

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 1014 (“*Shao*”)

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 260 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 515 identifies the numbering peculiarities or publishing patterns, reports year coverage, revised edition and/or issuance in parts.

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.

VIII. Public Availability of *Shao* (Exhibit 1014)

6. This Declaration relates to the dates of receipt and public availability of the following reference: Shuai Shao, Asimina Kiourti, Robert J

Burkholder, and John L Volakis, "Broadband Textile-Based Passive UHF RFID Tag Antenna for Elastic Material," (*"Shao"*) found within the IEEE Antennas and Wireless Propagation Letters, volume 14, pp. 1385–1388. I understand that *Shao* has been submitted as **Exhibit 1014** in this proceeding. That same reference is appended to my Declaration as **Appendix A**.

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

8. **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 Antennas and Wireless Propagation Letters* containing *Shao* held by the Library of Congress. **Appendix A** also include pages 1385–1388, which comprises the publication, "Broadband Textile-Based Passive UHF RFID Tag Antenna for Elastic Material," *i.e.* *Shao*.

17. 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 *the IEEE Antennas and Wireless Propagation Letters* containing *Saho*. The public catalog record indicates it is a “periodical or newspaper” record and, specifically, identifies the serial title name as “IEEE Antennas and Wireless Propagation Letters,” and the main title as “IEEE

Antennas and Wireless Propagation Letters.” 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 TK7871.6 .I3514. This information indicates serial cataloguing, as discussed above. The public catalog record also notes a publication location in New York, NY, with copyright date 2002, 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 Antennas and Wireless Propagation Letters* containing *Shao* (**Appendix A**).

18. **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 Antennas and Wireless Propagation Letters*, containing *Shao*, which was downloaded from: <https://lcn.loc.gov/2001211737>.

19. The Library of Congress MARC record for *Shao* identifies the fixed data elements of MARC field tag 008 as 030730c20029999nyuar 0 a0eng c. This indicates that the record for *IEEE Antennas and Wireless Propagation Letters* was last catalogued by the Library of Congress on July 30, 2003. 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 Antennas and Wireless Propagation Letters* by the Library of Congress, *Shao* would have been catalogued and made available to the public in 2016.

20. The Library of Congress MARC record for *IEEE Antennas and Wireless Propagation Letters* containing *Shao* includes field tag 245, which denotes the title and statement of responsibility for the work as “IEEE Antennas and Wireless Propagation Letters.”

21. In the Library of Congress MARC record, field tag 260 denotes information relating to the place of publication, name of publisher, and date of publication of *IEEE Antennas and Wireless Propagation Letters* as “a| New York, NY :b| Institute of Electrical and Electronics Engineers, c| 2002-. Subfield code “a” refers to the place of publication. Subfield code “b” refers to the name of the publisher. Subfield code “c” refers to date of publication, which for this record is 2002.

22. In the Library of Congress MARC record, field tag 310 indicates that *IEEE Antennas and Wireless Propagation Letters* is an annual publication.

23. In the Library of Congress MARC record, field tag 515 denotes the numbering peculiarities for the serial as vol. 3 (2004) also designated as v. 3, no. 1 (Dec. 2004).

24. Based on the information in **Appendices B and C**, it is clear that the MARC record (**Appendix C**) references *IEEE Antennas and Wireless Propagation Letters* containing *Shao*.

25. **Appendix D** to this declaration is a true and accurate copy of the U.S Copyright Office record for it copy of the *IEEE Antennas and Wireless Propagation Letters*, vol. 14 Parts I-II containing *Shao* which was retrieved from https://cocatalog.loc.gov/cgi-bin/Pwebrecon.cgi?v1=9&ti=1,9&Search%5FArg=IEEE%20Antennas%20and%20wireless&Search%5FCode=TALL&CNT=25&PID=HVyc__AZl2dIqaRv8xY0Jw7_&SEQ=20230920143226&SID=1. This record indicates a title of *IEEE Antennas and Wireless Propagation Letters*, volume 14, Part I-II which is the same title as found in *Shao*. The record shows the publication date for volume 14 Part I-II as December 11, 2015.

26. Based on the information in this **Appendix D** the issue of *IEEE Antennas and Wireless Propagation Letters*, containing *Shao* would have been publicly available within a few days or weeks of December 11, 2015.

27. **Appendix E** to this declaration is a true and accurate copy of the IEEE *Xplore* record for *Shao*. This record indicates the article entitled “*Broadband Textile-Based Passive UHF RFID Tag Antenna for Elastic Material*” was published in *IEEE Antennas and Wireless Propagation Letters* (Volume: 14), Page(s): 1385 - 1388. Further, this record indicates a publication date of February 27, 2015.

28. Based on the information in **Appendix E**, it is clear that the issue of *IEEE Antennas and Wireless Propagation Letters* containing *Shao* was published by IEEE Xplore on February 27, 2015. *Shao* would have been disseminated within a matter of a few days or weeks of receipt of February 27, 2015.

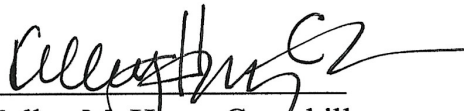
IX. Conclusion

29. 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.

30. 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



IEEE
ANTENNAS
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LETTERS

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Vol 14
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2015

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YANG HAO, *Editor-in-Chief*
School of Electronic Engineering and Computer Science
Queen Mary College, University of London
London E1 4NS, U.K.
Tel: +044 20 78825341
e-mail: awpl@ieeeaps.org
<http://ieee-awpl.eecs.qmul.ac.uk/>

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Broadband Textile-Based Passive UHF RFID Tag Antenna for Elastic Material

Shuai Shao, *Student Member, IEEE*, Asimina Kiourti, *Member, IEEE*, Robert J. Burkholder, *Fellow, IEEE*, and John L. Volakis, *Fellow, IEEE*

Abstract—We present a broadband textile-based UHF RFID tag antenna. Its wide bandwidth makes the tag less susceptible to objects and materials in the vicinity. Also high conductive textile material (E-fiber) is used to introduce elasticity, flexibility, and mechanical strength. As a result, the designed tag antenna can operate in a wide range of dielectric materials and various environments. By contrast, conventional RFID tag antennas have narrow bandwidth and must be designed for placement in different materials. The new tag is designed for implementing with elastic materials; as an example, the designed tags are tested on automotive tires. Experimental results show that the designed tag achieves much better performance compared with commercially available tags.

Index Terms—Antenna design, RFID, tag antenna, textile.

I. INTRODUCTION

RFID technology has been implemented widely for item identification and inventory tracking. Recently there is also strong interest for integrating RFIDs with sensors to wirelessly monitor conditions of structures or devices while in service and possibly hostile environments [1], [2]. Generally speaking, the RFID tag/sensor tag antenna is only designed for a given material to optimize impedance matching and read range. However, a tag's performance deteriorates significantly when mounting location or nearby material changes. Therefore, it is desirable to design a broad impedance bandwidth RFID tag antenna for operation in a variety of material structures.

Broadband RFID tag antennas have been considered before, but primarily for covering multiple bands [3]–[5]. Here, we focus on a broadband UHF RFID tag antenna delivering a bandwidth of 263 MHz (free space) for the purpose of maintaining performance over a wide range of materials. Previous UHF RFID antennas have been designed for operation on metallic objects [6], [7], extreme environments [8], and metallic/dielectrics [9]. However, there is no solution in the literature for UHF RFIDs that can operate in different dielectrics, including elastic materials.

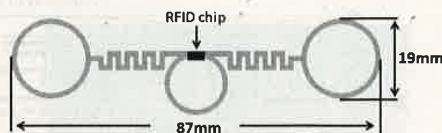


Fig. 1. Design of the proposed RFID tag antenna.

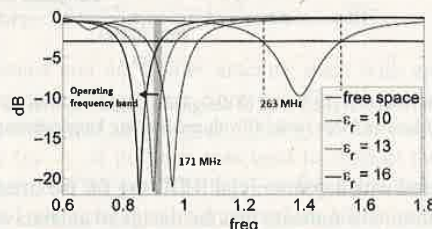


Fig. 2. Power reflection coefficient of the proposed antenna in free space and on a 4 mm dielectric slab for three different permittivities.

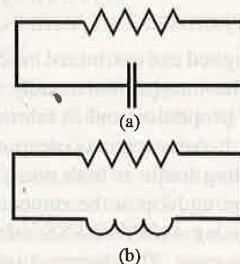


Fig. 3. Equivalent circuit model for: (a) the chip impedance and (b) the dipole antenna loaded with a short stub.

Here, we present an RFID tag antenna constructed from conductive textiles for flexible and stretchable designs [10]. A single E-fiber thread is employed to embroider a stand-alone RFID wire antenna. This is an attractive approach since former technologies based on stretchable conductive wires (e.g., liquid metal [11], copper traces [12], silver nanowires [13], etc.) are prone to fatigue and wear. Using the proposed textile wires, the RFID antenna exhibits excellent mechanical properties that favor its application in hostile environments.

In this work, a textile-based broadband RFID tag antenna is presented. The proposed tag antenna is designed incorporating three aspects: 1) electrical properties: broad bandwidth and electrically small size; 2) mechanical properties: elasticity, flexibility, and mechanical robustness; and 3) fabrication complexity: low profile and easy to mass produce. The designed antenna achieves a wide frequency bandwidth making it functional over a wide range of materials. Various tags are fabricated with copper wire and E-fiber threads. Their performance is evaluated

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The authors are with the Department of Electrical and Computer Engineering, ElectroScience Lab, The Ohio State University, Columbus, OH 43212 USA (e-mail: shao.64@osu.edu; kiourti.1@osu.edu; burkholder.1@osu.edu; volakis.1@osu.edu).

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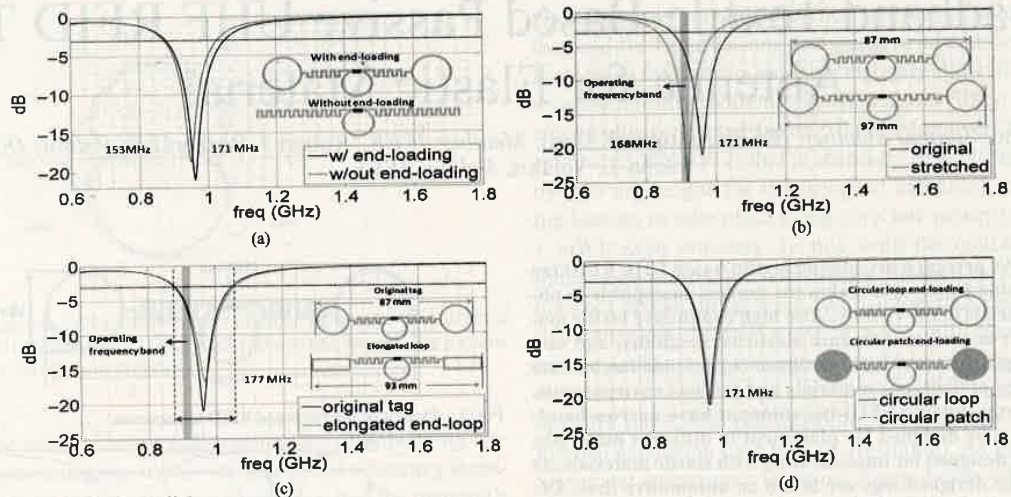


Fig. 4. Power reflection coefficient of designed antenna: (a) with versus without end-loading; (b) non-stretched versus stretched by 10%; (c) with original versus elongated end-loading loops; and (d) with end-loading loops versus patches.

and compared with a commercial RFID tag for the tire application. Measurements indicate that the designed antenna achieves significant improvement as compared to a conventional one, without loss of flexibility.

II. PROPOSED TAG ANTENNA

The antenna is designed and optimized based on the three key aspects described in the introduction, namely: 1) electrical properties; 2) mechanical properties; and 3) fabrication complexity. As illustrated in Fig. 1, the antenna is composed of three parts: the circular end-loading loops at both ends, the meander-line dipole arms, and a tuning loop in the center. Design optimization was performed using ANSYS HFSS software.

1) *Electrical Properties*: The designed tag antenna is electrically small (87 mm × 19 mm) and broadband. As such, it is able to maintain tuned behavior over a wide range of mounting locations and nearby materials. Fig. 2 plots the power reflection coefficient between the RFID chip and antenna. Specifically, in Fig. 2, the red curve and the blue curve correspond to the power reflection coefficient of the antenna in free space and when mounted on a 4 mm-thick dielectric with $\epsilon_r = 10, 13, 16$, respectively. As seen, the tag antenna delivers a 3 dB bandwidth of 263 MHz in free space. More importantly, it is tuned to maintain a good impedance match over the US RFID band (902–928 MHz) with sufficient bandwidth (171 MHz $\epsilon_r = 10$) to allow variability in the underlying or surrounding material. The impact of dielectric materials placed in the vicinity of the tag antenna and the need for a broadband antenna to mitigate these effects are discussed in [14] and [15].

In the proposed antenna design the circular loop in the center is used to provide sufficient inductance for impedance matching to the RFID chip. An RFID tag consists of two parts, an antenna and an RFID chip. For maximum power delivery, it is necessary to match the antenna impedance to that of the chip. Therefore, we must minimize the power reflection coefficient given by [16]

$$|\Gamma(f)|^2 = \left| \frac{Z_c(f) - Z_a^*}{Z_c(f) + Z_a^*} \right|^2. \quad (1)$$

Here, Z_c and Z_a refer to the complex impedances of the RFID chip and antenna, respectively. Generally speaking, the RFID chip does not incorporate a matching circuit. Its impedance is highly capacitive and can be modeled as a resistor and a capacitor in parallel, shown in Fig. 3(a). Based on transmission line theory, the circular center loop can be viewed as a short stub, and therefore serves as a parallel inductor. The equivalent circuit model of the antenna and the center loop is provided in Fig. 3(b). We note that the length of the loop was optimized such that complex conjugate matching can be achieved at the desired frequency.

The meander-line structure was adopted to reduce the tag's size [17]. As compared with a straight dipole of the same length, the resonance frequency can be significantly reduced using meander-lining, typically at the expense of narrower bandwidth.

The circular end-loading wire loops are employed to increase the impedance bandwidth of the antenna. The end-loading (or top-loading) of the dipole serves to broaden its bandwidth [18]. Fig. 4(a) compares the designed antenna with and without end-loading. As would be expected, the end-loading loops improve impedance bandwidth. Furthermore, the end-loading reduces the overall size of the antenna. As depicted in Fig. 4(a), the antenna with end-loading is 3 mm shorter than the one without end-loading.

2) *Mechanical Properties*: The tag antenna was designed to be mechanically robust. This implies that its physical integrity and electrical performance remain intact when the tag is subject to external forces. To do so, the shape of the meander-lines was optimized such that the tag's performance is preserved even if the antenna undergoes deformation. Importantly, the meander line structure enables stretching of the tag. Fig 4(b) compares the performance of the original antenna and the one stretched by 10% (overall length remains the same). As expected, the simulations show that the antenna's resonance is shifted downwards in frequency after stretching. However, its bandwidth still overlaps the operating frequency band. The end-loading circular loops also allow stretching in any dimension. Fig. 4(c) compares the

antenna with the original and elongated loops. The elongated loops are of rectangular shape, but maintain the same perimeter.

3) *Fabrication Complexity*: The designed tag antenna incorporates a low profile structure such that the fabrication complexity and manufacturing cost are reduced. Previous textile-based RFID tag antennas use densely stitched conductive textile to produce the surface of planar antennas. In this work, the tag antenna only requires a single thread of the conductive textile. This is because end-loading loops were used instead of patches in order to avoid rigid planar surfaces. The adoption of the loops was inspired by the observation that for end-loading patches, the current is primarily distributed on the edges. Fig. 4(d) compares the antenna when the end-loading is formed of loops and patches. The results show that the antenna with end-loading loops achieves equally good performance as that with patches. When fabricated using single textile threads, the circular loop is more attractive as it avoids sharp corners. That is, rectangular loops are challenging to fabricate. Therefore, circular loops were adopted to avoid sharp corners and increase fabrication accuracy. The meander-line does not require embroidering sharp edges either. As will be shown in the following section, the shape of the antenna could be preserved after cured with polymer material.

III. TEXTILE-BASED TAG ANTENNA

To realize a flexible and stretchable version of the proposed broadband RFID tag, we used electrically conductive metal-polymer fibers (E-fibers) embedded in elastic polymer. Flexibility and elasticity are important for RFID tags that operate in hostile environments subjecting them to mechanical deformation. These E-fibers have already been validated for some textile antennas and sensors [10], [19], indicating excellent mechanical strength, flexibility, low DC resistance (about 0.5–0.7 Ω/m), and low loss at RF frequencies. They have been found to have comparable performance to their copper counterparts. Polydimethylsiloxane (PDMS) was employed as the polymer material ($\epsilon_r = 3$, $\tan \delta < 0.02$) because it is flexible and allows for antenna elongation of about 10% of its original size.

The fabrication procedure may be summarized as follows: 1) convert the antenna CAD file into a digital stitching pattern, or, equivalently, needle path; 2) use a standard sewing machine to embroider the prescribed antenna pattern onto a polyester fabric (as an intermediate support); 3) solder the RFID chip to the antenna; 4) melt the non-stretchable polyester fabric via heating (melting point $\approx 250^\circ\text{C}$) without damaging the E-fiber (melting point $\approx 600^\circ\text{C}$); 5) pour 1–2 mm thick liquid PDMS polymer on the RFID tag; and 6) cure the PDMS polymer by placing it on an elevated temperature (120°C) hot plate. The resulting product is the flexible and stretchable E-fiber RFID prototype tag shown in Fig. 5.

The prototype was found to withstand repetitive flexing and stretching. The surrounding polymer also preserves the integrity of the E-fiber and protects it from corrosion.

IV. EXPERIMENTAL RESULTS

Four versions of the designed antenna were fabricated and soldered to G2XM RFID chips (impedance: 16–148j):¹ a copper



Fig. 5. Fabricated prototype of the flexible and stretchable textile RFID tag embedded in polymer.



Fig. 6. Copper wire version prototype embedded in polymer.

wire antenna and an E-fiber antenna, each with and without being embedded in polymer. Shown in Fig. 6 is the copper wire version embedded in polymer. Thin (1–2 mm) and low-permittivity ($\epsilon_r = 3$) polymer was used to support the mechanical integrity of the tag. The tags' performance was evaluated using read range and threshold power tests (the minimum reader output power required to detect the tag). An Impinj Speedway RFID reader was used to collect data.² All measurements were conducted in a large RFID lab.

A. Read Range Test

In this test the fabricated copper wire tag embedded in polymer and a commercially available RFID tag for tires (the Speedy Core) were tested and compared. The commercial tag has the same G2XM chip and its structure is shown in [20]. Both tags were measured on truck tires. Truck tires are constructed of multiple layers of rubber with different dielectric constants and thicknesses [14]. It is necessary to have a broadband antenna such that the RFID tag maintains good performance over a wide range of tires.

The measurement setup is shown in Fig. 7. The tag under test was mounted at the same position on the outer surfaces S1, S2, S3, and S4 of two truck tires. The space between the two adjacent tires is 15 cm, equal to the separation of dual tires on trucks. The output power of the RFID reader was set to be 30 dBm. The RFID reader antenna was moved away from the tires until the tag cannot be detected. The distance between the reader antenna and the tire on the left is the read range of the tag. Measurement results are shown in Table I.

As the table shows, the designed tag has much longer read range than the Speedy Core. More importantly, the designed tag was readable at all positions whereas the Speedy Core was not readable at positions S3 and S4.

B. Threshold Power Test

In this test all four fabricated tags were evaluated for threshold power sensitivity. The threshold power of a tag is the minimum reader output power required to detect the tag at a

¹[Online]. Available: http://www.nxp.com/documents/data_sheet/SL3ICS1002_1202.pdf

²[Online]. Available: <http://www.impinj.com/products/speedway/>



Fig. 7. Read range experiment setup.

TABLE I
READ RANGE TEST OF THE COPPER WIRE VERSION OF THE BROAD IMPEDANCE
BANDWIDTH RFID TAG COMPARED TO A COMMERCIALLY AVAILABLE TAG
FOR TIRES, THE SPEEDY CORE

Antenna/Surface	S1	S2	S3	S4
Commercial Tag for Tires (Speedy Core)	4ft	0.5ft	Cannot be read	Cannot be read
Copper wire antenna embedded in polymer	13+ft	8ft	4ft	4ft

TABLE II
THRESHOLD POWER TEST OF PROTOTYPES

Copper Wire	E-fiber	Embedded copper wire	Embedded E-fiber	Speedy Core tag
20 dBm	21 dBm	21 dBm	20 dBm	27dBm

TABLE III
STRETCH TEST OF THE COPPER WIRE TAG

Antenna	Length	Threshold power
Original	85 mm	20 dBm
Stretched	93 mm	20 dBm

fixed range. A lower power indicates a better performing tag. The tags under test were placed in turn on surface S1 of the tire (see Fig. 7). The reader antenna was fixed 5 ft from the tire. The results are given in Table II. The threshold power is nearly the same for all four versions of the tag. We may therefore conclude that all of the fabricated tags would outperform the commercial Speedy Core tag.

C. Stretch Test

The performance of the copper wire prototype was tested in an elongated condition. As the tags will be embedded in the sidewall of a tire during the manufacturing process, the tag antenna would suffer a certain amount of deformation along its longitudinal direction. Therefore it is very important that the tag antenna maintains its electrical properties after the embedding process. Threshold power measurements were carried out and listed in Table III. The designed tag achieved the same good performance after being stretched by nearly 10%.

V. CONCLUSION

In this work, a textile-based broadband elastic RFID tag antenna was designed, fabricated and tested. It was demonstrated that the designed antenna achieves a bandwidth of 263 MHz in free space, and more importantly, it maintains its tuned behavior when placed on dielectrics with varying permittivity. Different versions of the designed tag antenna were fabricated and tested.

Experimental results show that the designed tags achieve consistently better performance as compared to an existing commercial tag. Furthermore, the performance of the designed tag antenna does not degrade under mechanical deformation up to 10%, which makes it a good candidate for elastic and hostile environments.

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APPENDIX D



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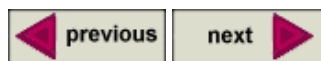
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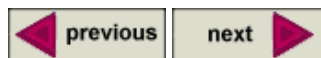
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I. Introduction

II. Proposed Tag Antenna

III. Textile-Based Tag Antenna

IV. Experimental Results

V. Conclusion

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Keywords

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Footnotes

Abstract:

We present a broadband textile-based UHF RFID tag antenna. Its wide bandwidth makes the tag less susceptible to objects and materials in the vicinity. Also high conductive textile material (E-fiber) is used to introduce elasticity, flexibility, and mechanical strength. As a result, the designed tag antenna can operate in a wide range of dielectric materials and various environments. By contrast, conventional RFID tag antennas have narrow bandwidth and must be designed for placement in different materials. The new tag is designed for implementing with elastic materials; as an example, the designed tags are tested on automotive tires. Experimental results show that the designed tag achieves much better performance compared with commercially available tags.

Published in: IEEE Antennas and Wireless Propagation Letters (Volume: 14)

Referenced in:IEEE RFID Virtual Journal

Page(s): 1385 - 1388 **INSPEC Accession Number:** 15209514

Date of Publication: 27 February 2015 **DOI:** 10.1109/LAWP.2015.2407879

ISSN Information: **Publisher:** IEEE

Funding Agency:

I. Introduction

RFID technology has been implemented widely for item identification and inventory tracking. Recently there is also strong interest for integrating RFIDs with sensors to wirelessly monitor conditions of structures or devices while in service and possibly hostile environments [1], [2]. However, a tag's performance deteriorates significantly when mounting location or nearby material changes. Therefore, it is desirable to design a broad impedance

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Published in: [IEEE Antennas and Wireless Propagation Letters](#) (Volume: 14)

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