Tucson, Arizona, USA.
- [5] L. Ukkonen, L. Sydänheimo, Y. Rahmat-Samii, "Sewed textile RFID tag and sensor antennas for on-body use", *6th European Conference on Antennas and Propagation (EUCAP)*, 26-30 March 2012, Prague, Czech Republic.
- [6] Y. Bayram, Z. Yijun, S.S. Bong, X. Shimei, Z. Jian, N.A. Kotov, J.L. Volakis, "E-textile conductors and polymer composites for conformal lightweight antennas", *IEEE Trans. Antennas Propag.*, vol. 58, no. 8, pp. 2732-2736, Aug. 2010.
- [7] I. Locher, G. Tröster, "Enabling technologies for electrical circuits on a woven monofilament hybrid fabric", *Textile Research Journal*, vol. 78, no. 7, pp. 583-594, July 2008.
- [8] J. H. Choi, K. Yeonho, L. Kyoungwan, C. C. You, "Various wearable embroidery RFID tag antenna using electro-thread", *IEEE Antennas and Propagation Society International Symposium*, 5-11 July 2008, San Diego, CA, USA.
- [9] K. Yeonho, L. Kyoungwan, K. Yongju, C. C. You, "Wearable UHF RFID tag antenna design using flexible electro-thread and textile", *IEEE Antennas and Propagation Society International Symposium*, 9-15 June 2007, Honolulu, HI, USA.
- [10] K. Goojo, L. Jinseong, H. L. Kyoung, C. C. You, Y. Junho, H. M. Byung, Y. Jeonmo, C. K. Hee, "Design of a UHF RFID fiber tag antenna with electric-thread using a sewing machine", *Asia-Pacific Microwave Conference*, 16-20 Dec. 2008, Macau, China.
- [11] Shieldex, USA, Yarns and fillers, datasheets available at: http://www.shieldextrading.net/yarn_and_filler.html
- [12] S. Sankaralingam, B. Gupta, "Determination of dielectric constant of fabric materials and their use as substrates for design and development of antennas for wearable applications", *IEEE Trans. Instrum. Meas.*, vol. 59, no. 12, pp. 3122-3130, Dec. 2010.
- [13] C. A. Balanis, *Antenna theory - analysis and design*, 3rd edition, John Wiley & Sons, USA, 2005.
- [14] Alien Technology, Morgan Hill, CA, USA. Higgs series tag ICs, available at: http://www.alientechnology.com/tags/rfid_ic.php
- [15] Chemtronics, USA, Circuit Works Cw2400 Tech Data Sheet, available at: <http://www.industrycortex.com/datasheets/profile/263551545/circuit-works-cw2400-tech-data-sheet>
- [16] Voyantic Ltd, Espoo, Finland, Tagformance lite, available at: <http://www.voyantic.com>



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Title: 2012 IEEE International Conference on RFID-Technologies and Applications (RFID-TA) (12EX7672)

Description: Book.

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Date of Creation: 2012

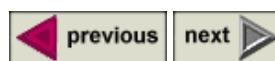
Date of Publication: 2012-12-17

Nation of First Publication: United States

Authorship on Application: IEEE (author of anonymous contribution), employer for hire; Domicile: United States; Citizenship: United States. Authorship: Collective Work.

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I. Introduction

II. Design and Fabrication of Embroidered Antennas

III. Performance of the Embroidered Antennas

IV. Simulation Model for the Embroidered Antennas

V. Conclusions

Authors

Figures

References

Citations

Keywords

Metrics

Abstract:

Wearable RFID tags and wireless sensors can be used for on-body and human monitoring applications. Embroidery with conductive thread provides compelling means for the fabrication of seamlessly garment-integrable antennas for wearable tags and wireless sensors. In this paper, we present the fabrication of fully assembled tags based on embroidered dipole-type antennas. The prototype tags achieve 5.5-to-7 meters read range. Moreover, we present a method for estimating the effective conductivity of the embroidery pattern, which depends on the sewing pattern and the stitch density. This will enable the judicious optimization of embroidered tag antennas using electromagnetic simulation tools.

Published in: 2012 IEEE International Conference on RFID-Technologies and Applications (RFID-TA)

Date of Conference: 05-07 November 2012

INSPEC Accession Number: 13244230

Date Added to IEEE Xplore: 10 January 2013

DOI: 10.1109/RFID-TA.2012.6404522

Publisher: IEEE

Conference Location: Nice, France

▼ ISBN Information:

Electronic ISBN:978-1-4673-4659-7

Print ISBN:978-1-4673-4656-6

Online ISBN:978-1-4673-4658-0

I. Introduction

Radio Frequency Identification (RFID) system consists of a reader, and a remote transponder, denoted as a tag, which is attached to a labelled object. The tag is made of an antenna and a microchip containing the identification code related to the object. Passive tags provide the required energy to drive the microchip from the radio frequency wave transmitted by the reader antenna. In a passive RFID system, communication happens through the reader antenna. The reader sends carrier wave to activate the tag and the tag sends identification data. When

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