医学拾萃

IMPROVE REVIEW

标本处理系统篇

Pre-Analytical System

二〇二二年六月刊

June 2022

Article Reading Guidance 文献导读 | Article Abstract Collection 文献摘要 | Featured Article 文献精读 | Original Article Reading 文献原文

IMPROVE 阳普医疗 IMPROVE MEDICAL

医学拾萃

CONTENTS

主编 Chief Editor 邓冠华 博士 Dr. Guanhua Deng

联合主编 Co-Editor-in-Chief 朱勇 博士 Dr.Yong Zhu

执行主编 Executive Editor 高树勇 Shuyong Gao

专刊编辑 Special Editor 李小林 博士 Dr. Jerry Li; 孙其岭 博士 Dr. Qiling Sun; 杨艳 博士 Dr. Yan Yang; 田艳丽 博士 Dr. Yanli Tian; 罗江兰 Jianglan Luo

审核编辑 Audit Editor 卢嘉丽 Jiali Lu

协作单位 Partnership
阳普学院 Improve College
广东省医用材料血液相容性研究企业重点实验室 Guangdong Enterprise Key Laboratory of Blood Compatibility of Medical Materials
美国吉迪思诊断有限公司 GIMDx,Inc.

联系方式 Contact Us yxsc@improve-medical.com

IMPROVE 陽普醫療 IMPROVE MEDICAL

电子文献

Article Reading Guidance

文献导读

本期的文献导读介绍了射频识别技术（RFID）技术在医疗标本管理中的应用，一套完整的 RFID 系统，可以接收标签中的信号，读取信息并解码后送至中央信息系统进行有关数据处理，以获得对应的标签信息。RFID 技术可用于医疗保健领域，可对患者信息、医疗设备、药品、血液样本等项目进行高效管理，有效改善医疗信息系统及管理系统不完善导致的信息不能及时准确地共享或因人力不足及疏忽，而造成的时间浪费和严重后果的发生。

RFID 技术及其在医疗和标本管理中的应用与发展

何野 韦晶晶

阳普医疗科技股份有限公司

射频识别技术（RFID），是 20 世纪 80 年代发展起来的一种新兴自动识别技术，射频识别技术是一项利用射频信号通过空间耦合（交变磁场或电磁场）实现无接触信息传递并通过所传递的信息达到识别目的的技术。最初在技术领域，应答器是指能够传输信息回复信息的电子模块，近些年，由于射频技术发展迅猛，应答器有了新的说法和含义，又被叫做智能标签或标签。使用此技术的常见应用包括安全识别、零售物品管理、库存、访问控制和跟踪。RFID 技术可用于医疗保健领域，更具体地说，用于医院智能管理系统和在医疗中心内用于血液样本管理[1,2]。RFID 相较于快速响应码（QR）和条形码等光学技术有一些好处，例如它可以提高储存、识别、跟踪和监控任务的自动化水平[3]，从而减少可能的人为干预错误。

本文将从 RFID 的定义、在医疗行业的应用、以及 RFID 血液样本管理技术这些角度来进行讲述分析。

1. 什么是 RFID 标签?

一套完整的 RFID 系统，是由阅读器（Reader）与电子标签（TAG）也就是所谓的应答器（Transponder）及应用软件系统三个部份所组成，其工作原理为 RFID 标签进入磁场后，接收解读器发出的射频信号，凭借感应电流所获得的能量发送出存储在芯片中的产品信息（Passive Tag，无源标签或被动标签），或者由标签主动发送某一频率的信号（Active Tag，有源标签或主动标签），解读器读取信息并解码后，送至中央信息系统进行有关数据处理[4]。

2. RFID 在医疗行业的应用

传统的医疗产业由于涉及范围之广，医疗信息系统及管理系统不完善，导致信息不能及时准确地共享或因人力不足及疏忽，而造成很多时间的浪费，甚至导致严重后果，例如在急诊中，医护人员需先对患者的病历及过敏史等情况有所了解，才能救治，这样会浪费很多时间，延误救治时机[5]；再如集体事故中，可能出现医护人员人手不足，加之传统的人工登记速度慢且错误率高，对于濒危病人而言，很可能因此错失救治的最佳时机；与此同时，关于医用物品及设备的核对与管理，人工操作会有疏忽失误，发生相似物品的误置事件。为了应对日益增长的患者需求、改善医院现有的管理系统与结构、提高医院服务质量与工作效率，嵌入式系统技术、传感器技术、无线局域网技术、数据处理技术、视频检测识别技术、DPS 及 RFID 等物联网技术被提出应用于医疗领域[6]，希望能建立起实时、准确、高效的医疗管理系统，架构起移动式医疗网络。

2.1. 患者信息管理

医疗信息包括病人各方面的信息，例如：药物过敏情况、家族病史、既往病史等的自身信息，还包括病人就诊情况：挂号、治疗记录、住院出院、付费等信息。RFID 技术，可以很好的解决存在的问题,当病人身份未知而病人又处于危重状态时，我们可以借助 RFID 技术，快速确认病人身份及详细的医疗信

息；对于住院的患者，可以让他们佩戴采用 RFID 技术开发的标签，里面存储患者相关的医疗信息，医生只需用终端设备靠近或扫描便可了解详细信息[7]。移动医疗是与现有的 HIS 系统集成，以无线局域网技术和 RFID 为底层，配有智能型手持数据终端，为移动中的医护人员提供随身数据的应用方向[20]。

2.2. 医疗设备管理

医疗设备分为体型较大，不易移动的静态设备和便于移动的动态设备。确定静态设备位置进行盘点、维护和检测的难度不大，目前国内医院普遍使用的 HIS 系统。一般都包含设备管理模块，主要是静态资产管理，对于动态设备管理还有所欠缺，应用 RFID 技术，自动实时定位静态与动态设备。同时在设备上都附上 RFID 芯片，存储设备信息及维护巡检的记录[8]。不仅管理上更加简便，还可实时追踪，极大的降低了人力工作的难度。

2.3. 药品管理中可使用的方法

应用现代信息技术，进行医院药品管理，就是对每种药品都加一个代码，将其名称、规格、有效期、生产批号等信息录入计算机进行管理，并设置有效期报警，防止药品过期。而药品的消耗统计等工作也可以交由计算机完成，快速准确。但是不能记录下每一药品的去处，且一旦相似药品发生误置，人工不一定可以发现。而使用 RFID 技术来管理医院药品时，通过无线传感器网络与 RFID 标签的共同作用，可以实时获取该药品的所有信息[9]。尤其是当药房人流量多时，取药效率提高，在给药时还可以最后确认药品。

3. RFID 血液样本管理

3.1. 智能血液储备系统

世界范围内每分钟都有人需要输血，在美国每年大约需要输入 3000 万种血液成分[10]。每年大约有 60 例因错误输血而死亡，提醒我们需要注意减少输血错误。错误识别血液和/或输血患者是一种严重的生命威胁，目前在收集到献血者的血袋后，血液管理机构或医院大多采用条形码标签管理。每个血袋上都贴有各种条形码，其中包含有关血液的特定信息，例如血型、采集日期、有效期、每一步处理人员等。从血库系统检索血袋时，会手动读取条形码，以记录检索到的血袋，然后将其投放到指定医院或患者。即使使用这种血液管理系统，在血库中也会出现大约 14 个识别错误，在临床时也会出现 86 个识别错误[11]。

此前有报道提出一种智能血液储备系统，通过一个拥有大量 RFID 标签的系统来缓解此类识别错误[12]。该系统包括三个主要部分：储存柜、收发器和检索 PC。所有重要的数据都可以存储在一个 RFID 芯片中，每个血袋都可以使用一个标签。储存柜内收集的血袋的位置会被自动检测，并通过在架子和血袋上放置双 UHF RFID（高频射频标签）标签引入数据库，并且抽屉的读取传感器经过专门设计，特定方向才能有效读取，以免检测到来自其他抽屉的标签。医院工作人员将使用数据库搜索他们需要的特定血袋，并立即了解柜内的哪个位置是所需的血液。此外，该系统还可以与临床 RFID 系统集成，实现血袋与患者血型的自动交叉检查。智能血液储备系统将有助于确保正确的血液管理比普通条形码库存系统更可靠、更准确。

3.2. 用于管理采血管的特殊 RFID 标签

在医疗中心，人体血液被收集在血袋或采血管中。血袋由柔性 PVC 塑料制成[13]，用于储存大量血液，而血管由玻璃或聚对苯二甲酸乙二醇酯（PET）硬质容器制成[14]，其中装有少量血液样本。对于采血管来说，RFID 设计的难题在于非平面的管体对标签的延展性和柔性有较高的要求。

有研究提出了一种适用于欧洲 RFID UHF 系统的用于采血管可追溯性应用的新型紧凑型高性能标签[15]。所提出的标签基于电容偶极子设计，在 Kapton 聚酰亚胺基板上通过使用低成本和快速原型制作技术制造的。这是一种具有优异电气参数的柔性基板，可使标签符合临床管的弯曲形状。结果如表一所示，贴在装满血液的诊所试管上的新标签的读数范围超过 2 m。此外，其电容式设计对管内血液的存在表现出很强的敏感性。因此，当试管为空时，读数范围会急剧下降，激活标签所需的最小功率上升。此属性可能对许多跟踪应用程序很有用，因为它可以减少空管生成的信息量。也可以利用相同的特性将标签用作传感系统来检测和测量临床采血管中的血液量。除此之外，RFID 的基本信息储存功能也不会收到影响。

表 1. 装有不同血量的采血管激活所需的最小发射功率以及标签的读取范围

Blood Level (mL)	Transmitted Power (dBm)	Reading Range (m)
4	15.1	2.2
2.5	20.1	1.1
1.5	22.6	0.8
0	25.9	0.6

值得一提的时，早在 2012 年便有文献指出当血液样本暴露于 820 ~ 960 MHz 射频时，sRBCs 的上清液 pH 值和氯含量降低，游离血红蛋白、钾和钠含量增加，但在试验组和对照组之间没有显著性差异（$p > 0.05$）。在贮藏期间，试验组和对照组的 pH 值、PLT 计数和 PLT 聚集率均降低，但差异 d 不显著（$p > 0.05$）。这说明高频的射频对血液样本没有影响[16]，同时低频射频下血液样本也样能保持稳定[17]。

4. 总结

在医院管理中使用 RFID 技术可以为医疗保健组织的业务运营提供多种好处。RFID 技术可以提高患者安全性，加快关键治疗速度，降低救治成本，并更好地跟踪患者的药物治疗依从性，从而实现更好的后续治疗[18]。而与目前用于跟踪血液制品从抽血到输血或检测的传统程序相比，RFID 能有效避免其中由人引起的失误。

然而 RFID 技术为医疗机构提供了提高生产力，提供更高质量护理和提高安全标准的同时，也存在涉及患者信息隐私和安全性的风险。使用低质量的标签会导致未经授权的来源访问患者信息的可能性增加[19]。另一方面相较于传统的光学标签，RFID 相对较高的成本也是医疗从业人员需要考虑的因素之一。尽管如此，考虑到物联网的时代到来，医疗机构管理智能化大势所趋，希望不断进步的 RFID 技术能够有效的帮助到医疗从业人员和患者。

参考文献

1. Sun R, Rahmadya B, Kong F, Takeda S. Visual management of medical things with an advanced color-change RFID tag. Sci Rep. 2021;11(1):22990. Published 2021 Nov 26. doi:10.1038/s41598-021-02501-x.

2. Hohberger C., Davis R., Briggs L., Gutierrez A., Veeramani D. Applying radio-frequency identification (RFID) technology in transfusion medicine. Biologicals. 2012; 40: 209-213. doi: 10.1016/j.biologicals.2011.10.008.

3. Rajasekar SJS. An Enhanced IoT Based Tracing and Tracking Model for COVID -19 Cases. SN Comput Sci. 2021;2(1):42. doi: 10.1007/s42979-020-00400-y. Epub 2021 Jan 18. PMID: 33490971; PMCID: PMC7812980.

4. Costa F, Genovesi S, Borgese M, Michel A, Dicandia FA, Manara G. A Review of RFID Sensors, the New Frontier of Internet of Things. Sensors (Basel). 2021 Apr 30; 21(9): 3138. doi: 10.3390/s21093138. PMID: 33946500; PMCID: PMC8124958.

5. Zhu F, Li P, Xu H, Wang R. A Novel Lightweight Authentication Scheme for RFID-Based Healthcare Systems.Sensors (Basel). 2020; 20(17):4846. Published 2020 Aug 27. doi:10.3390/s20174846.

6. Chen X, Zhu H, Geng D, Liu W, Yang R, Li S. Merging RFID and Blockchain Technologies to Accelerate Big Data Medical Research Based on Physiological Signals. J Healthc Eng. 2020 Apr 14; 2020: 2452683. doi: 10.1155/2020/2452683. PMID: 32351676; PMCID: PMC7178520.

7. Jeon B, Jeong B, Jee S, Huang Y, Kim Y, Park GH, Kim J, Wufuer M, Jin X, Kim SW, Choi TH. A Facial Recognition Mobile App for Patient Safety and Biometric Identification: Design, Development, and Validation. JMIR Mhealth Uhealth. 2019 Apr 8;7(4): e11472. doi: 10.2196/11472. PMID: 30958275; PMCID: PMC6475824.

8. Yoshikawa T, Kimura E, Akama E, Nakao H, Yorozuya T, Ishihara K. Prediction of the service life of surgical instruments from the surgical instrument management system log using radio frequency identification. BMC Health Serv Res. 2019 Oct 15;19(1):695. doi: 10.1186/s12913-019-4540-0. PMID: 31615497; PMCID: PMC6794753.

9. Pérez MM, González GV, Dafonte C. The Development of an RFID Solution to Facilitate the Traceability of Patient and Pharmaceutical Data. Sensors (Basel). 2017 Sep 29;17(10):2247. doi: 10.3390/s17102247. PMID: 28961207; PMCID: PMC5677332.

10. Blood Facts and Statistics. American Red Cross, Washington, DC, USA. [Online]. Available: http://www.redcrossblood.org/learn-about-blood/blood-facts-and-statistics.

11. R. R. Sharma, S. Kumar, and S. K. Agnihotri, “Sources of preventable errors related to transfusion,” Vox Sanguinis, vol. 81, no. 1, pp. 37-41, Jul. 2001.

12. Zaric A., Cruz C.C., de Matos A., da Silva M., Costa J.R., Fernandes C.A. RFID-based Smart blood stock system. IEEE Antennas Propag. Mag. 2015; 57: 54-65. doi: 10.1109/MAP.2015.2420491.

13. Lozano M., Cid J. DEHP plasticizer and blood bags: Challenges ahead. ISBT Sci. Ser. 2013; 8: 127-130. doi: 10.1111/voxs.12027.

14. Kratz A., Stanganelli N., Van Cott E.M. A comparison of glass and plastic collection tubes for routine and specialized coagulation assays: A comprehensive study. Arch. Pathol. Lab. Med. 2006; 130: 39-44.

15. El Khamlichi, M., Alvarez Melcon, A., El Mrabet, O., Ennasar, M. A., & Hinojosa, J. (2019). Flexible UHF RFID Tag for Blood Tubes Monitoring. Sensors (Basel, Switzerland), 19(22), 4903. https://doi.org/10.3390/s19224903.

16. Wang Q L, Wang X W, Zhuo H L, et al. Impact on storage quality of red blood cells and platelets by ultrahigh-frequency radiofrequency identification tags[J]. Transfusion, 2013, 53(4):868-871.

17. Rogowska A, Chabowska AM, Lipska A, Boczkowska-Radziwon B, Bujno M, Rusak T, Dziemianczuk M, Radziwon P. High-frequency (13.56-MHz) and ultrahigh-frequency (915-MHz) radio identification systems do not affect platelet activation and functions. Transfusion. 2016 May;56(5):1148-52. doi: 10.1111/trf.13506. PMID: 27167357.

18. Wicks A., Visich J., Li S. Radio Frequency Identification Applications in Hospital Environments. Hospital Topics. 2006;84(3):3-8.

19. Lockton V., Rosenberg R. RFID: The Next Serious Threat to Privacy. Ethics and Information Technology. 2005; 7(4): 221-231.

20. álvarez López Yuri, Jacqueline F, álvarez Narciandi Guillermo, et al. RFID Technology for Management and Tracking: e-Health Applications[J]. Sensors, 2018, 18(8): 2663.

陽普醫療
IMPROVE IMPROVE MEDICAL

——采血一小步，检验一大步

阳普医疗IMPROVACUTER®真空采血管系列

一如既往的卓越.

ALWAYS EXELLENCE.

Article Abstract Collection

文献摘要

本期的文献摘要，选取了综述中若干重要的参考文献，针对其摘要做了中文翻译。这些文献对射频识别技术（RFID）技术在医疗机构的使用进行了介绍，阐述了该项技术在提高医疗信息系统流程和管理上的效率的重要作用，为医疗机构提高信息管理效率的方式提供了参考。

参考文献摘要翻译

1. **Sun R, Rahmadya B, Kong F, Takeda S. Visual management of medical things with an advanced color-change RFID tag. Sci Rep. 2021;11(1):22990. Published 2021 Nov 26. doi:10.1038/s41598-021-02501-x.**

摘要

本文提出了一种带有变色射频识别（RFID）标签的医疗物品可视化管理方案。变色 RFID 标签采用特定的 RFID 标签集成电路（IC）和层压 pH 指示纸。该 IC 具有能量收集和开关接地功能，使其能够为层压的 pH 指示纸发电。这种现象导致吸收在层压 pH 指示纸中的 NaCl 溶液电解，电解产生的碱性物质可改变 pH 指示纸的颜色。本文提出了一种新型灵敏层压 pH 指示纸结构。所提出的先进变色 RFID 标签采用新型层压 pH 指示纸，使用发射 1 W 无线电波的 RFID 阅读器成功地在 1 m 距离处显著改变其颜色，开始无线电波照射后 3 ~ 5 秒观察到了颜色变化。本实验的结果也证实了改变后的颜色可以保持 24 小时以上。此外，本文还提供了医疗用品（病人衣物和消毒剂）可视化管理系统的两个演示。

2. **Hohberger C., Davis R., Briggs L., Gutierrez A., Veeramani D. Applying radio-frequency identification (RFID) technology in transfusion medicine. Biologicals. 2012; 40:209-213. doi: 10.1016/j.biologicals.2011.10.008.**

摘要

基于 ISO/IEC 18000-3 协议模式 1 下的标准 13.56 MHz RFID 标签已被国际输血协会（ISBT）和美国食品和药物管理局（FDA）接受为数据载体，以集成和增强血液制品上携带的 ISBT 128 条形码数据。使用携带 ISBT 128 数据结构的 13.56 MHz RFID，可以在全球部署和使用 RFID，支持血液的国际转移和国际救灾。

威斯康星州血液中心正在进行的部署和爱荷华大学健康中心的测试是 FDA 首次允许在血库和输血捐赠的所有阶段实施 RFID。本文中，RFID 技术和设备选择将与 FDA 要求的射频安全测试一起讨论；并结合血液企业计算系统和所需的 RFID 标签性能。由于血袋会经受离心和辐照，标签的设计和持久性是一个问题。相应的开发问题在本文中将会被讨论。与血液中心运营中使用条形码相比，RFID 的使用通过节省劳动力和减少错误，可带来显著的投资回报。

3. **Rajasekar SJS. An Enhanced IoT Based Tracing and Tracking Model for COVID -19 Cases. SN Comput Sci. 2021;2(1):42. doi: 10.1007/s42979-020-00400-y. Epub 2021 Jan 18. PMID: 33490971; PMCID: PMC7812980.**

摘要

COVID - 19 大流行已警告世界各国实施严格的宵禁和紧急状态，以防止该疾病的社会传播。为了实现这一目标，需要对疑似 COVID - 19 病例进行有效的示踪和追踪。鉴于每天记录的病例数量巨大，简单的人工追踪无

法有效地执行这一过程。因此，我们提出了一种基于物联网（IoT）的自动示踪和追踪方法，通过使用经济高效的 RFID 标签和充当阅读器的个人移动设备来识别可能的联系人。由此，即使在不知道疑似病例的情况下，也可以追踪接触的人。这将使行政机构能够对可能的主要和次要接触者进行百分之百的隔离，并对其进行监控。这将增强各国应对疫情的能力。

4. **Costa F, Genovesi S, Borgese M, Michel A, Dicandia FA, Manara G. A Review of RFID Sensors, the New Frontier of Internet of Things. Sensors (Basel). 2021 Apr 30;21(9):3138. doi: 10.3390/s21093138. PMID: 33946500; PMCID: PMC8124958.**

摘要

本文介绍了 RFID 传感技术解决方案及其当前或未来的应用。第一部分总结了无线传感技术的基本原理，并讨论了采用 RFID 传感器替代配备标准传感器的 Wi-Fi 节点的好处。重点在于，与市场上可用的其他传感器解决方案相比，RFID 传感器没有电池、成本更低。通过将 RFID 传感器分为芯片和无芯片配置，对它们进行了严格的比较。参考它们的工作机制（电子、电磁和声学）进一步分析了这两个类别。通过配备芯片的标签进行 RFID 感应现在是一种成熟的技术解决方案，它在市场和多个场景中的应用率不断提高。另一方面，无芯片 RFID 传感是一个相对较新的概念，可能会成为市场上的颠覆性解决方案，但需要对该领域进一步研究以定制其在特定场景中的应用。本文展示并讨论了几种标签配置的优点和局限性。总结了最适合 RFID 传感器的应用场景。最后，对市场上可用的一些传感解决方案进行了描述和比较。

5. **Zhu F, Li P, Xu H, Wang R. A Novel Lightweight Authentication Scheme for RFID-Based Healthcare Systems. Sensors (Basel). 2020;20(17):4846. Published 2020 Aug 27. doi:10.3390/s20174846.**

摘要

物联网（IoT）已被整合到传统医疗保健系统中，以改善医疗保健流程。作为物联网的关键技术之一，射频识别（RFID）技术已被应用于提供病人监护、药物管理和医疗资产跟踪等服务。然而，人们担心基于 RFID 的医疗保健系统的安全性和隐私性，这需要一个合适的解决方案。为了解决这个问题，最近在 2019 年，范等人在 IEEE 网络中提出了一种轻量级 RFID 认证方案。他们声称，他们的方案能够以较低的实现成本抵御 RFID 系统中的各种攻击，因此适用于基于 RFID 的医疗保健系统。在本文中，我们的贡献主要包括两部分。首先，我们分析了范等人的方案的安全性并找出其安全漏洞。其次，我们提出了一种新的轻量级认证方案来克服这些安全弱点。安全性分析表明，我们的方案能够满足必要的安全性要求。此外，性能评估表明我们的方案成本较低。因此，我们的方案非常适合实际的基于 RFID 的医疗保健系统。

6. **Chen X, Zhu H, Geng D, Liu W, Yang R, Li S. Merging RFID and Blockchain Technologies to Accelerate Big Data Medical Research Based on Physiological Signals. J Healthc Eng. 2020 Apr 14;2020:2452683. doi: 10.1155/2020/2452683. PMID: 32351676; PMCID: PMC7178520.**

摘要

生理信号采集和监测系统的普及，导致了生理信号数据的爆炸式增长。此外，RFID 系统、区块链技术和雾计算机制通过大数据研究显著提高了生理信号信息的可用性。混合系统发展的驱动力是不断努力提高医疗保健服务的效率和可持续性。植入式医疗设备（IMD）是通过手术植入患者体内以持续监测其生理参数的治疗设备。由于 IMD 治疗和挽救生命的益处，患者可以治疗心律失常。我们专注于为重症监护和临床实践中的患者生理信号收集、存储保护和监测开发的混合系统。为了提供医疗数据隐私保护和医疗决策支持而提出了混合系统，并利用 RFID、区块链和大数据技术分析生理信号。

7. Jeon B, Jeong B, Jee S, Huang Y, Kim Y, Park GH, Kim J, Wufuer M, Jin X, Kim SW, Choi TH. A Facial Recognition Mobile App for Patient Safety and Biometric Identification: Design, Development, and Validation. JMIR Mhealth Uhealth. 2019 Apr 8;7(4):e11472. doi: 10.2196/11472. PMID: 30958275; PMCID: PMC6475824.

摘要

背景：通过唯一标识对患者进行验证是医疗保健机构中的一项重要程序。由于未能正确识别患者，会导致患者不正确、现场程序不正确、用药不正确和其他错误，因此在整个医疗保健机构中都会出现患者安全风险。为了避免医疗事故，医疗机构已经采用了射频识别（RFID）、指纹扫描仪、虹膜扫描仪和其他技术。这些技术的缺点包括可能丢失 RFID 手镯、感染传播以及在患者昏迷时不实用。

目的：本研究旨在开发一款用于患者身份识别的移动健康应用程序，以克服当前患者身份识别替代方案的局限性。该应用程序的开发有望为患者身份识别提供一种易于使用的替代方法。

方法：我们开发了一款面部识别移动应用程序来改进患者验证。作为评估目的，共有 62 名儿科患者（包括门诊和住院患者）登记参加面部识别测试，并在整个设施内进行跟踪以进行患者验证。

结果：该应用程序包含 5 个主要部分：挂号、病历、检查、处方和预约。62 例患者中，30 例为整形外科门诊患者，32 例为手术预约住院患者。无论患者处于麻醉状态还是昏迷状态，即使在手术后，面部识别都能以 99% 的准确率验证所有患者。

结论：通过使用移动面部识别应用程序，可以非常准确地识别门诊和住院患者，并减少不必要的患者验证成本。我们的移动应用程序可以为患者验证提供有价值的帮助，包括在患者昏迷时作为替代识别方法。

8. Yoshikawa T, Kimura E, Akama E, Nakao H, Yorozuya T, Ishihara K. Prediction of the service life of surgical instruments from the surgical instrument management system log using radio frequency identification. BMC Health Serv Res. 2019 Oct 15;19(1):695. doi: 10.1186/s12913-019-4540-0. PMID: 31615497; PMCID: PMC6794753.

摘要

背景：基于条形码或射频识别（RFID）的医疗器械管理系统已逐渐被引入外科医学领域，用于对器械进行个体化管理和识别。我们推测使用 RFID 标签对器械进行单独管理可以提供以前无法获得的信息，尤其是仪器的精确使用寿命。此类信息可用于预防因手术器械故障导致的医疗事故。本研究旨在通过分析器械管理系统中可用的数据来预测器械的精确使用寿命。

方法：评估器械的维修历史和故障前的使用次数，然后通过以下三种方法分析数据：确定器械使用次数的分布，通过逻辑回归分析生成器械故障概率模型，并进行生存分析以预测器械故障。

结果：使用次数服从正态分布。分析表明，手术中器械的使用并不统一。此外，针对五种器械绘制的 Kaplan-Meier 曲线显示，不同器械的累积生存率存在显著差异。

结论：通过 RFID 标签或条形码获得的器械的使用历史可以用来预测器械故障的概率。该预测对于确定器械的使用寿命具有重要意义。在器械管理系统中实施开发的模型有助于防止由于器械故障导致的事故。了解器械使用寿命也将有助于制定器械采购计划，以尽量减少浪费。

9. Pérez MM, González GV, Dafonte C. The Development of an RFID Solution to Facilitate the Traceability of Patient and Pharmaceutical Data. Sensors (Basel). 2017 Sep 29;17(10):2247. doi: 10.3390/s17102247. PMID: 28961207; PMCID: PMC5677332.

摘要

医院的主要目标之一是提高患者的护理质量。这在日间医院中更为重要，因为从药房服务的准备到日间医院将某些药物交付给患者时需要特别注意。对于昂贵的药

物，护理人员在对患者给药时必须遵守非常详细的说明（药物名称、途径、剂量、时间表、以前的药物治疗、保存条件等）。这项工作的重点是开发一个多方面的中心应用程序，以促进混合静脉用药从处方-核实-给药-准备-用药（PVD - PA）过程的开始到结束的可追溯性，并提供给所有相关的卫生专业人员：医生、药剂师、医院药房和日间医院的护理人员。

10. Blood Facts and Statistics. American Red Cross, Washington, DC, USA. [Online]. Available: http://www.redcrossblood.org/learn-about-blood/blood-facts-and-statistics.

摘要

关于血液需求、血液供应、献血过程、血液及其成分、献血者、美国红十字会血液服务的事实。关于血液需求的事实：每两秒钟，美国就有一个人需要血液，每天需要 4.1 万多人献血。在美国，每年共输血 3000 万份血液成分，平均红细胞输血量约为 3 品脱。医院最常需求的血型是 O 型。紧急情况下使用的血液在事件发生之前已经上架。镰状细胞病影响着美国超过 7 万人，每年约有 1000 名婴儿出生时患有该病。镰状细胞患者一生中可能需要频繁输血。去年有 160 多万人被诊断出患有癌症。他们中的许多人在化疗期间需要血液，有时每天都需要。一名车祸受害者可能需要多达 100 品脱的血液。关于血液供应的事实：美国一年内采集的献血数量为 1570 万，献血人数为 920 万。尽管估计有 38%的美国人口是有捐献条件的，但每年实际捐献的人不到 10%。

11. R. R. Sharma, S. Kumar, and S. K. Agnihotri, "Sources of preventable errors related to transfusion," Vox Sanguinis, vol. 81, no. 1, pp. 37-41, Jul. 2001.

摘要

背景和目的：由于医院工作人员缺乏对输血相关不良事件的认识以及大多数输血中心的反馈系统不完善，输血错误总是被低估。本文报告了一项研究的结果，该研究旨在调查我们三级医院中错误的来源和类型。

材料和方法：对血库工作人员（即接待柜台文员和技术人员）和负责患者的居民报告的错误进行了为期一年（从 1998 年 5 月 ~ 1999 年 4 月）的研究，并根据发生地点进行了分类。

结果：在一年的研究期间共检测到 123 个错误。在这 123 个错误中，107 个（86.99%）发生在血库外，16 个（13%）发生在血库内。

结论：错误最常发生在血库以外，患者的床边是主要地点。

12. Zaric A., Cruz C.C., de Matos A., da Silva M., Costa J.R., Fernandes C.A. RFID-based Smart blood stock system. IEEE Antennas Propag. Mag. 2015; 57:54-65. doi: 10.1109/MAP.2015.2420491.

摘要

将伪定位原理应用于基于 RFID 的智能血库系统，以实现医院和其他存储单元血液管理的自动化和改进。该原理基于在血袋和抽屉表面使用冗余标签来识别和定位柜内和抽屉内的每个血袋。本文介绍了一个成本低于 1500 美元的原型系统，并对其性能进行了验证。

13. Lozano M., Cid J. DEHP plasticizer and blood bags: Challenges ahead. ISBT Sci. Ser. 2013; 8:127-130. doi: 10.1111/voxs.12027.

摘要

塑料容器的发明代表了血液疗法的重大进步，为血液成分的制备和输血打开了大门。后来发现，增塑剂二-2-乙基己基-邻苯二甲酸酯（DEHP）与聚氯乙烯（PVC）结合使用，会浸出到塑料袋中的血液成分中，而对于红细胞而言，细胞膜的稳定允许将储存时间延长至 49 天，具体取决于所使用的添加剂溶液。将增塑剂浸出到成分中，不仅使输血受者暴露于显著水平的 DEHP，而且使

血浆和血小板单采供体也暴露其中。尽管尚未确定明确的人体毒性，但对于一些人来说，应在现有数据面前唤起预防原则，特别是在新生儿和儿童中，只有不含 DEHP 的一次性塑料袋才能用于输血。对于血小板来说，这已经在大多数容器中实现，对于血浆来说应该也不是一个问题。然而，对于最常输血的血液成分，尽管近年来一些新的增塑剂似乎有望成为更安全的替代品，红细胞浓缩物仍然是一个尚未解决的挑战。

14. Kratz A., Stanganelli N., Van Cott E.M. A comparison of glass and plastic collection tubes for routine and specialized coagulation assays: A comprehensive study. Arch. Pathol. Lab. Med. 2006; 130: 39-44.

摘要

背景：由塑料制成的采血管开始取代玻璃管。凝血测试结果很容易受到分析前因素的影响，包括暴露于激活凝血级联反应的表面。

目的：比较采血管材料对临床实验室进行的 22 种凝血试验的影响。

设计：将 28 名健康志愿者的配对血液样本抽取到 B* Vacutainer 柠檬酸盐玻璃管和 B* Vacutainer plus 柠檬酸盐塑料管中，平行测定凝血试验结果。

结果：在 14 次检测中，玻璃和塑料之间没有观察到统计学上的显著差异，包括：凝血酶原时间（和国际标准化比率）；活化部分凝血活酶时间；活化蛋白 C 抗性；抗凝血酶活性；因子 II、V、VIII 和 IX；α2-抗纤溶酶；纤溶酶原活性；血管性血友病因子抗原；瑞斯托霉素辅助因子；凝血酶时间；蛇毒凝血酶时间。纤维蛋白原的差异具有统计学意义；显色蛋白 C 活性；蛋白 S 活性；PTT-LA 狼疮抗凝剂敏感性活化部分凝血活酶时间；因子 VII、X、XI 和 XII。但平均差异在 0.4% ~ 5.5%之间，不太可能具有临床意义。

结论：本研究的结果表明，塑料管可以代替玻璃管用于多种凝血检测。

15. El Khamlichi, M., Alvarez Melcon, A., El Mrabet, O., Ennasar, M. A., & Hinojosa, J. (2019). Flexible UHF RFID Tag for Blood Tubes Monitoring. Sensors (Basel, Switzerland), 19(22), 4903. https://doi.org/10.3390/s19224903.

摘要

医疗保健行业迫切需要低成本、灵活的射频识别（RFID）标签来自动识别、跟踪和监测血液制品。还需要强大的性能来满足不同血样采集和分析中心的安全性和可追溯性要求。本文提出了一种用于血液样本采集管的新型低成本且灵活的无源 RFID 标签。标签天线基于两个紧凑的对称电容结构，在超高频（UHF）欧洲频段（865 ~ 868 MHz）工作。标签天线的设计考虑了血液、基板和管子等整个介电参数。这样，它可以在存在血液的情况下有效地工作，血液具有高介电常数和损耗。该标签的实测结果证实了模拟结果。标签的实测性能显示其在所需频段内具有良好的匹配性，读取距离可达 2.2 m，是典型商用标签的 4.4 倍。该标签作为传感器监测临床试管中血液含量的潜力也得到了证明。预计该标签将在未来的 RFID 系统中发挥作用，在不同的血液样本采集和分析中心引入安全性和可追溯性。

16. Wang Q L, Wang X W, Zhuo H L, et al. Impact on storage quality of red blood cells and platelets by ultrahigh - frequency radiofrequency identification tags[J]. Transfusion, 2013, 53(4): 868-871.

摘要

背景：与 ISBT128 码标签相比，射频识别（RFID）标签具有不可比拟的优势，并逐渐应用于血液管理系统中。然而，对于 RFID 频率的使用没有全球标准。尽管 ISBT 推荐使用 13.56 MHz 的高频 RFID，但 820 ~ 960 MHz 的超高频（UHF）RFID 技术在许多方面都具有更多优势。因此，我们研究了暴露在 820 ~ 960 MHz 频率下的 UHF RFID 标签对红细胞（RBC）和血小板（PLT）存储质量的影响。

研究设计和方法：将收集和制备的 30 个单位的悬浮红细胞（sRBCs）和 PLT 分为两袋，分别用于试验组和对照组。sRBCs 储存在 4 ± 2°C冰箱中，PLTs 储存在 22 ± 2°C 摇床中。试验组在储存期间持续暴露于 RF 阅读器。检测

不同时间点的采样和生物学变化。

结果：随着储存时间的延长，sRBCs 上清液的 pH 和氯含量降低，游离血红蛋白、钾和钠含量增加，但试验组和对照组之间无显著性差异（$p > 0.05$）。储存期间，试验组和对照组的 pH 值、PLT 计数和 PLT 聚集率均降低，但差异不显著（$p>0.05$）。

结论：当暴露在 820 ~ 960 MHz 射频下时，sRBC 和 PLT 分别在 35 天和 5 天的储存期内，生物和生化指标没有恶化。

17. **Rogowska A, Chabowska AM, Lipska A, Boczkowska-Radziwon B, Bujno M, Rusak T, Dziemianczuk M, Radziwon P. High-frequency (13.56-MHz) and ultrahigh-frequency (915-MHz) radio identification systems do not affect platelet activation and functions. Transfusion. 2016 May; 56(5):1148-1152. doi: 10.1111/trf.13506. PMID: 27167357.**

摘要

背景：在用于标记血液成分的射频识别（RFID）系统中，血细胞在整个储存期间都会受到电磁波的直接影响。本研究的目的是证明在贴有 RFID 标签的容器中储存浓缩血小板（PCs）的安全性。

研究设计和方法：从悬浮在添加剂溶液中的 12 份血沉棕黄层中获得的 10 份混合 PCs 被分装入三个独立的容器，分为三组：对照组、贴有超高频（UHF）范围标签并暴露于 91.5 MHz 无线电波的 PCs，以及贴有高频（HF）范围标签并暴露于 13.56 MHz 无线电波的 PCs。PCs 在 20 ~ 24°C下储存 7 天。在储存的第一天、第五天和第七天进行血小板（PLT）功能的体外测试。

结果：在持续暴露于两种不同频率的无线电波的情况下，PCs 在储存的第一天、第五天和第七天，与对照组之间的 pH；抗低渗性休克；CD62P、CD42a 或 CD63 的表面表达；PLT 衍生微粒的释放；PLT 聚集；PLT 数量均无显著性差异。

结论：研究结果表明，HF 和 UHF RFID 系统中产生的电磁辐射以及与标签的持续接触对存储 PCs 的质量没有影响。

18. **Wicks A., Visich J., Li S. Radio Frequency Identification Applications in Hospital Environments. Hospital Topics. 2006;84(3):3-8.**

摘要

射频识别（RFID）技术最近开始受到从业者和学术界越来越多的关注。这种兴趣是由沃尔玛、塔吉特和麦德龙集团等主要零售商以及美国国防部的授权推动的，目的是提高供应链中物料和信息流的效率和可见性。然而，供应链管理者并没有垄断 RFID 的使用。在本文中，作者讨论了 RFID 在医院环境中的潜在优势、应用领域、实施挑战以及相应的策略。

19. **Lockton V., Rosenberg R. RFID: The Next Serious Threat to Privacy. Ethics and Information Technology. 2005;7(4):221-231.**

摘要

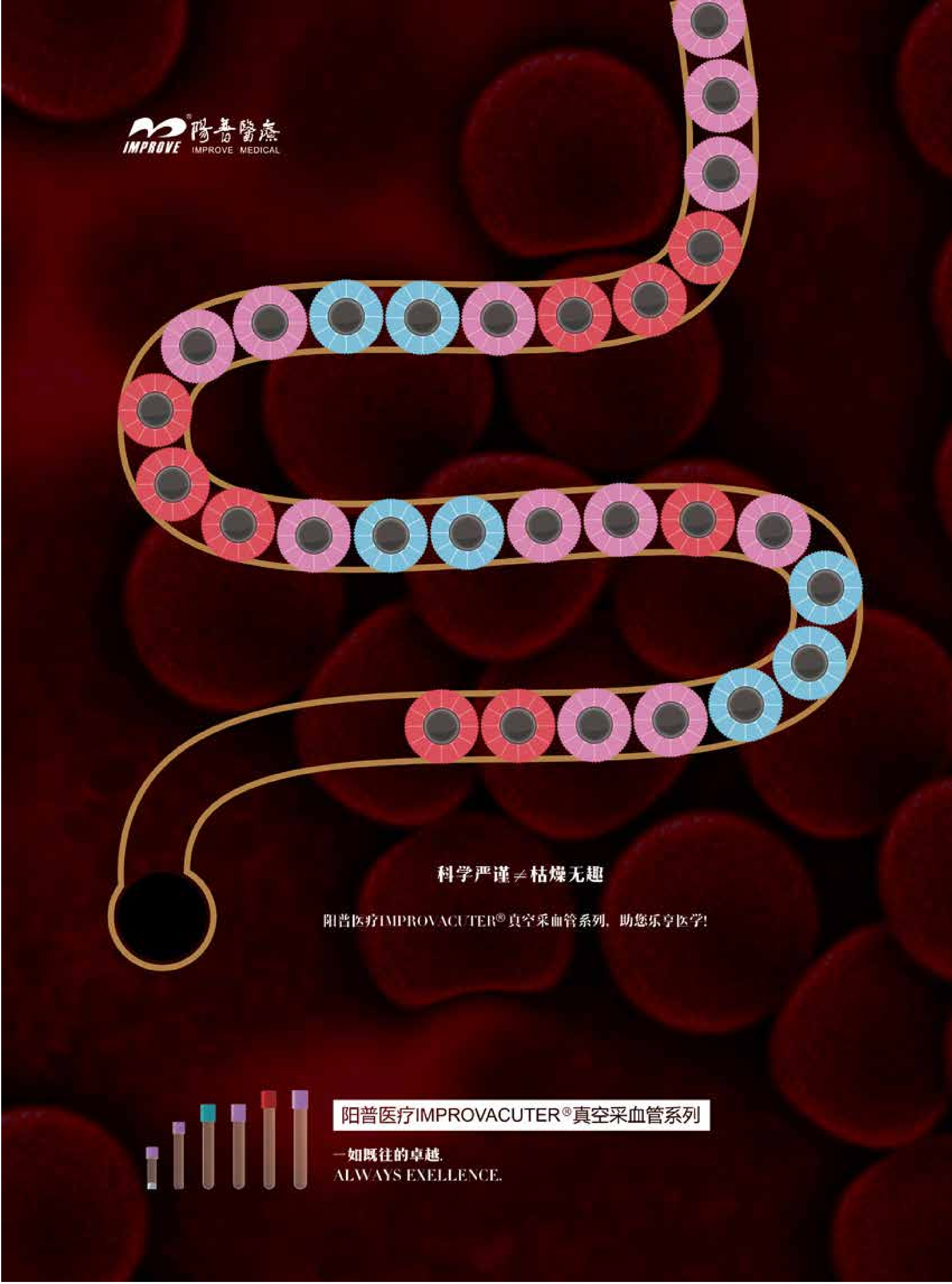
射频识别（RFID）是近年来受到广泛关注的一项技术。这是一种相当简单的技术，涉及微芯片和电子阅读器之间的无线电波通信，其中存储在芯片上的识别号被传输和处理；它经常出现在库存跟踪和访问控制系统中。在

本文中，我们研究了 RFID 的当前用途，并确定了该技术未来的潜在用途，包括物品级标签、人体植入物和 RFID 芯片护照，同时讨论了每种用途可能对个人隐私产生的影响。然后介绍了 RFID 使用的可能指导原则，包括公平信息原则和 RFID 权利法案，以及针对个人隐私问题的技术解决方案，例如标签消除和屏蔽，以及用于护照的简单铝箔防护罩。然而，指导方针和技术解决方案将对隐私保护无效，而这项立法对于防范 RFID 带来的威胁是必要的。最后，我们提出了我们认为必须解决的最重要的立法问题。

20. álvarez López Yuri, Jacqueline F, álvarez Narciandi Guillermo, et al. RFID Technology for Management and Tracking: e-Health Applications [J]. Sensors, 2018, 18(8):2663.

摘要

射频识别技术（RFID）由于其成本低、易于在被跟踪物品内部署和集成等特点，已成为物流管理行业的关键技术。因此，RFID 在所谓的数字工厂或工业 4.0 中扮演着基础性的角色，旨在提高工业过程的自动化水平。此外，RFID 还被发现在改善对患者、药品和医院医疗资产的跟踪方面有很大的帮助，这些操作的数字化提高了效率和安全性。本文回顾了 RFID 在电子医疗应用中的最新技术，描述了它对改善医疗服务的贡献，并讨论了其局限性。特别是,我们发现了在软件开发上以及做了很多努力，但大多数情况下在详细的物理层研究（也就是说，系统部署区域内的射频识别信号的特征）没有正确地进行。这篇文章描述了一个用于跟踪和管理医院资产的基本 RFID 系统，旨在提供关于确保系统正确运行方面的细节。尽管本文中所描述的 RFID 系统的范围仅限于医院的一个小区域，但该架构是完全可扩展的，可以覆盖医院中不同医疗服务的需求。超高频（UHF）RFID 技术优于最广泛的近场通信（NFC）和高频（HF）RFID 技术来最小化硬件基础设施。特别地，UHF RFID 还通过使用不同种类的天线使覆盖/读取区域信息更容易。信息存储在一个数据库中，可从终端用户移动设备（平板电脑、智能手机）访问，在这些设备中可以显示要跟踪的资产的位置和状态。


IMPROVE
陽普醫療
IMPROVE MEDICAL
科学严谨≠枯燥无趣
阳普医疗IMPROVACUTER® 真空采血管系列，助您乐享医学!
阳普医疗IMPROVACUTER®真空采血管系列
一如既往的卓越.
ALWAYS EXELLENCE.

Featured Article

文献精读

本期文献精读是一篇《基于 RFID 的智能血液库存系统》，原文标题为《RFID-based Smart Blood Stock System》。本文介绍了将伪定位原理应用于基于 RFID 的智能血库系统，可以实现医院和其他存储单元血液管理的自动化和改进。该原理基于在血袋和抽屉表面使用冗余标签来识别和定位柜内和抽屉内的每个血袋。本文介绍的原型系统成本低于 1500 美元，并验证了其性能。

基于 RFID 的智能血液库存系统

摘要

一个完整的 UHF 射频识别（RFID）为基础的系统，能够在侧存储柜抽屉中定位单个血袋。它的开发是为了展示当前血液库存管理系统改进的可能性，并提交给 2014 年 IEEE AP-S 学生设计竞赛:应用的 RFID 天线。该系统由机柜模型、收发单元、PC 机和控制模块软件组成。一种新的伪定位原理的实现被用于对血袋进行定位，这些血袋配备了专门的标签，旨在适应袋子里面小部分的血液。探测器天线放置在抽屉底部，并利用额外的无源标签来识别每个抽屉中的单个位置。收发单元由现成的商用电路板制成，通过软件进行无线控制在 PC 上运行。整个系统体积小，可运输，电池供电，成本低。

关键词：射频识别（RFID）超高频天线；RFID 伪定位；液体 RFID 标签；射频识别智能柜

作者：Andela Zaric, Catarina C. Cruz , António M. de Matos , Marta R. da Silva , Jorge R. Costa, and Carlos A. Fernandes

原文出处：Zaric A., Cruz C.C., de Matos A., da Silva M., Costa J.R., Fernandes C.A. RFID-based Smart blood stock system. IEEE Antennas Propag. Mag. 2015;57:54-65. doi: 10.1109/MAP.2015.2420491.

1. 导读

这里展示的作品是 2014 年 IEEE AP-S 学生设计竞赛的最终入围项目：射频识别（RFID）应用天线。学生团队的挑战是通过为特定的应用程序定制开发 RFID 系统来挑战创造性，制定和解决有趣的天线设计问题的能力。该系统必须是安全耐用，易于复制，便宜（总预算为 1500 美元）和便携（手持携带）。RFID 系统必须在 UHF RFID 频段 902～928 MHz 下运行，限制在 4 w EIRP 范围内，阅读器使用电池供电，标签无电池（被动），最大尺寸限制在 50 mm × 5 mm ×5 mm。学生版本的常用软件（MATLAB, C 等）和免费软件包被允许与笔记本电脑一起使用，不包括在预算限制内。本文是一个完整的项目报告，从选择应用场景的动机开始，然后描述所开发的系统，定位方法，所开发的 RFID 天线的特性，所开发的软件，最后说明如何组装和操作。本文还附带了一个半决赛时准备的系统演示的视频[1]。

在美国，每分钟都需要输血,每年大约有 3000 万血液成分被输入[2]。每年大约有 60 人死于错误的输血，这需要特别注意减少输血错误，因此，跟踪血液从献血者到患者[4]。血液和/或输血患者的错误识别是严重的生命威胁，目前通过血袋的条形码标签来管理[5]。每个袋子上都有不同的条形码，上面印有血液的详细信息，例如血型、采集日期、有效期、每一步处理的人等等。当从血库中取出血袋时会手动读取条形码，以登记血袋已经拿出，然后就会交给病人。即使有了这个血液管理系统，大约有 14Q 的识别错误发生在血库，86Q 发生在床边。

这种错误可以通过丰富的 RFID 标签系统来减轻，使交叉检查血液信息和患者的需求在血库和床侧。所有必要的数据都可以存储在一个 RFID 芯片中，每个血袋都可以使用一个标签。为此，本文开发并介绍了一种适用于采血中心和医院的智能血液储存系统。通过放置在货架和血袋上的双 UHF RFID 标签，自动检测到柜内收集的血袋的存在和位置，并将其引入到数据中。医院工作人员会使用柜子数据库搜索他们需要的特定血袋，并立即知道，在柜内的哪个位置是需要的血液。此外，该系统还可以与床边射频识别系统集成，使患者的血袋能够自动与患者的血型交叉检查。智能血液库存系统将有助于确保正确血液的管理比普通条码库存系统是更可靠和准确的。

2. 系统前景

一种智能血液库存系统的解决方案被提出了，包括三个主要部分：柜子单元和在 MATLAB 的学生版中设计的 PC 图形用户界面（GUI），如图 1a 和 1b。柜子单元包括两个抽屉（10 cm × 30 cm），但是在一般情况下,它可以是任意数量的抽屉。每个抽屉都被分成适合放血袋的小隔间（长 6 cm）。每个抽屉底部有一个 RFID 阅读器天线（“抽屉天线”），每个小隔间都有一个专用标签（血袋标签），如图 1c。此外，每个血袋都携带另一种特殊的标签（天线 VB 血袋标签），它对血液有很强的近距离抵抗力（见图 1d）。抽屉天线和这两种标签将在第 4 节中详细介绍。收发器单元由以下商业通用组件组成：AS3992 UHF RFID 读写器[7]、Arduino Mega ADK[8]、HC-06 蓝牙收发器[9]、锂背板[10]。在外部控制组件的提示下，读取器能够同时盘点各种无源 UHF RFID 标签，这叫 Arduino。阅读器将标签的电子产品代码（EPC）传递给 Arduino，然后 Arduino 使用蓝牙收发器将信息发送到 PC，而锂背板则是一块电池板，为整个收发器提供电力，使便于携带。最后，PC 机用于系统的用户控制和处理从收发单元接收到的数据。硬件组件将在第 5 节中详细描述，软件将在第 6 节中描述。

3. RFID 伪定位原则

典型的 RFID 应用程序，如仓库和商店库存或资产跟踪，包括少量的固定阅读器（有时甚至只有一个）和大量的标记对象。阅读器通过定期发送询问信号来跟踪其范围内的标签。当标签收到信号时，每个标签都以其唯一的识别号（EPC）进行响应。因此，只有接收到足够能量进行响应的标签才在阅读器的范围内。然而，如果阅读器配备了一个天线，只能知道标签的存在。这里，伪定位原则用于确定标记位置，因为阅读器能够区分哪个阅读器天线正在检测对象。这是通过设计具有已知的空间受限辐射特性的专用阅读器天线来实现的，并放置在一个网格中以覆盖没有重叠的空间。这个解决方案被提交发送到具有基于微带的货架阅读器天线，其辐射模式只覆盖了货架上方的存储空间。这样，阅读器仅通过一个阅读器天线检测每个对象，并知道对象被放置在哪个架子上。

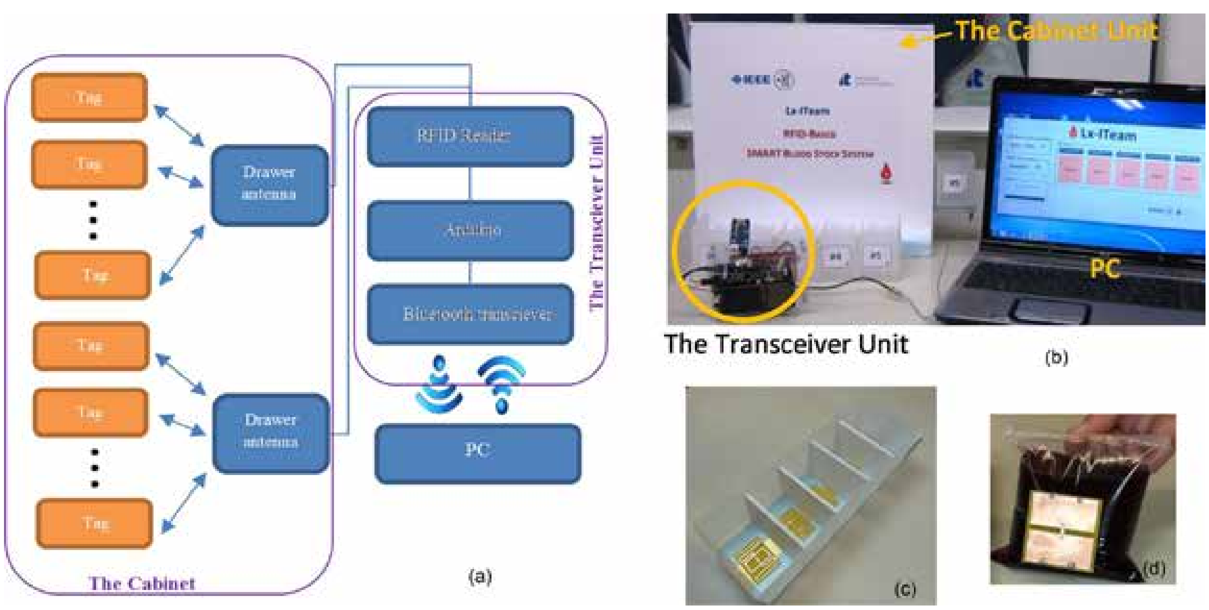


图 1. （a）基于 RFID 的智能血液库存系统示意图和（b）照片，有 C 标签的抽屉（c）隔室和（d）带 B 标签的血袋

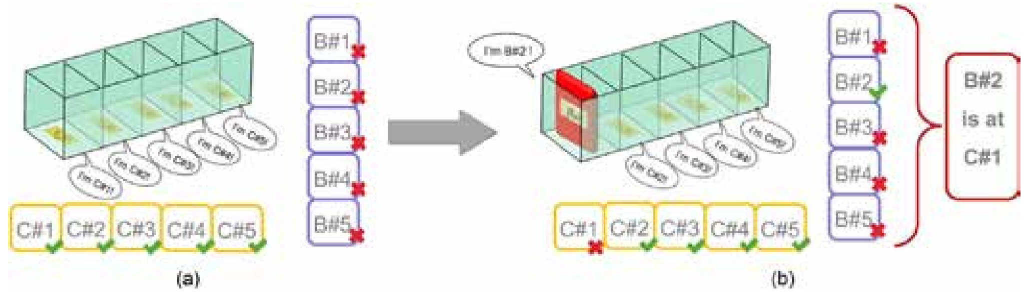


图 2. 伪定位原则，C 标签确定位置（不被检测到），B 标签决定了血袋的“身份”，在空的单元检测到 C 标签。（a）当血袋放置在隔室时，不再检测到相应的 C 标签，而检测到血袋 B 标签如（b）所示

4. 天线设计、模拟和测量

4.1. 血袋标签天线（B 标签天线）

如第 2 节所述，B 标签的目的是携带每个血袋的标识。B 标签贴在血袋上，因此必须能抵抗负液体介质的影响。在大多数情况下，这是通过在标签上添加一个线层来实现的。因此，提出的天线配置来自于包含一个线层的两个 RFID 天线设计[12,13]。文献中的这两个标签都为所需的 UHF RFID 频段（902 ~ 928 MHz）进行了调优，但尺寸（116 mm × 40 mm × 1.8 mm 和 85.5 mm × 54 mm × 1.6 mm）远远没有符合比赛所需的最大尺寸（50 mm × 50 mm × 5 mm）。此外,这两个天线是为不同的 RFID 芯片设计的，而不是将在这里使用的 ALIEN Higgs-3 IC[14]。对于 ALIEN Higgs-3 IC，制造商提供了一个集总元件模型，这是一个 1500Ω 电阻和 0.85pF 电容器之间的并联。它导致一个芯片阻抗 Zchip = 27.83-j199.15Ω@915 MHz。这意味着 RFID 端口必须匹配芯片的复杂共轭阻抗，以确保在 915 MHz 的最大功率传输。

设计的血袋标签的几何形状如图 3 所示。它是一个平面天线，正面印刷一个金属层（见图 3a），背面印刷一个接地面（见图 3b）。使用了厚度 3.6 mm 的 FR-4 基板。在正面印刷两个 46 mm × 22 mm 的金属贴片，每个贴片用 2 个孔到地面的距离，以便孔放置尽可能靠近边缘。两个金属贴片之间有一个 4 mm 的间隙。ALIEN 的希格斯-3 IC 是焊接在缝隙中间的。可以看出，这个天线的几何形状受到了[12]和[13]天线的启发，与[13]相比，设计的简化和在每个[13]的末尾引入了第二个 via 贴片，随着基材厚度的增加，尺寸更小，符合竞赛要求。成品天线如图 3c 所示，关键尺寸见表 1。

表 1. B 标签的参数值，单位为毫米

W	L	R_w	R_l	S	$\varnothing_{vias}$	D_{vias}
50	50	46	22	4	0.7	20

为了在背面有血袋的情况下调整 B 标签天线的阻抗，联合设计了天线，并将其与一个 200 mm × 200 mm × 30 mm 的血袋放置在一起，如图 4 所示。人类血液 61.31 相对介电常数和电导率 1.54 S/m[15]，这些值用于血块,然而模拟原型系统的血液袋是由水和红色水溶性液体，由于水的介电性能和血液是非常相似的（约 80%的血液是水）。与血液相比，水的相对介电常数略有不同，为 78，电导率几乎相等，为 1.59 S/m。

与经典的 s11 分析不同，对于 RFID 标签天线，分析从天线到芯片的功率传递函数是有意义的，因为这直接关系到标签的可实现范围。功率传递函数测量天线端口可用功率的最大分数转移到芯片[16]。分别进行了有无血袋的两种模拟，功率传输系数如图 4 所示，使用学校授权的 CST 软件获取。当有血袋存在时，功率传输系数更高，这是因为天线的设计和调适考虑了血袋的存在。电力传输整体在 70Q 以上水平要求超高频频段，这意味着良好的检测能力，在最终的比赛视频[1]中已经被实验证明。

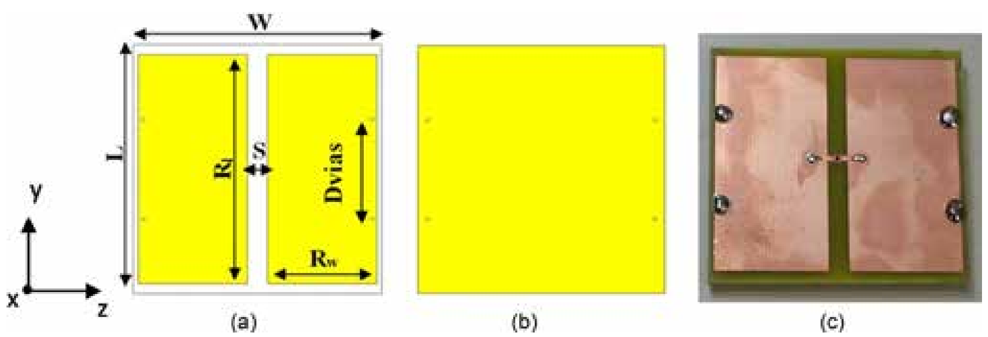


图 3. B 标签天线的几何形状。（a）前面；（b）背面；（c）模拟图

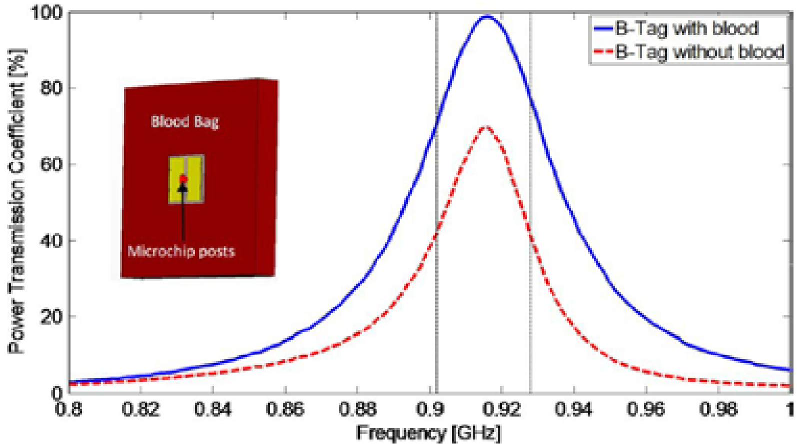


图 4. 模拟有和没有血袋存在时的功率传输系数，（插图）放置在血袋旁边的 B 标签示意图，垂线表示使用的 UHF 射频识别频带（902 ～928MHz）

4.2. 货舱标签天线（C 标签）

血库系统中的 C 标签天线的功能是检测血袋何时被放入隔层里。当介质（如血液）接近 C 标签时，它将不再被 RFID 阅读器检测到，这将发出血袋存在的信号。为了实现这一点，我们使用了一个经典的 RFID 标签设计，不像 B 标签一样。如图 5a 所示，标签是具有单一金属层的平面天线，包括一个双环和一个弯曲偶极子。该设计基于其中一个作者[18]以前设计的 UHF 标签天线。标签打印在厚度 0.75 mm 的 FR-4 底物的一侧，介电常数 4.3，损耗切线 0.025。该天线的设计也考虑了 ALIEN Higgs – 3IC[14]的输入阻抗。RFID 端口阻抗必须为 ZRFID＝27 : 83＋j199.15 Ω@915 MHz，因此，天线必须表现出电感应行为，这是通过双环实现的。通过加入偶极子得到了辐射特性，偶极子被弯曲以缩短其长度。为了达到天线最大尺寸方面的竞争要求，同时用所述芯片生产出能够正常工作的 RFID 标签，需要在[18]中调整原有 RFID 天线设计的环路和偶极子参数。比较原始天线和本文介绍的 C 标签，主要的挑战是在保持所需特性的情况下调整天线结构，因为原天线更大且具有不同的芯片阻抗。

C 标签的最终尺寸为 50 mm × 40 mm（制作的天线如图 5b 所示），得到的参数值如表 2 所示。

无血袋情况下 C 标签的功率传递系数仿真如图 6（蓝色曲线）所示。在要求的 UHF 波段，电力传输超过 65Q 级别。我们还进行了模拟，以了解当血袋放置在标签顶部时，C 标签的行为。对应的功率传输系数如图 6 中红色虚线的插图所示。正如预期和本应用的需要，UHF 频段的功率传输低于 10Q（如图 6 中灰色阴影区域所示）。这这意味着血袋使天线完全失谐，因此，天线不能充分辐射；因此，它不会被 RFID 阅读器检测到。这种模拟行为被实验测量所证实，正如决赛视频[1]中所示。

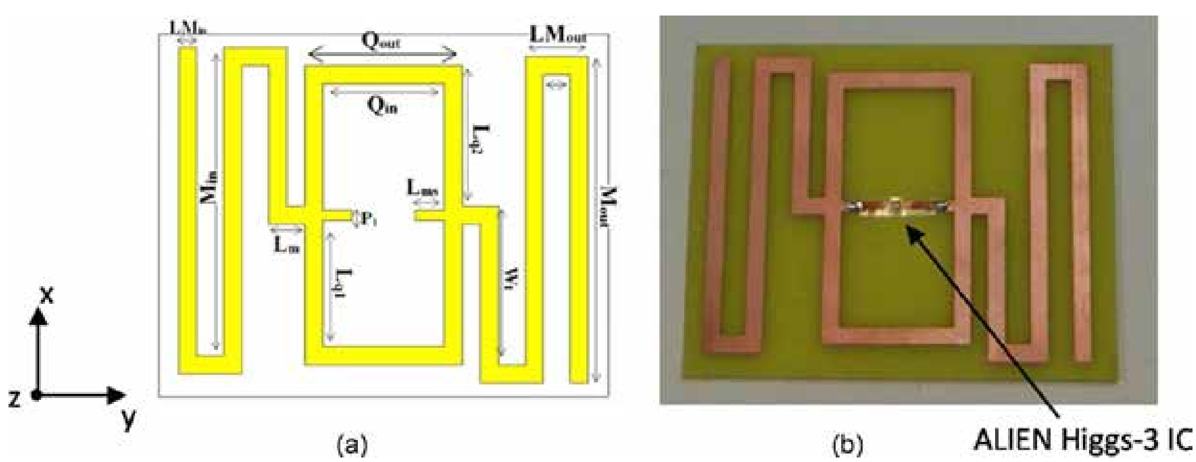


图 5.（a）C 标签天线的几何形状；（b）焊接 ALIEN Higgs-3 IC 芯片制造的天线

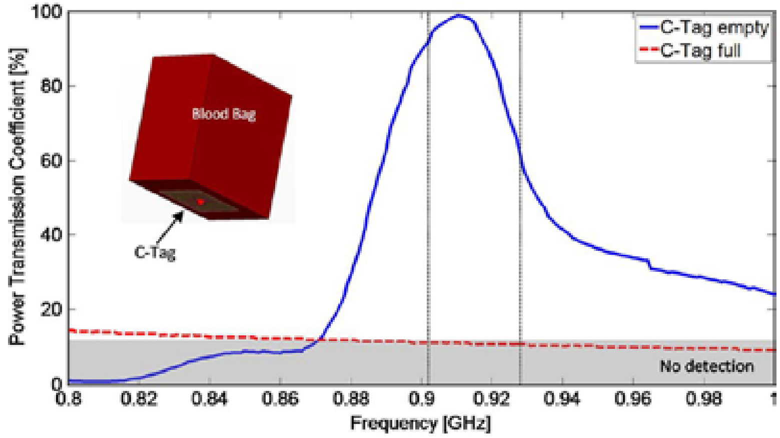


图 6. 模拟了有和没有血袋存在的 C 标签的功率传输系数，（插图）C 标签天线顶部血袋示意图，垂直线表示使用的 UHF RFID 频段（902 ~ 928 MHz）

表 2. C 标签参数值，单位为毫米

LM_{in}	LM_{out}	Q_{in}	Q_{out}	M_{in}	M_{out}	W_l	L_m	L_{ms}	L_{q1}	L_{q2}	P_1
2	7	13.5	17.5	34	36	17.5	4	3.25	13.9	15.5	1.2

4.3. 抽屉天线

抽屉天线的想法来自于之前的工作[11]，这种结构在 RFID 应用中被证明是有用的，它要求检测器天线只读取放置在单个架子上的标签。如果是经典的高增益、长距离的，探测器天线将在这种情况下使用，放置在邻近的架子上的物体将被错误地检测到在架子上。[11]中基于微带的天线在垂直于天线平面的平面上具有有限的能量辐射，这使得它非常适合用于包括货架和/或抽屉的应用。嵌入式微带线延伸横跨抽屉的底面全长，它是探头馈电的一端，并在另一端终止与负载（一个 50Ω 电阻）匹配。

抽屉天线结构如图 7a 所示，传输线沿 x 轴方向贯穿整个天线长度。其整体尺寸为 100 mm × 300 mm。制造过程如图 7b 和 7c 所示，采用 0.5 cm 厚的泡沫聚苯乙烯基板层，其相对介电常数接近 1，有利于场泄漏。传输线以地平面为中心，宽度为 27 mm，得到 50Ω 的阻抗线。该结构由 50Ω 同轴电缆馈电，通过 SMA 同轴插头连接器，线端接一个 50Ω 负载。在传输线的顶部增加了一层泡沫聚苯乙烯基板（未显示），以增加机械稳定性，并避免车厢 RFID 标签（C 标签）和微带之间的直接接触。

天线重新设计的主要挑战来自于这个天线的长度比[11]中原来的天线小得多。虽然这里使用的抽屉天线要小得多，但它把辐射限制在抽屉结构中以符合要求。yz 和 xy 平面近场能量分布如图 8 所示。结果证实，正如预期的那样，主要的电场成分是 Ez 和 Ey。Ex 分量很低，没有显示在图 8 中；而是显示总字段 Et。值得注意的是，电场被合理地限制在靠近区域的抽屉内，在图中，标签检测所需的最小能量对应于 20 dBV/m。

在 yz 平面分量 Ez 在微带的中心有一个空点（y = 0 mm），辐射集中在两侧，而 Ey 集中在中心。当选择 B 标签的朝向时，这是很重要的。假设 B 标签在焊接芯片的方向上是线性极化的（垂直于矩形贴片的较长的一侧），如果它们被放置在抽屉的中间，它们应该在 z 方向对齐，如果更靠近血袋一侧，标签 z 方向必须与抽屉 y 方向对齐，以保证良好的检测。在 xy 平面上，Ez 和 Ey 分量也存在互补行为。C 标签被平放在这个平面上，因为 Ey 组件在中间有空值，它们必须被放置在微带的两侧，它们的极化（焊接芯片的方向）与 y 对齐。

空抽屉天线的模拟和测量输入回波损耗如图 9 所示，以及抽屉满时的测量（5 个 C 标签和 5 个配备 B 标签的血袋）。可以看到，s11 参数低于 10 dB 空抽屉和抽屉内放置多个血袋时都需要 UHF 射频识别总频带。这是很重要的，因为血袋往往会耗尽抽屉天线的能量，因此它可能会影响标签的读取。然而，在这里和最后的比赛视频[1]中展示了抽屉天线能够检测 C 标签和 B 标签，即使是多个隔间被放了血袋。

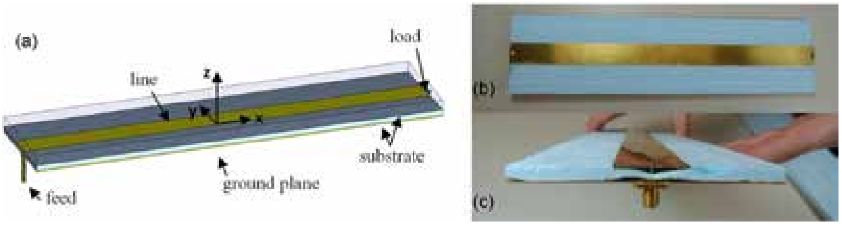


图 7. 智能抽屉天线配置。（a）模型；（b）生产天线俯视图；（c）生成的馈电天线视图

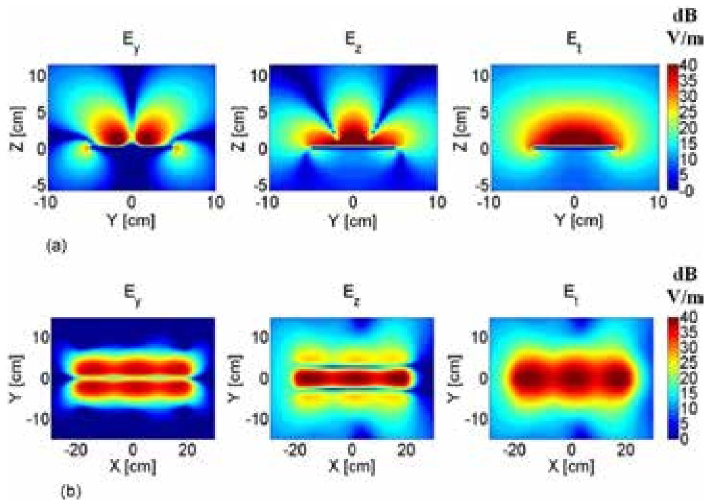


图 8. 近场组件。（a）X = 0 平面；（b）Z = 0 平面（天线表面的下部分）

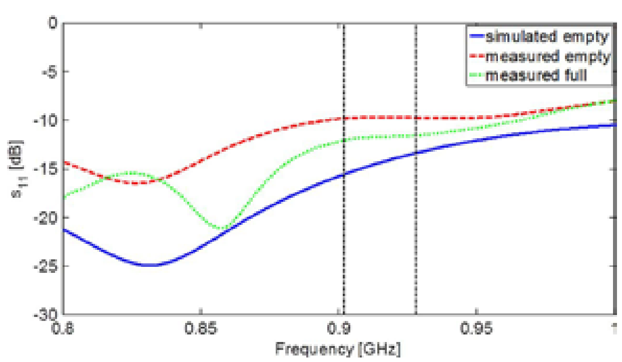


图 9. 模拟并测量了抽屉天线的输入回波损耗，垂直线表示 UHF RFID 频段（902 ~ 928 MHz）

5. 硬件描述

本文详细介绍了我们设计的接收机的硬件组成：AS3992 UHF RFID 读写器、Arduino Mega ADK、HC-06 蓝牙收发器、锂背板以及末端射频开关。

AS3992 超高频射频识别读写器由 Solid[7]公司生产，基于 AS3992 单片机芯片。该阅读器能够在符合不同世界标准的各种频带中工作。在这里，它被设置为从 902 ~ 928 MHz 的工作频率，这是竞赛提案所要求的。它是兼容 ISO18000-6C 协议（EPC Gen2 协议），最大输出射频功率 20 dBm（0.1 W），完全符合 4 W 等效各向同性辐射功率（EIRP）的限制。阅读器由制造商预先编写，用于与外部通信组件（如 PC 机或微处理器板）通过一个双向通用异步接收/发友射机串行接口，在我们的情况下，连接到 Arduino Mega ADK。阅读器可以在不到 6 毫秒钟内列出各种无源 RFID 标签。使用正确的命令，会提示读取器进行库存循环，完成后，它会报告所有标签 EPC 编号。阅读板如图 10a 所示，单板总尺寸为 90 mm × 49 mm。

Arduino 是收发单元的核心控制元件。它控制 RFID 阅读器和 HC-06 蓝牙收发器。这里选择 Arduino Mega ADK[8]，因为它与其他型号不同，它有多个串行通信接口，需要与阅读器和蓝牙收发器通信。之所以选择这个特定的电路板，是因为它

有四个不同的串行接口，用于与其他设备通信，而其他所有 Arduino 板都只有一个。默认情况下，一个串口专用于对单板编程通过 USB 线与 PC 机通信，另外三个串口可自由使用，这里，其中两个用于与 RFID 阅读器和蓝牙收发器通信。图 10b 为 Arduino Mega ADK，Arduino Mega ADK 的总尺寸为 100 mm × 50 mm。Arduino 电路板来没有任何编程，使用开放源码开发环境 IDE 1.0.5[19]创建、编译和上传草图到 Arduino 板，草图是在 Arduino 板微处理器上运行的代码。

HC-06[9]是一个简单的蓝牙收发器，通过将 Arduino 板的一个串行接口分配给该收发器，它可以使 Arduino 板与 PC 机进行无线通信。此收发器兼容几乎所有 Arduino 板，以及所有集成或外部 PC 蓝牙接口。图 10c 为本文所使用的收发器外观，总体尺寸为 20 mm × 15 mm。

锂背板[10]，即图 10d，是基于锂离子电池，并根据需要为所有用于收发器的其他板提供 3.3V 和 5V 调节。锂离子电池可以在不需要任何软件的情况下，通过一根迷你 USB 线从任何 PC 上直接给电池充电，容量为 2200 mAh，大约可以让整个系统自主运行 8 小时。

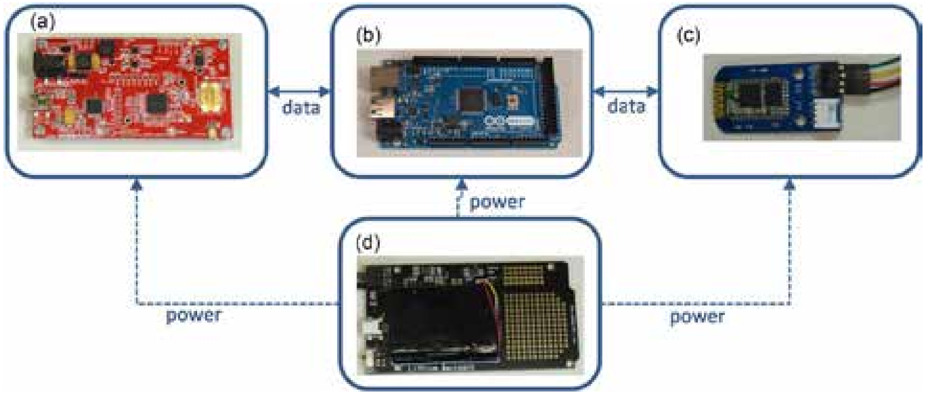


图 10.（a）AS3992 UHF RFID 阅读器；（b）Arduino Mega ADK；（c）HC-06 蓝色收发器；（d）超大锂背板

5.1. 硬件组装

所有的硬件组件（Arduino，RFID 阅读器，蓝牙收发器，电池背包）组装在一个大约 100 mm × 100 mm × 150 mm 大小的单个收发器单元中，如图 11 所示。140 mm × 80 mm 亚克力支撑板为 Arduino，RFID 阅读器和电池背板所设计，他们用金属螺钉和螺母固定在一起。支撑的亚克力板也通过金属螺钉和螺母与射频开关板连接在一起，最后将蓝牙收发器固定在立方体的一侧，最后，蓝牙收发器是固定在立方体的一面有更好的全方位覆盖。需要在收发器组件之间进行的电气连接可以在表 3 中找到。

表 3. 收发器单元的电气连接

Component	Connection to be made
AS3992 UHF RFID Reader	Barrel connector (power) → GND + 3.3V Lithium Mega Battery Backpack
	TX → RX1, pin 19 Arduino Mega ADK
	RX → TX1, pin 18 Arduino Mega ADK
	GND → GND Arduino Mega ADK
HC-06 Bluetooth transceiver	GND → GND Lithium Mega Battery Backpack
	V → 3.3V Arduino Mega ADK
	DI → TX2, pin 16 Arduino Mega ADK
	DO → RX2, pin 17 Arduino Mega ADK
Lithium Mega Batt. Backpack	GND → GND Arduino Mega ADK
	5V → 5V Arduino Mega ADK

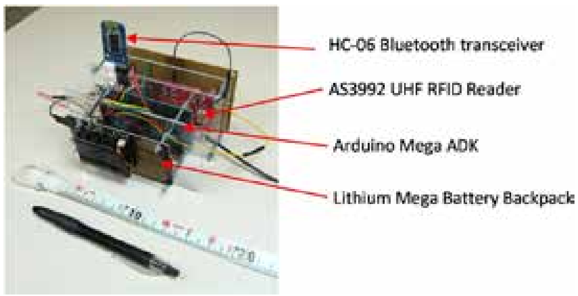


图 11. 组装的收发器单元规模和一个普通的圆珠笔的大小对比

6. 软件描述

用 MATLAB 的学生版本使用 GUIDE 制作一个控制软件 GUI（MATLAB 制作 GUI 向导）。初始屏幕如图 12a 所示，除了我们团队的名称外（Lx-Item），它还包括屏幕左侧的三个控制面板，以及一个用于显示消息的柜子抽屉的面板，每个抽屉都有屏风。这里展示的 GUI 是比赛视频[1]中 GUI 的新版本，唯一的区别是控制面板的可视化外观。

蓝牙通信面板用于建立和取消 PC 机与收发单元的蓝牙通信。通信按“开始”按钮开始，按“停止”按钮停止。蓝牙连接建立后，面板右侧的图标显示为蓝色，如图 12b 所示。RFID 标签库存面板用于读取标签，除了按钮“单读”，它包括一个指示灯，在读取过程中是红色的，当标签成功读取时它变成绿色，如图 12b 所示。点击“单读”，程序通过蓝牙对象向

Arduino 发送一条命令，开始一轮对 RFID 阅读器的询问。Arduino 将适当的 API 命令发送到 RFID 阅读器，并等待其响应。包含所有找到的标签的 EPC 号码的响应由蓝牙返回到 MATLAB 程序。根据之前的状态，程序检查是否有任何隔间被填满（等于列表中消失的隔间 C 标签 EPC 编号）或清空（等于列表中出现的隔间 C 标签 EPC 编号），以及哪个血袋被填满（血袋 B 标签的 EPC 出现在列表中）。在状态面板中，状态栏显示了操作的进度，并显示了根据操作的状态消息。

图 13 显示了 Arduino 草图的流程图（在其上运行的代码）。默认情况下，代码会在启动 Arduino 时循环运行。当通过蓝牙通信接收到读取标签的命令时，RFID 阅读器将提示读取标签，并将收集的信息通过蓝牙转发回 PC。图 14-16 显示了在 MATLAB GUI 中实现的算法流程图。按下蓝牙控制面板中“开始”和“停止”按钮发生的动作如图 14 所示。图 15 描述了标记读取和状态检测。在提示收发器读取和接收标签后，EPC 会做出一系列决定，以确定抽屉内容发生了哪些变化。决策基于与之前的读数相比，标签列表中发生了哪些变化：是检测到的 C 标签和 B 标签列表都发生了变化、只在 C 标签列表中发生了变化，还是只在 B 标签列表中发生了变化。

图 16 显示了来自图 15 的三个子算法，第一种算法（见图 16a）显示了如何检测新放置的袋子；第二种算法（见图 16b）显示了在第一次读取时如何检测 C 标签；第三种算法（见图 16c）显示了如何检测袋子放置中的错误。

要操作基于 RFID 的智能血液储存系统，首先需要使用 USB 电缆和带有 IDE 环境的 PC 机将代码上传到 Arduino。接下来，应按照第 5.1 节表 3 所述进行连接，并且给收发器上电。然后在带有内置或外接蓝牙收发器的 PC 机上，在 MATLAB 中运行 GUI，点击蓝牙面板中的“开始”按钮。所有的 C 标签被放置在其对应的隔间，下一步单击“单读”按钮。带 B 标签的血袋可以放在任意隔间，“单读”按钮刷新标签列表后，将会在 GUI 窗口中显示分区及其数据。这意味着在每个读取周期只能在抽屉中放置一个袋子，以便能够正确地确定被占用的隔间。要停止操作系统，必须点击蓝牙面板中的“停止”按钮，这将停止 PC 与收发单元的连接。对于更直观的系统操作，请参阅观看比赛视频[1]。

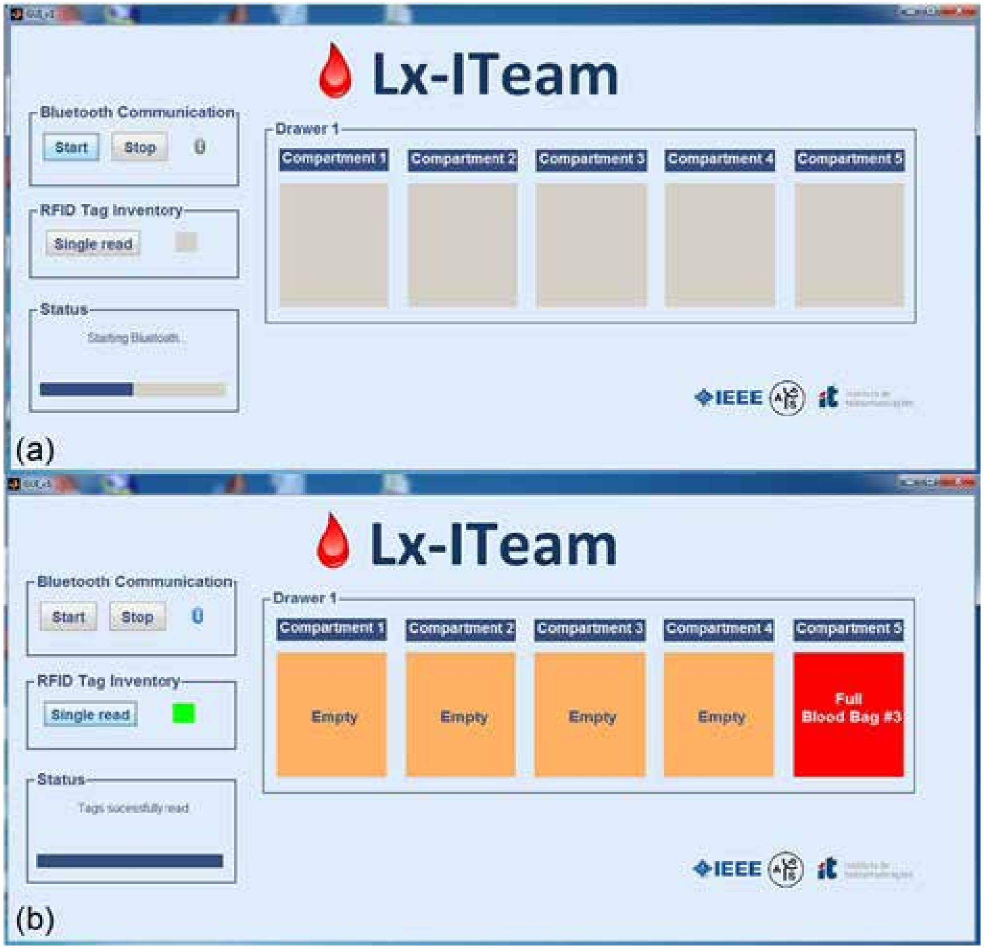


图 12. 用 MATLAB 开发的图形用户界面。（a）初始状态；（b）运作状态的例子

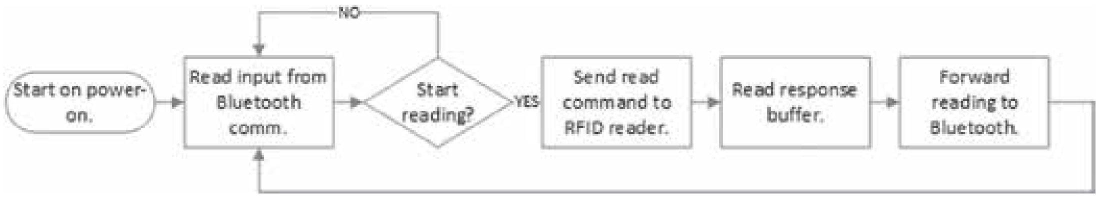


图 13. Arduino 流程图草图

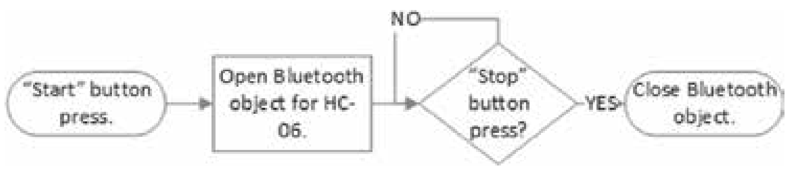


图 14. 蓝牙通信的 MATLAB 控制代码流程图

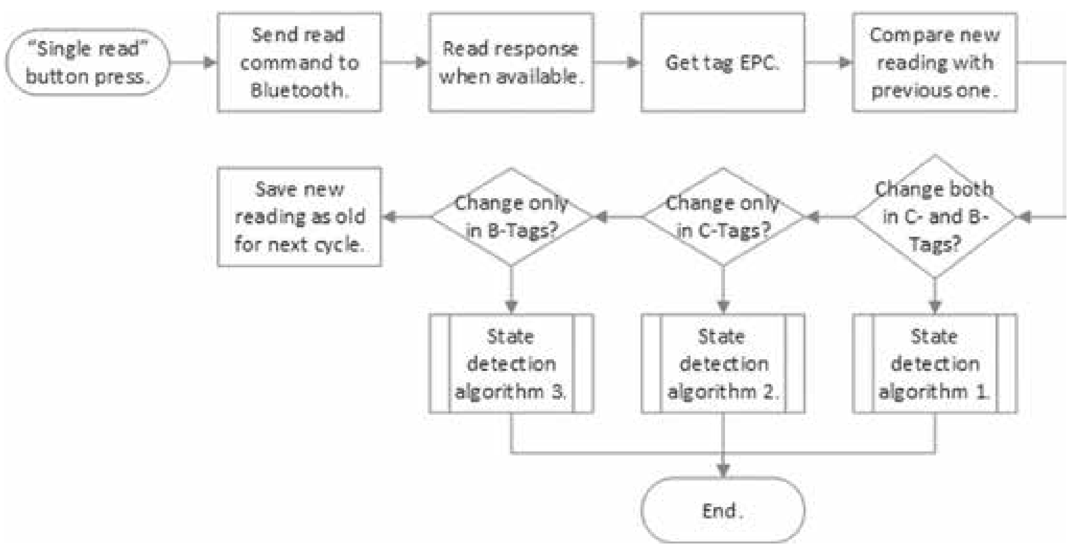


图 15. 标签读取的 MATLAB 代码流程图

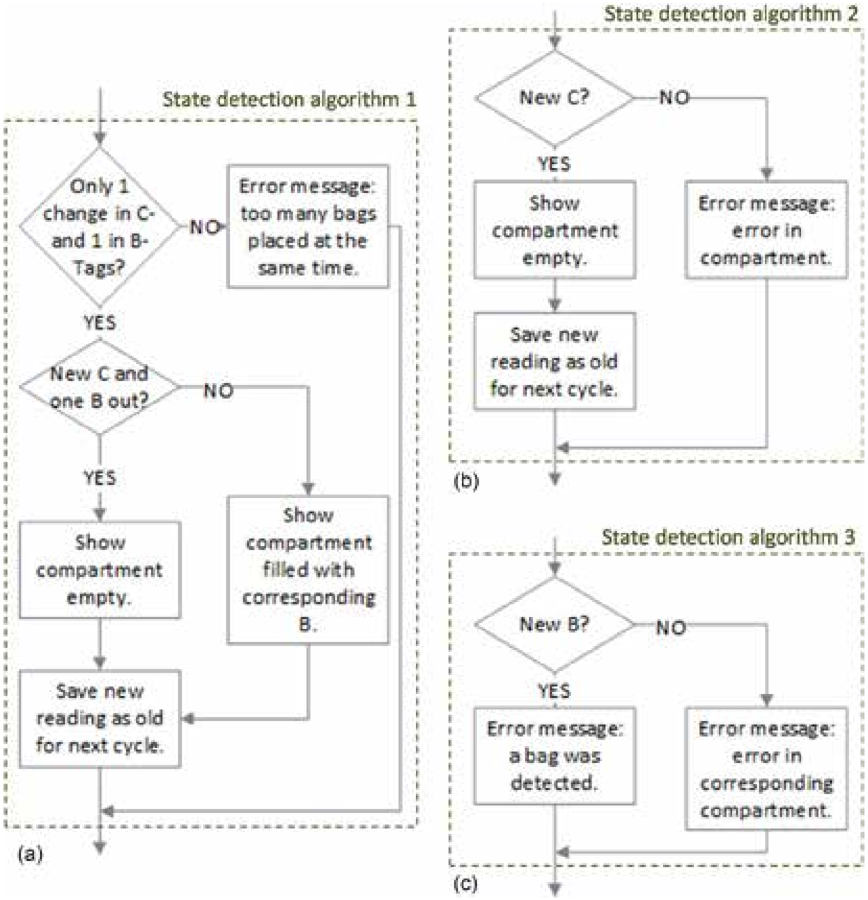


图 16. 状态检测算法从标签读取代码。（a）算法 1；（b）算法 2；（c）算法 3

7. 系统性能

为了评估系统性能，必须组装完整的系统，机柜单元由 k 线板制成，单独的抽屉可以建造或购买。如比赛视频[1]所示，基于 RFID 的智能血液库存系统能够检测各种配备血袋的标签。在开头的视频中演示了抽屉中有各种带标签的血袋，系统正确地识别了每个血袋。该视频还展示了 C 标签和 B 标签的作用。此外，还展示了两种标签的鲁棒性，即两个袋子被放置在抽屉的两个隔间中，中间有一个空隔间。他们之间的车厢标签也被正确地检测到，这意味着袋子没有影响中间的 C 标签。接下来，在中间隔间放置一个配备了标签的袋子，也正确的检测到了，说明相邻的袋子没有对血袋标签产生负面影响。为了更好地理解这个原理，请参阅比赛视频[1]。

如前所述，这里使用的伪定位方法只有一个基本的限制，为了能够准确地连接"消失的"C 标签和"出现的"B 标签，每个周期只能放置一个袋子在一个抽屉隔间。在这里实现的系统需要几秒钟，然而，通过使用更快的 RFID 阅读器和更快的微处理器，优先地连同蓝牙收发器（完全集成系统）全部配置在一个单板上，这样的时间将大大缩短。这里，出于原理论证的目的，响应时间并不是最关键的因素。

8. 结论

本系统是用于血库的输血血液的管理和储存的。系统能够定位和识别如[1]所示放置在机柜中的各种血袋。它基于 UHF RFID 技术，由机柜模型、收发单元和用于运行系统运行所需软件的 PC 组成。采用一种新颖的方法实现了伪定位原理，不仅能检测出血袋所在抽屉的位置，而且能检测抽屉隔间。为了实现这一点，每个抽屉底部都有一个阅读器天线，每个隔间有一个专用的 RFID C 标签。这些袋子还贴上了专用的 RFID B 标签，通过结合这两种标签类型的检测，每个袋子都被识别并定位在柜内。抽屉式读卡器天线是专门设计的，具有局限的辐射模式命令不检测其他抽屉的标签。B 标签与血袋共同设计，以适应里面的血液，这是通过在标签几何结构中加入一个线层来完成的。最大的挑战是通过调整两个金属贴片的尺寸，优化衬底厚度和短通孔的位置来实现 B 标签尺寸的最小化。与 B 标签相反，C 标签被设计成具有经典的弯曲偶极子几何结构，在血液存在时显著地失谐。收发器和机柜体积小，可移动，电池供电，成本低。所提出的伪定位化策略被证明是有效的，为现有的无源 UHF RFID 识别技术增加本地化能力，同样的策略可以扩展到其他用户应用程序。

Karl F. Warnick
Department of Electrical and Computer Engineering
Brigham Young University
459 Clyde Building
Provo, UT 84602
Tel.: (801) 422-1732

RFID-based Smart Blood Stock System

Andela Zaric[1], Catarina C. Cruz[1], António M. de Matos[2], Marta R. da Silva[2], Jorge R. Costa[1,2], and Carlos A. Fernandes[1]

[1]Instituto de Telecomunicações, Instituto Superior Técnico—Universidade de Lisboa (IST-UL), 1049-001 Lisboa, Portugal
E-mails: andela.zaric@lx.it.pt; katarinakruz@hotmail.com; jorge.costa@iscte.pt; carlos.fernandes@lx.it.pt

[2]Departamento de Ciências e Tecnologias da Informação, Instituto Universitário de Lisboa (ISCTE-IUL), 1649-026 Lisboa, Portugal
E-mails: antoniompm91@gmail.com; martaraquel90@gmail.com

Abstract

A complete UHF radio-frequency identification (RFID)-based system capable of localizing individual blood bags inside storage cabinet drawers is presented. It was developed to demonstrate the improvement possibility of current blood stock management systems and as the submission to the 2014 IEEE AP-S Student Design Contest: Antennas for RFID Application. The system is composed of a cabinet model, a transceiver unit, and a PC with the controlling software. A new implementation of pseudolocalization principle is used to localize the blood bags that are equipped with dedicated passive tags designed to be resilient to blood proximity and small size. The detector antennas are placed at the drawers bottoms and additional passive tags are utilized to identify individual locations in each drawer. The transceiver unit is made from off-the-shelf commercial electronic boards and wirelessly controlled by software run on the PC. The entire system is small, transportable, battery powered, and low cost.

Keywords: Radio-frequency identification (RFID) UHF antennas; RFID pseudolocalization; RFID tags for liquids; RFID smart shelf

1. Introduction

The work presented here was the winning finalist project for 2014 IEEE AP-S Student Design Contest: Antennas for radio-frequency identification (RFID) Application. Student teams were challenged to be creative, to formulate, and

Digital Object Identifier 10.1109/MAP.2015.2420491
Date of publication: 13 May 2015

to solve interesting antenna design problems by developing a RFID system that is custom built for a specific application. The system had to be safe and durable, easily reproducible, inexpensive (total budget of $1500), and portable (for hand carry). The RFID system had to operate at UHF RFID band 902–928 MHz, limited to 4-W EIRP, with the reader powered by a battery, the tags being batteryless (passive) and limited to maximum size of 50 mm × 50 mm × 5 mm. Student versions of commonly used software (MATLAB, C, etc.) and free software packages were allowed to be used along with a laptop PC that is not included in the budget limit. This paper is the full project report starting with the motivation for the chosen application scenario, and following description of the developed system, localization method, characterization of developed RFID antennas, developed software, and at the end instructions on how to assemble and operate it. This paper is also accompanied by a demonstration video of the system prepared for the semifinal phase of the contest [1].

In the U.S., blood transfusion is needed every minute and around 30 million blood components are transfused each year [2]. Around 60 fatalities per year happen due to erroneous blood transfusion [3], which calls for special attention to diminishing transfusion errors, therefore, tracking the blood from donor to patient [4]. Erroneous identification of the blood and/or the patient for transfusion is a serious life threat that is currently managed by bar code tagging of blood bags [5]. Each bag is tagged with various barcodes carrying specific information about the blood as, for instance, the blood type, collection date, expiry date, person that processed it in each step, etc. When a blood bag is retrieved from the blood bank the barcodes are read manually to register that the bag was retrieved, and then, it is administered to the patient. Even with this blood management system around 14% of identification errors occur in the blood bank and 86% at bedside [6].

This kind of errors can be mitigated with a system abundant with RFID tags to enable crosschecking the blood information and patient needs both in blood bank and at bedside. All necessary data can be stored in a single RFID chip, and a single tag can be used for each blood bag. Therefore, a Smart Blood Stock System for blood collecting and storing centers and hospitals was developed and presented here. The presence and the location of the collected blood bags inside the cabinet is automatically detected and introduced into a database using double UHF RFID tag placement on the shelves and on the bags. The hospital personnel would use the cabinet database to search for specific blood bag they need and immediately get to know, in which location inside the cabinet is the needed blood. Furthermore this system could be integrated with a bedside RFID system that would enable automatic cross checking of the blood bags with the patient blood type. The Smart Blood Stock System would help in ensuring that the correct blood is administered more reliably and accurately than common barcode-inventory systems.

2. System Overview

The proposed solution for smart blood stock system comprises three main parts: the cabinet unit, the transceiver unit and the PC with a graphical user interface (GUI) developed in student version of MATLAB, as shown in Figure 1a and b. The developed cabinet unit consists of two drawers (10 cm × 30 cm), but in the general case, it can have from just one to any number of drawers. Each of the drawers is

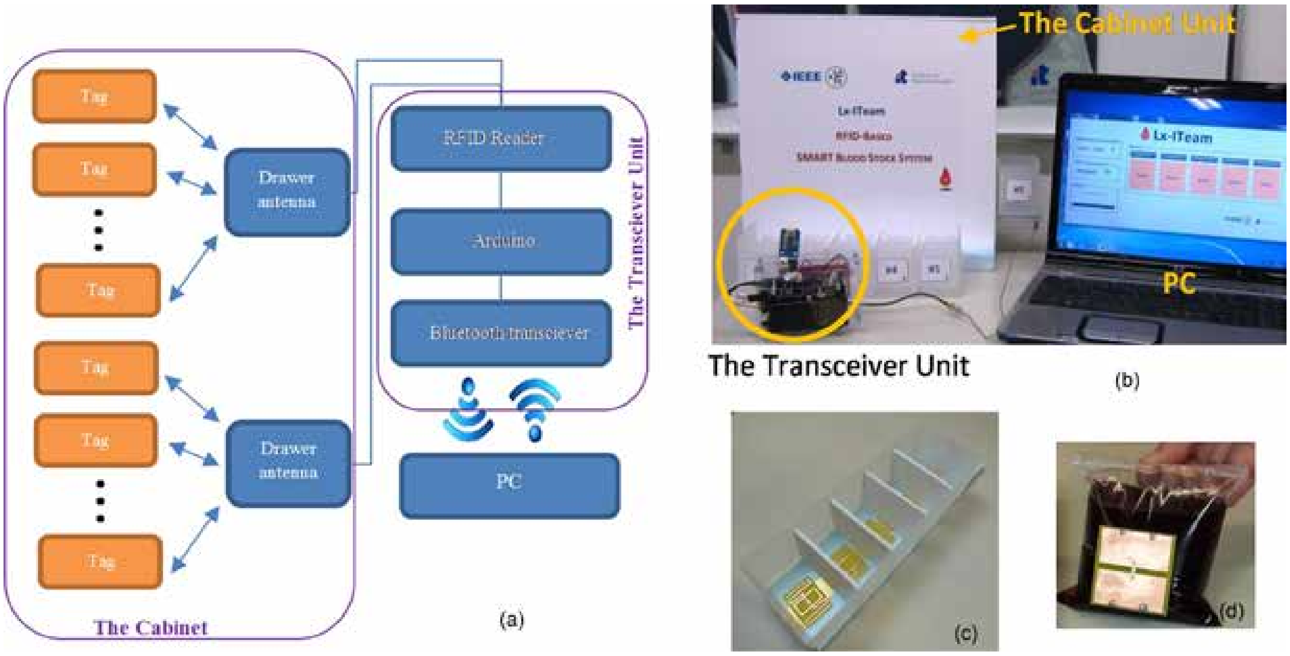


Figure 1. (a) Schematic and (b) photo of the RFID-based Smart Blood Stock System. Drawer with C-Tags in (c) compartments and (d) blood bag with B-Tag.

divided into small compartments (6 cm in length) suited to hold one bag of blood each. The bottom of each drawer has a RFID reader antenna (Drawer Antenna) and each of the small compartments is equipped with a dedicated tag (Compartment Tag Antenna—C-Tag)—Figure 1c. Additionally, each of the blood bags carries another specialized tag (Blood Bag Tag Antenna—B-Tag), which is very resistant to blood proximity [see Figure 1d]. The Drawer Antenna and the two types of tags will be presented in more detail in Section 4. The transceiver unit is made by joining the following commercially available components: AS3992 UHF RFID reader [7], Arduino Mega ADK [8], HC-06 Bluetooth transceiver [9], and Lithium Mega Backpack [10]. The reader is able to inventory various passive UHF RFID tags at the same time upon being prompted by an external control component, which here is the Arduino board. The Reader communicates the tags electronic product code (EPC) to Arduino, which then using the Bluetooth transceiver transmits the information to the PC, whereas the Lithium Mega Backpack is the battery board that provides power for the entire transceiver and makes it portable and viable for hand carry. Finally, the PC is used for user control of the system and for processing the data received from the transceiver unit. The hardware components will be described in more detail in Section 5, and the software in Section 6.

3. RFID Pseudolocalization Principle

Typical RFID application, such as warehouse and store inventory or asset tracking, comprises a small number of fixed readers, sometimes even only one, and a large number of tagged objects. The reader keeps track of the tags in its range by sending periodically an interrogation signal. When the tags receive the signal each of them responds with its unique identification number (EPC). Therefore, only the tags that receive sufficient energy to respond are in the reader's range. However, the reader, if equipped with one antenna, only knows that the tag is present. Here, the pseudolocalization principle is used to determine the tag location since the reader is capable of distinguishing which of the reader antennas is detecting the object. This is achieved by designing dedicated reader antennas that have known spatially confined radiation characteristics and are placed in a grid to cover the desired space without overlapping. This solution was presented in [11] featuring microstrip-based shelf reader antennas whose radiation pattern covers only the storage space above the shelf. This way, the reader detects each object only by one reader antenna and knows on which shelf the object was placed.

For the blood stock system presented here, a new implementation of the pseudolocalization principle is employed in order to not only be able to identify on which shelf is the object but also where on the shelf it is. This is accomplished by using two types of tags, i.e., the first type of tags (C-Tags) are used as known anchors on the shelf, and the second type (B-Tags) are the tags to be localized. More specifically, each C-Tag is assigned to one of the drawer compartments in the software's internal database. When all of the C-Tags are detected, it means that all of the compartments are empty (see Figure 2). On the other hand, when a blood bag is placed on top of a C-Tag due to its design the blood presence detunes the tag, and it is no longer read. In its place, a B-Tag is read. This is how the location of the blood bag is determined, whereas the "identity" of the blood bag is determined by the EPC of the B-tag attached to it. This is graphically presented in Figure 2. It needs to be noted that a new reading cycle has to be performed after each bag placement, to avoid ambiguity in detection of the compartment, in which each bag was placed.

4. Antenna Design, Simulation, and Measurement

4.1 Blood Bag Tag Antenna (B-Tag)

The purpose of B-Tags is, as explained in Section 2, to carry identification of each blood bag. The B-Tags are attached to blood bags and therefore have to be resilient to the negative liquid dielectric influence. This resilience is, in most cases, achieved by adding a ground plane to the tag. Hence, the proposed antenna configuration derives from two RFID

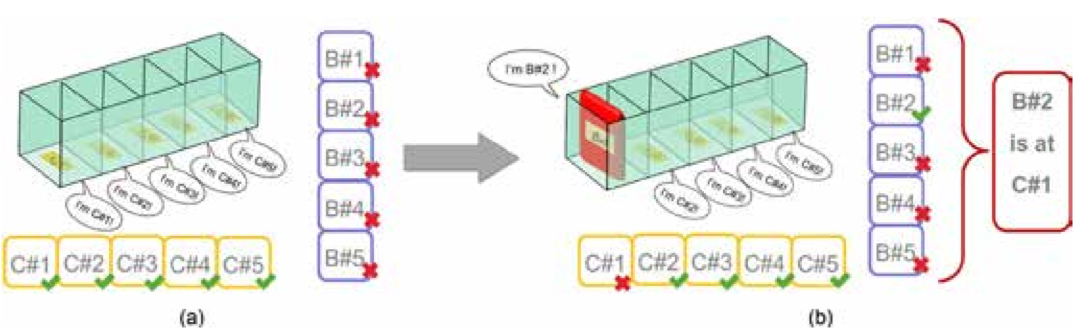


Figure 2. Pseudolocalization principle. The C-Tag determines the position (by not being detected) and the B-Tag determines the "identity" of the bag. In the empty state, the C-Tag is detected (a) and when a blood bag is placed in the compartment the corresponding C-Tag is no longer detected, instead the bag B-Tag is as shown in (b).

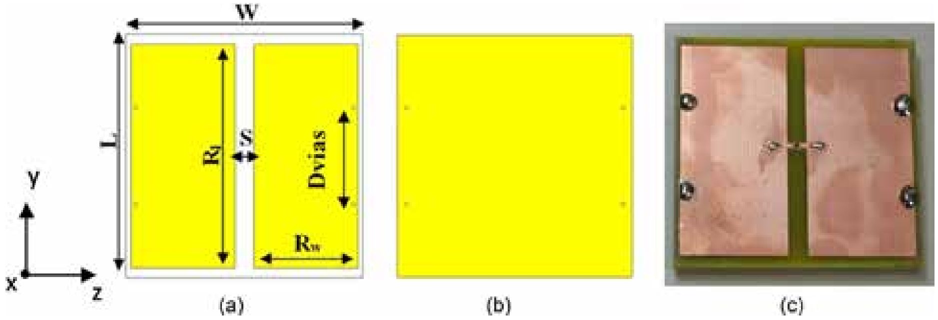


Figure 3. Geometry of the B-Tag antenna. (a) Front. (b) Back. (c) Fabricated.

antenna designs comprising a ground plane [12, 13]. Both these tags from the literature are tuned for the required UHF RFID band (902–928 MHz), but dimensions (116 mm × 40 mm × 1.8 mm and 85.5 mm × 54 mm × 1.6 mm) are far from complying with the maximum required dimensions for the contest (50 mm × 50 mm × 5 mm). Additionally, both of the antennas were designed for different RFID chips than the ALIEN Higgs-3 IC [14], which will be used here. For the ALIEN Higgs-3 IC, the manufacturer provides a lumped element model, which is parallel between a 1500-Ω resistor and 0.85-pF capacitor. It results in a chip impedance of $Z_{chip} = 27.83 - j199.15\ \Omega$ @915 MHz. This means that the RFID port must match the complex conjugate impedance of the chip to ensure maximum power transfer at 915 MHz.

The geometry of the designed blood bag tag is presented in Figure 3. It is a planar antenna with a single metal layer printed on the front face [see Figure 3a] and a ground plane on the back face [see Figure 3b]. A FR-4 substrate with 3.6-mm thickness is used. In the front face two metallic patches with 46 mm × 22 mm are printed and each shortened to the ground with 2 vias so that the vias are placed as close as possible to the edge. The two metallic patches are separated by a gap of 4 mm. The ALIEN Higgs-3 IC is soldered at gap middle. As seen, the geometry of this antenna is inspired by both antennas in [12] and [13], and in comparison to [13], the simplification of design and introduction of second via at the end of each patch along with the increase in substrate thickness has resulted in smaller dimensions that comply with contest requirements. The manufactured antenna is shown in Figure 3c and the key dimensions are given in Table 1.

To tune the B-Tag antenna impedance in the presence of a blood bag on its back, the antenna was codesigned and adjusted with a blood bag of 200 mm × 200 mm × 30 mm, as in the inset of Figure 4. Human blood has relative electrical permittivity 61.31 and conductivity 1.54 S/m [15] and these values are used for the blood block, however for the prototype system the mock blood bags are made of water and water-soluble red color since the dielectric properties of water and blood are very similar (around 80% of blood is water). The water has just slightly different relative permittivity 78 and almost equal conductivity 1.59 S/m compared with blood.

Table 1. Parameter values of the B-tag in millimeters.

W	L	R_w	R_l	S	$\varnothing_{vias}$	D_{vias}
50	50	46	22	4	0.7	20

Instead of the classical s_{11} analysis, for RFID tag antennas, it makes sense to analyze the power transfer function from the antenna to chip as this relates directly to the tag achievable range. The power transfer function measures the maximum fraction of the available power at the antenna port that is transferred to the chip [16]. Both simulations, with and without the blood bag, are performed and the power transmission coefficients are shown in Figure 4 that were obtained using university-licensed CST software [17]. The power transmission coefficient is higher for the blood bag presence, which is explained by the fact that the antenna is designed and tuned considering the presence of the blood bag. Power transmission is above 70% level across the entire required UHF band, which implies good detection as it is proved, experimentally, in the final competition video [1].

4.2 Compartment Tag Antenna (C-Tag)

The C-Tag antenna function in the blood stock system is to detect when a blood bag is placed in its compartment. The proximity of dielectric such as blood is supposed to detune the C-Tag and it would no longer be detected by the

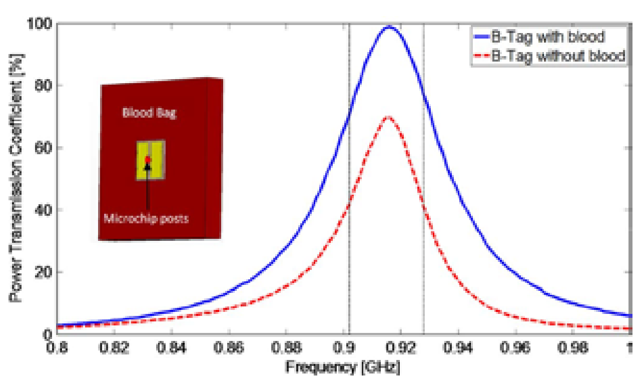


Figure 4. Simulated Power Transmission Coefficient with and without blood bag presence. (Inset) Schematic of the B-Tag placed next to a blood bag. The vertical lines denote the used UHF RFID band (902–928 MHz).

RFID reader, this would signal the presence of the blood bag. To achieve this, a classical RFID tag design is used, unlike for the B-Tag. As presented in Figure 5a, the tag is a planar antenna with a single metallic layer and comprises a double loop and a meandered dipole. The design was based on a previous UHF tag antenna designed by one of the authors [18]. The tag is printed on one side of a FR-4 substrate with 0.75-mm thickness, permittivity 4.3, and loss tangent 0.025. This antenna is also designed considering the input impedance of the ALIEN Higgs-3 IC [14]. The RFID port impedance must be $Z_{RFID} = 27.83 + j199.15\ \Omega$ @915 MHz and as a result of this, the antenna must exhibit inductive behavior, which is achieved using the double loop. The radiating behavior is obtained with the addition of a dipole, which is meandered to reduce its length. To achieve the competition requirements in terms of antenna maximum size, and simultaneously produce an RFID tag working properly with the referred chip, it was necessary to adjust loop and dipole parameters of the original RFID antenna design in [18]. Comparing the original antenna and the C-Tag presented here, the main challenge was to resize the antenna structure while keeping the desired characteristics given that the original antenna was larger and had different chip impedance.

The C-Tag's final size is 50 mm × 40 mm [the manufactured antenna is presented in Figure 5b] and the obtained parameters values are given in Table 2.

Simulated power transmission coefficient for C-Tag without the blood bag is presented in Figure 6 (blue curve). Power transmission is above 65% level across the required UHF band. A simulation was carried also to understand the behavior of the C-Tag when a blood bag is positioned on top of the tag. The corresponding power transmission coefficient is shown in the inset of Figure 6 with the red dashed curve. As expected, and as required for this application, the power

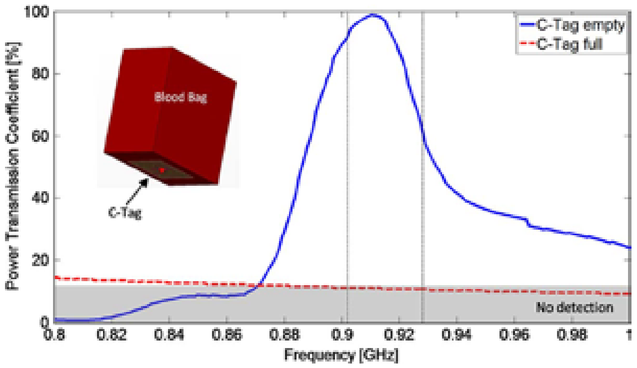


Figure 6. Simulated power transmission coefficient for the proposed C-Tag with and without blood bag presence. (Inset) Schematic of the C-Tag antenna with a blood bag on top. The vertical lines denote the used UHF RFID band (902–928 MHz).

transmission is under 10% for the UHF band (denoted with the gray shadowed area in Figure 6). This means that the blood bag drastically detunes the antenna and, consequently, the antenna does not adequately radiate; and therefore, it is not detected by the RFID reader. This simulation behavior was confirmed by experimental measurements, as demonstrated in the final competition video [1].

4.3 Drawer Antenna

The idea for the drawer antenna comes from previous work [11], where this kind of structure has proven useful in a RFID application that required that a detector antenna would only read the tags placed above a single shelf. If a classical high gain, therefore long range, detector antenna would be used in such scenario objects placed on the adjacent shelves

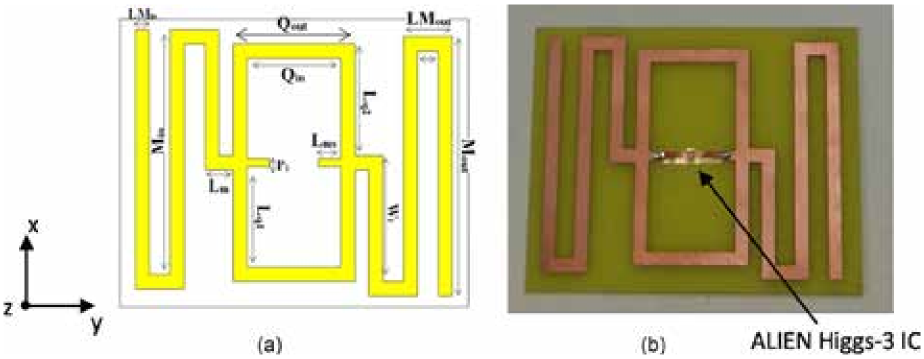


Figure 5. (a) Geometry of the C-Tag antenna. (b) Manufactured antenna with soldered ALIEN Higgs-3 IC chip.

Table 2. Parameter values of the C-tag in millimeters.

LM_{in}	LM_{out}	Q_{in}	Q_{out}	M_{in}	M_{out}	W_l	L_m	L_{ms}	L_{q1}	L_{q2}	P_1
2	7	13.5	17.5	34	36	17.5	4	3.25	13.9	15.5	1.2

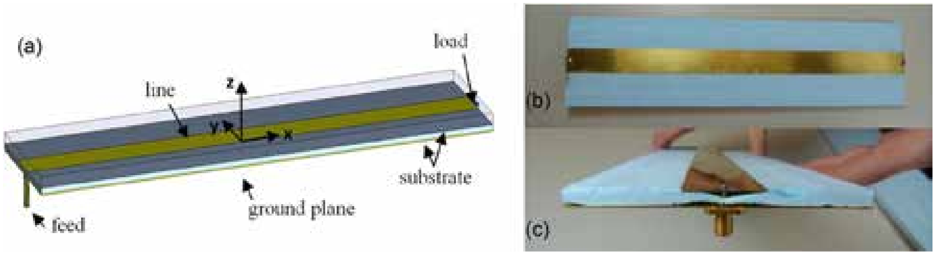


Figure 7. Smart drawer antenna configuration. (a) Model. (b) Produced antenna top view. (c) Produced antenna view of the feed.

would be falsely detected as present on the shelf in question. The microstrip-based antenna in [11] has a limited energy radiation in the plane perpendicular to the antenna plane, which makes it ideal for applications comprising shelves and/or drawers. The embedded microstrip line extends across the drawer length with full ground plane on the bottom side; it is probe fed at one end, and terminated with a matched load (a 50-Ω resistor) at the other end.

The drawer antenna structure is presented in Figure 7a, where the transmission line is oriented along the x-axis throughout the entire length of the antenna. Its overall dimensions are 100 mm × 300 mm. To manufacture it, as shown in Figure 7b and c, 0.5-cm-thick Styrofoam substrate layer is used, whose relative permittivity, close to 1, favors field leakage. The transmission line is centered on the ground plane and its width is 27 mm in order to obtain a 50-Ω impedance line. The structure is fed by 50-Ω coaxial cable, via SMA coaxial plug connector, and the line is terminated by a 50-Ω load. An additional layer of Styrofoam substrate is added on top of the transmission line (not shown) to increase mechanical stability and to avoid direct contact between the compartment RFID tags (C-Tags) and the microstrip.

The main challenge in the antenna redesign comes from the fact that this antenna has much smaller length than the original one presented in [11]. Although the drawer antenna used here is significantly smaller, it confines the radiation to the drawer structure as desired. Near-field energy distribution for yz and xy planes is presented in Figure 8. The results confirm, as could be expected, that the dominant electric field components are E_z and E_y. The E_x component is very low, and it is not shown in Figure 8; instead the total field E_t is shown. It is noted that the fields are reasonably confined to the drawer near zone and minimum energy needed for tag detection corresponds, in this figure, to 20 dBV/m.

In yz plane component E_z has a null at the center of the microstrip (y = 0 mm) and radiation concentrated on the sides, whereas E_y is concentrated at the center. This is important to have in mind when choosing the orientation of the B-Tag. Given that the B-Tags are linearly polarized in the direction of the soldered chip (perpendicular to the longer side of the rectangular patches), if they are placed at the middle of the drawer they should be aligned in z direction, and if they are placed more to the side of the blood bag the tags z direction has to be aligned with drawer y direction to ensure

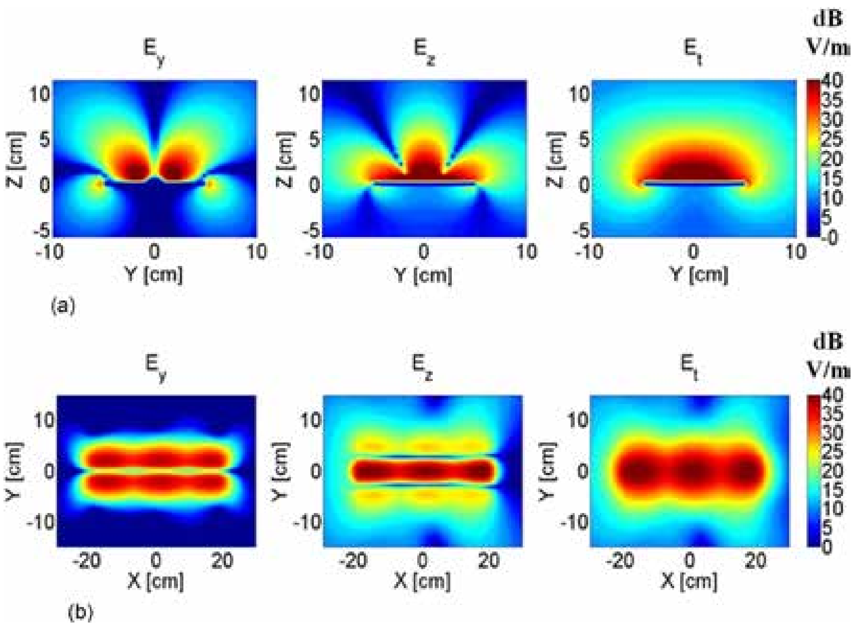


Figure 8. Near-field components. (a) X = 0 plane. (b) Z = 0 plane (bottom part of the antenna surface).

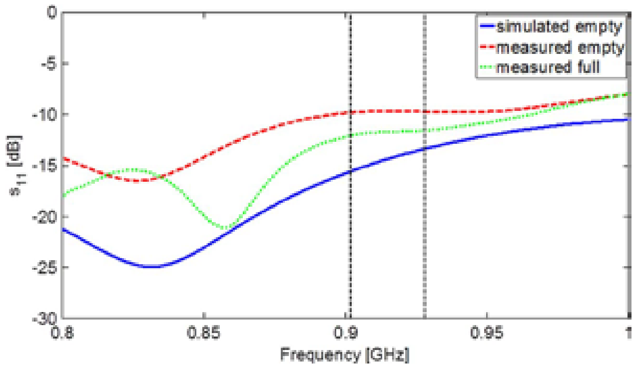


Figure 9. Simulated and measured input return loss of the drawer antenna. The vertical lines denote the UHF RFID band (902–928 MHz).

good detection. Complementary behavior of components E_z and E_y can be observed in xy plane as well. The C-Tags are placed flat in this plane and since E_y component has the null at the middle they have to be placed more to the sides of the microstrip with their polarization (direction of the soldered chip) aligned with y.

Simulated and measured input return loss of the empty drawer antenna is presented in Figure 9 along with measurement when the drawer is full (five C-tags and five blood bags equipped with B-Tags). As seen, s_{11} parameter is below -10 dB for the total UHF RFID band as is required both for the empty drawer and when multiple blood bags are positioned inside the drawer. This is important because the blood bags tend to drain out the power of the drawer antenna and for this reason it could influence the reading of tags. However, it is demonstrated here and in the final competition video [1] that the drawer antenna is capable of detecting the C- and B-Tags even when multiple compartments are occupied.

5. Hardware Description

Here, the hardware components used to make our transceiver unit are described in detail: AS3992 UHF RFID reader, Arduino Mega ADK, HC-06 Bluetooth transceiver, Lithium Mega Backpack, and at the end RF switch.

AS3992 UHF RFID reader is made by Solid [7] and is based on single UHF RFID chip reader AS3992. The reader is capable of working in various frequency bands conforming to different world standards. Here, it is set to work from 902 to 928 MHz, as required by the contest proposal. It is compatible with ISO18000-6C protocol (EPC Gen2 protocol) and maximum output RF power is 20 dBm (0.1 W), which complies fully with the limit of 4-W equivalent isotropically radiated power (EIRP) limit. The reader is preprogramed by the manufacturer to communicate with external components (such as a PC or a microprocessor board) by a two-way Universal Asynchronous Receiver/Transmitter serial interface, which, in our case, is connected to the Arduino Mega ADK. The reader is able to inventory various passive RFID tags in less than 6 ms. Using the correct command, the reader is prompted to make an inventory round, and upon completing, it reports back all the tags EPC numbers. The reader board is shown in Figure 10a. The total size of the board is 90 mm × 49 mm.

Arduino is the core controlling element of the transceiver unit. It controls the RFID reader and the HC-06 Bluetooth transceiver. The Arduino Mega ADK [8] used here is chosen because unlike other models, it has more than one serial communication interface, which are needed for communication with the reader and with the Bluetooth transceiver. This specific board was chosen for this project because it has four different serial interfaces for communications with other devices, whereas all other Arduino boards have only one. By default, one serial interface is dedicated for PC communication via USB cable, which is used to program the board, and the other three are free to use; here, two of them are used for communication with the RFID reader and the Bluetooth transceiver. Figure 10b shows the Arduino Mega ADK. The total size of Arduino Mega ADK is 100 mm × 50 mm. Arduino board comes without any programming, and an open source development environment IDE 1.0.5 [19] is used to create, compile, and upload sketches to the Arduino board. Sketch is the code that runs on the Arduino board microprocessor.

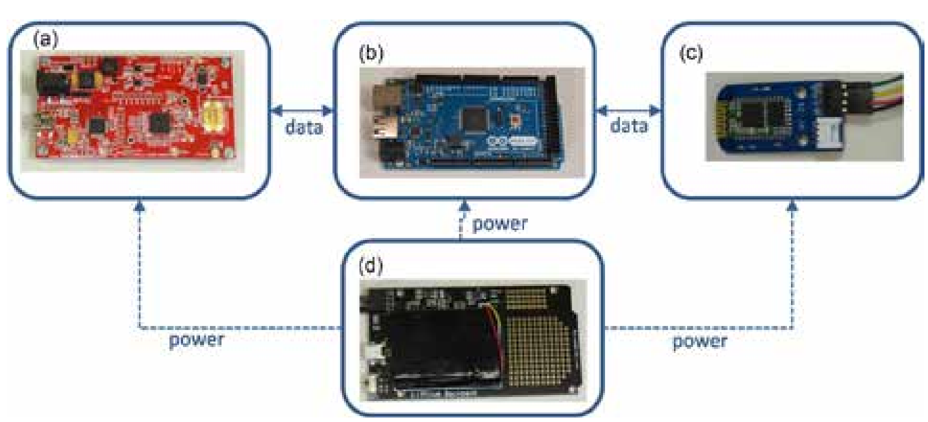


Figure 10. (a) AS3992 UHF RFID reader. (b) Arduino Mega ADK. (c) HC-06 Bluetooth transceiver. (d) Lithium Mega Backpack.

HC-06 [9] is a simple Bluetooth transceiver, which enables an Arduino board to communicate wirelessly with a PC by assigning one of its serial interfaces to the transceiver. This transceiver is compatible with almost all Arduino boards, and all integrated or external PC Bluetooth interfaces. Figure 10c shows the outlook of the transceiver used here, with overall size of 20 mm × 15 mm.

The Lithium Mega Backpack [10], i.e., Figure 10d, is based on a Li-ion battery and provides regulated 3.3 and 5 V as needed to all other boards used for the transceiver. The Li-ion battery can be charged by a mini USB cable directly from any PC without any software needed and it has a 2200 mAh of capacity, which is approximately 8 h of autonomous operation of the entire system.

Table 3. Electrical connections for the transceiver unit.

Component	Connection to be made
AS3992 UHF RFID Reader	Barrel connector (power) → GND + 3.3V Lithium Mega Battery Backpack
	TX → RX1, pin 19 Arduino Mega ADK
	RX → TX1, pin 18 Arduino Mega ADK
	GND → GND Arduino Mega ADK
HC-06 Bluetooth transceiver	GND → GND Lithium Mega Battery Backpack
	V → 3.3V Arduino Mega ADK
	DI → TX2, pin 16 Arduino Mega ADK
	DO → RX2, pin 17 Arduino Mega ADK
Lithium Mega Batt. Backpack	GND → GND Arduino Mega ADK
	5V → 5V Arduino Mega ADK

5.1 Hardware Assembly

All of the hardware components (Arduino, RFID Reader, Bluetooth transceiver, Battery Backpack) are assembled in a single transceiver unit of approximate size of 100 mm × 100 mm × 150 mm, as shown in Figure 11. 140 mm × 80 mm acrylic support boards are made for the Arduino, RFID reader, and the Battery Backpack, and they are fixed together using metallic screws and nuts. The supporting acrylic boards are also joined together with the RF switch board using metallic screws and nuts, and finally, the Bluetooth transceiver is fixed to one of the cube sides to have better omnidirectional coverage. The electrical connections that need to be made between the transceiver components can be found in Table 3.

6. Software Description

A student version of MATLAB was used to make a control software GUI using GUIDE (MATLAB wizard for making GUIs). The initial screen is shown in Figure 12a, aside from the name of our team (Lx-ITeam), it comprises three control panels on the left side of the screen, and a panel for the one of the cabinet drawers with message screens for each of the drawer compartments. The GUI presented here is a newer version of the GUI in the competition video [1], and the only difference is in the visual appearance of the control panels.

Bluetooth Communication panel is used for establishing and canceling the Bluetooth communication between the PC and the Transceiver Unit. The communication is started by pressing button "Start" and stopped by pressing "Stop." When the Bluetooth connection is established the icon on the right side of panel is illuminated in blue such as in Figure 12b. RFID Tag Inventory panel is used for reading the tags and aside from the button "Single read," it comprises an indicator light that is red when a reading is in progress and it turns green when the tags have been successfully read as in Figure 12b. Upon clicking the "Single read" button the program sends a command via the Bluetooth object to the Arduino to start one interrogation round of the RFID

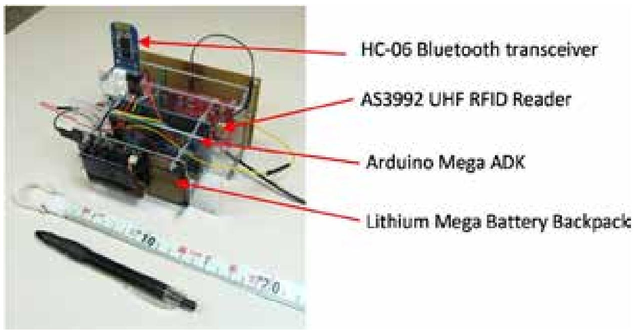


Figure 11. Assembled transceiver unit with a scale and a common ballpoint pen for size notion.

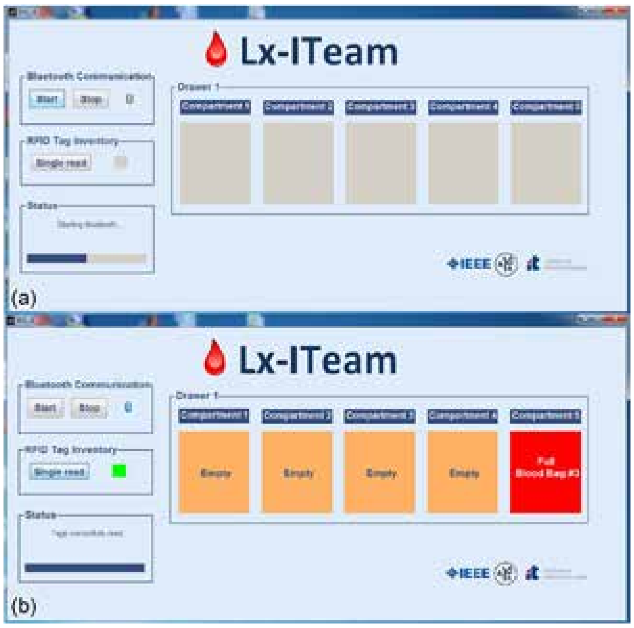


Figure 12. The GUI developed in MATLAB. (a) Initial state. (b) Example of functioning state.

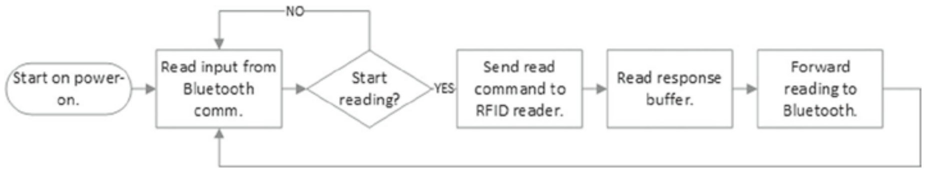


Figure 13. Arduino sketch flowchart.

Reader. Arduino sends the appropriate API command to the RFID Reader and waits for its response. The response containing EPC numbers of all found tags is returned by Bluetooth to the MATLAB program. Depending on the previous state the program checks if any compartments have been filled (equals to disappearing compartment C-tag EPC number form the list) or emptied (equals to appearing compartment C-tag EPC number on the list), and by which blood bag (EPC of blood bag B-tags appear on the list). In the Status panel a status bar shows the progress of the action and according actions status messages are shown.

The flowchart for the Arduino sketch (the code that is run on it) is shown in Figure 13. By default the code runs in loop upon powering the Arduino on. When the command to read tags is received through Bluetooth communication the RFID reader is prompted to read the tags and the collected information is forwarded to the PC back through Bluetooth. Figures 14–16 show the flowchart of the algorithms implemented in the MATLAB GUI. The actions that happen upon pressing "Start" and "Stop" buttons in the Bluetooth control panel are shown in Figure 14. The tag reading and state detection are described in Figure 15. Upon prompting the transceiver to read and receiving tag EPC's a series of decisions are made to determine which changes have happened in the drawer contents. The decisions are based on which changes have occurred in the tag presence list compared with the previous reading: changes both in detected C-Tag and B-Tag lists, or a change only in C-Tag or only in B-Tag list.

Figure 16 shows the three subalgorithms from Figure 15, i.e., first algorithm [see Figure 16a] shows how a newly placed bag is detected; second algorithm [see Figure 16b] shows how the C-Tags are detected at the first reading; and the third algorithm [see Figure 16c] shows how an error in bag placing is detected.

To operate the RFID-based Smart Blood Stock System, it is first necessary to upload the code to the Arduino using a USB cable and a PC with the IDE environment. Electrical connections as described in Section 5.1 Table 3 should be made next and the transceiver is the powered on. Then the GUI is run in MATLAB on a PC with a built-in or external

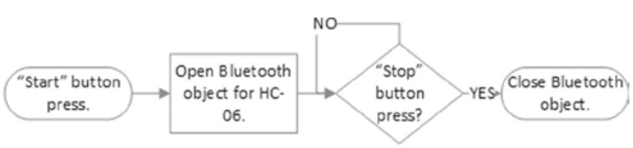


Figure 14. MATLAB control code flowchart for Bluetooth communication.

Bluetooth transceiver and button "Start" in the Bluetooth panel is clicked. All C-Tags are placed in their corresponding compartments, and "Single read" button is clicked next. Now, a blood bag with B-Tag can be placed in any of the compartments and its data will be shown in the GUI window after clicking the "Single read" button to refresh the list of read tags. This means that only one bag can be placed in the drawer in each reading cycle in order to be able to correctly determine the occupied compartment. To stop operating the system "Stop" in the Bluetooth panel has to be clicked, which will stop the PC connection with the transceiver unit. For more intuitive view of the system operating please refer to the competition video [1].

7. System Performance

To evaluate the system performance the complete system has to be assembled, the cabinet unit is made of K-line sheets, and the individual drawers can be constructed or bought. As shown in the competition video [1] the RFID-based Smart Blood Stock System is capable of detecting various tag equipped blood bags at the same time. At the beginning of the video a demonstration is performed in which various tagged blood bags are in the drawer and the system correctly recognized each one of them. The video also contains a demonstration of the role of the C-Tag and of the B-Tag. Additionally, a demonstration of both tags robustness is also presented, i.e., two bags are placed in the drawer in two compartments in a way that there is an empty compartment in between. They are also detected correctly and the compartment tag in between as well, which means that the bags did not influence the C-Tag in the middle. Next, a tag equipped bag is placed in the middle compartment, and it is also correctly detected, which shows that the adjacent bag did not negatively influence the blood bag tag. For better understanding of the principle please refer to the competition video [1].

As previously said the pseudolocalization method used here has only one fundamental limitation in order to be reliable, only one bag per cycle can be placed in one drawer compartment in order to be able to accurately connect the "disappeared" C-Tag with the B-Tag that "appeared." In the system implemented here that takes a few seconds, however by using faster RFID reader and faster microprocessor, preferentially all collocated on a single board along with the Bluetooth transceiver (fully integrated system), that time would be significantly shorter. Here, for the sake of principle demonstration the response time is not the most critical factor.

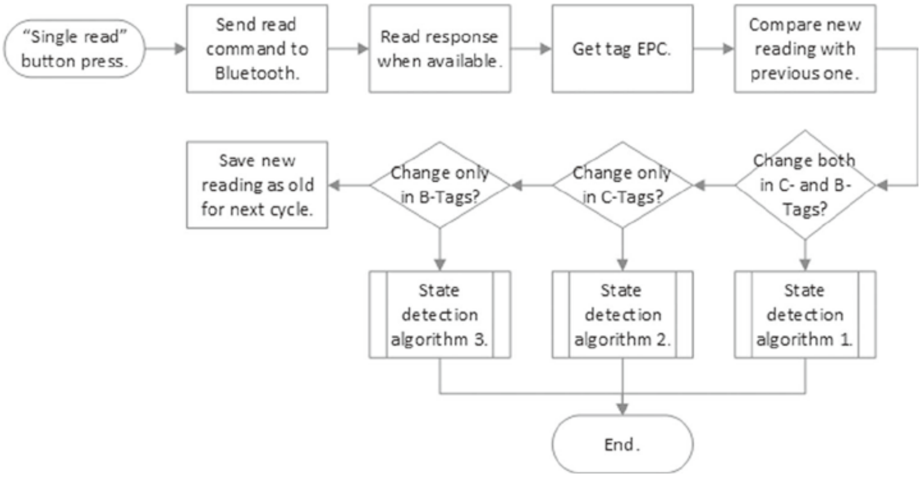


Figure 15. MATLAB code flowchart for tag reading.

8. Conclusion

The presented system is intended for use in blood banks that manage and store blood for transfusion. The system is capable of localizing and identifying various blood bags placed in the cabinet as seen in [1]. It is based on UHF RFID technology and comprises a cabinet model, a transceiver unit, and a PC used to run the software necessary for system operation. The pseudolocalization principle has been implemented in a novel way in order to detect not only, in which drawer the blood bag is but also, in which drawer compartment. To achieve this, each drawer has a reader antenna incorporated in the bottom, and each compartment has a dedicated RFID C-Tag. The bags are also tagged with dedicated RFID B-Tags and by combining the detection of both tag types each bag is identified and

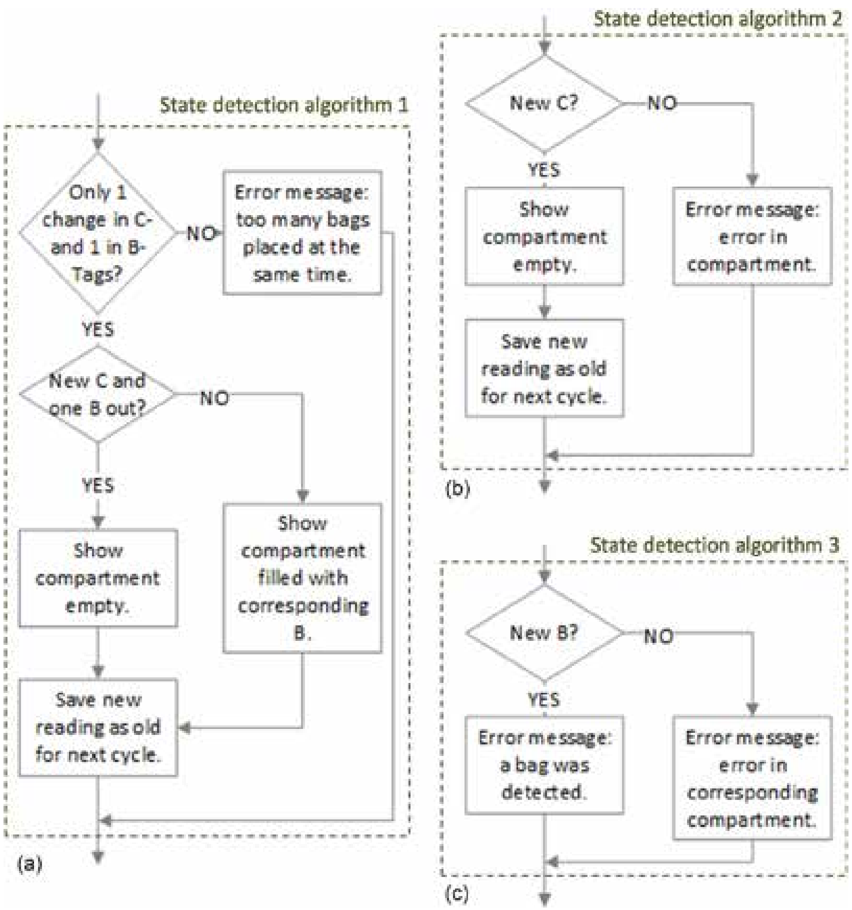


Figure 16. State detection algorithms from the tag reading code. (a) Algorithm 1. (b) Algorithm 2. (c) Algorithm 3.

localized inside the cabinet. The drawer reader antennas are specially designed to have confined radiation pattern in order not to detect tags from other drawers. The B-Tags were codesigned with the blood bags in order to be resilient to the blood proximity, which was accomplished by having a ground plane incorporated in the tag geometry. The biggest challenge to minimize the B-Tag size was achieved by adjusting the sizes of the two metallic patches, optimizing the substrate thickness and location of the shorting vias. On the contrary to B-Tag, the C-Tag was designed to significantly detune in blood presence by having classical meandered dipole geometry.

The transceiver unit and the cabinet are small and transportable, as well as battery powered and low cost. The proposed pseudolocalization strategy proved to be effective to adding localization capability to the existing passive UHF RFID-based identification technology. The same strategy can be extended to other user applications.

9. Appendix 1. Bill of Materials

Item	Qty.	Unt. price ($)	Tot. price ($)	Vendor
Arduino Mega ADK	1	97,65	97,65	InMotion
HC-06 Bluetooth Transceiver	1	21,82	21,82	InMotion
AS3992 RFID UHF Reader kit	2	233,40	466,8	Soliddepot
Lithium Mega Backpack	1	187,42	187,42	Liquidware
USB cables	1	34,22	34,22	Local store
Interface Cable MMCX to SMA	1	17,27	17,27	InMotion
Jumper cables for Arduino	-	21,87	21,87	InMotion
PCB FR-4		13,8	13,8	CrossNail Laminates
Etching	-	68,5	68,5	University prototype Shop
SMA connectors	5	17,28	86,4	Farnell
Coaxial cables	3	18,83	56,49	Farnell
K-line boards	5	10,27	51,35	Local store
Styrofoam	3	4,79	14,37	Local store
Brass plate	1	10,51	10,51	Local store
Alien Higgs-3 tags	20	0,50	10,00	AtlasRFID
Other small material	-	41,1	41,1	Local store
RFID reader import cost	2	132,46	264,92	Portuguese customs
		TOTAL	1464,49	

10. References

[1] Lx-ITeam Video Submission for IEEE AP-S 2014 Student Design Contest. [Online]. Available: http://www.youtube.com/watch?v=gq6CPM-yyM4

[2] Blood Facts and Statistics. American Red Cross, Washington, DC, USA. [Online]. Available: http://www.redcrossblood.org/learn-about-blood/blood-facts-and-statistics

[3] Fatalities Reported to FDA Following Blood Collection and Transfusion: Annual Summary for Fiscal Year 2013. U.S. Food and Drug Administration, Silver, Spring, MD, USA. [Online]. Available: http://www.fda.gov/BiologicsBloodVaccines/SafetyAvailability/ReportaProblem/TransfusionDonationFatalities/ucm391574.htm

[4] Blood Bag Labeling. BarcodesInc, Chicago, IL, USA. [Online]. Available: http://www.barcodesinc.com/news/?p=4612

[5] Guideline for the Uniform Labeling of Blood and Blood Components. FDA Center for Drugs and Biologics, Bethesda, MD, USA. [Online]. Available: http://www.fda.gov/downloads/BiologicsBloodVaccines/GuidanceComplianceRegulatorGuidanceComp/Guidances/Blood/UCM080974.pdf

[6] R. R. Sharma, S. Kumar, and S. K. Agnihotri, "Sources of preventable errors related to transfusion," *Vox Sanguinis*, vol. 81, no. 1, pp. 37–41, Jul. 2001.

[7] Solid Digi. [Online]. Available: http://www.soliddigi.com/portfolio/as3992-uhf-rfid-reader/

[8] Arduino. [Online]. Available: http://arduino.cc/en/Main/ArduinoBoardADK#.UytcL_nV-nw

[9] InMotion. [Online]. Available: http://www.inmotion.pt/store/hc06-serial-bluetooth-brick

[10] Liquidware. [Online]. Available: http://www.liquidware.com/shop/show/BPM/Mega+Backpack

[11] C. R. Medeiros, J. R. Costa, and C. A. Fernandes, "RFID smart shelf with confined detection volume at UHF," *IEEE Antennas Wireless Propag. Lett.*, vol. 7, pp. 773–776, Oct. 2008.
[12] H. Rajagopalan and Y. Rahmat-Samii, "Conformal RFID antenna design suitable for human monitoring and metallic platforms," in *Proc. 4th EuCAP*, Apr. 12–16, 2010, pp. 1–5.
[13] M.-C. Tsai, I.-G. Li, C.-W. Chiu, and H.-C. Wang, "UHF RFID PIFA array tag antenna for human body applications," in *Proc. 15th Int. Symp. WPMC*, Sep. 24–27, 2012, pp.434–437.
[14] Alien Technology. [Online]. Available: http://www.alientechnology.com
[15] Dielectric Properties of Body Tissues. [Online]. Available: http://niremf.ifac.cnr.it/tissprop/
[16] G. Marrocco, "The art of UHF RFID antenna design: impedance matching and size-reduction techniques," *IEEE Antennas Propag. Mag.*, vol. 50, no. 1, pp. 66–79, Feb. 2008.
[17] CST—Computer Simulation Technology. [Online]. Available: http://www.cst.com
[18] C. C. Cruz, J. R. Costa, and C. A. Fernandes, "Hybrid UHF/UWB antenna for passive indoor identification and localization systems," *IEEE Trans. Antennas Propag.*, vol. 61, no. 1, pp. 354–361, Sep. 2013.
[19] Arduino, (Accessed: January 2015). [Online]. Available: http://arduino.cc/en/Main/Software#.Uyty7PnV-nw

Andela Zaric (S'12) received the B.Sc. degree in electrical engineering and information technology and the M.Sc. degree in information and communication technology from the Faculty of Electrical Engineering and Computing, University of Zagreb, Zagreb, Croatia, in 2009 and 2011, respectively. She is currently working toward the Ph.D. degree in the Instituto Superior Técnico (IST), University of Lisbon, Lisbon, Portugal

She is a Researcher with the Instituto de Telecomunicações (IT). Her research interests include ultrawideband and radio-frequency identification (RFID) antennas for identification and localization.

Ms. Zaric was the recipient of the first prize in the 2014 AP-S Student Design Contest together with three team colleagues for designing and building a RFID-based Smart Blood Stock System. In 2013 she received a travel and attendance grant for European School of Antennas course "Antennas and Propagation for Body-Centric Wireless Communications."

Catarina C. Cruz was born in Lisbon, Portugal, in 1986. She received the Licenciado and the M.Sc. degrees in telecommunications engineering and computer science from the Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon, in 2009 and 2011, respectively. She is currently working toward the Ph.D. degree at the Instituto Superior Técnico (IST), Technical University of Lisbon, Lisbon.

Since 2010, she has been a Researcher with the Instituto de Telecomunicações (IT), focusing her work on antennas for wireless communications. Her current research interests are in the area of antennas for radio-frequency identification (RFID) and lenses.

Ms. Cruz was the recipient of the first prize in the 2014 AP-S Student Design Contest together with three team colleagues for designing and building a RFID-based Smart Blood Stock System. She received a travel and attendance grants for European Schools of Antennas courses: "Terahertz Technology and Applications" and "Antenna Project Management" in 2012 and 2011, respectively.

António M. de Matos is currently working toward the Licenciado (B.Sc. equivalent) degree in telecommunications engineering and computer science at the Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon, Portugal.

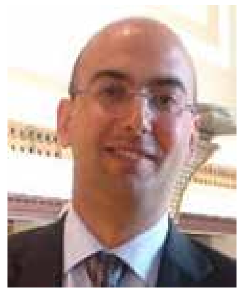
He is interested in antennas and electromagnetic propagation, in general, and in radio-frequency identification (RFID) applications.

Mr. Matos was the recipient of the first prize in the 2014 AP-S Student Design Contest together with three team colleagues for designing and building a RFID-based Smart Blood Stock System.

Marta R. da Silva is currently working toward the Licenciado (B.Sc. equivalent) degree in telecommunications engineering and computer science at the Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon, Portugal.

She is interested in antenna theory and radio-frequency identification (RFID) applications.

Ms. Silva was the recipient of the first prize in the 2014 AP-S Student Design Contest together with three team colleagues for designing and building a RFID-based Smart Blood Stock System.



Jorge R. Costa (S'97–M'03–SM'09) was born in Lisbon, Portugal, in 1974. He was the recipient of the Licenciado and Ph.D. degrees in electrical and computer engineering from the Instituto Superior Técnico (IST), Technical University of Lisbon, Lisbon, Portugal, in 1997 and 2002, respectively.

He is currently a Researcher with the Instituto de Telecomunicações, Lisbon, Portugal. He is also an Associate Professor with the Departamento de Ciências e Tecnologias da Informação, Instituto Universitário de Lisboa (ISCTE-IUL). His present research interests include lenses, reconfigurable antennas, microelectromechanical system switches, ultrawideband, multiple-input–multiple-output, and radio-frequency identification antennas. He is the coauthor of four patent applications and more than 100 contributions to peer reviewed journals and international conference proceedings. More than 20 of these papers have appeared in IEEE Journals.

Prof. Costa is currently serving as an Associate Editor for the IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION and he was a Guest Editor of the Special Issue on "Antennas and Propagation at mm- and Sub mm-Waves," from the IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, April 2013.

Carlos A. Fernandes (S'86–M'89–SM'08) received the Licenciado, M.Sc., and Ph.D. degrees in electrical and computer engineering from the Instituto Superior Técnico (IST), Technical University of Lisbon, Lisbon, Portugal, in 1980, 1985, and 1990, respectively.

He joined IST in 1980, where he is presently a Full Professor with the Department of Electrical and Computer Engineering in the areas of microwaves, radio wave propagation, and antennas. He is a Senior Researcher with the Instituto de Telecomunicações and member of the Board of Directors. He has been the leader of antenna activities in National and European Projects as RACE 2067—MBS (Mobile Broadband System), ACTS AC230—SAMBA (System for Advanced Mobile Broadband Applications) and ESA/ESTEC—ILASH (Integrated Lens Antenna Shaping). He has coauthored a book, a book chapter, and more than 150 technical papers in peer reviewed international journals and conference proceedings, in the areas of antennas and radiowave propagation modeling. His current research interests include dielectric antennas for millimeter-wave applications, antennas and propagation modeling for personal communication systems, radio-frequency identification antennas, and artificial dielectrics and metamaterials.

He was a Guest Editor of the Special Issue on "Antennas and Propagation at mm- and Sub mm-Waves," from the IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, April 2013.

阳普医疗
IMPROVE
IMPROVE MEDICAL
IMPRO+
"他们说，最幸福的事情是看到信号满格。"
阳普医疗IMPROVACUTER®真空采血管系列，让您的实验室时刻"信号满格"！
阳普医疗IMPROVACUTER®真空采血管系列
一如既往的卓越.
ALWAYS EXELLENCE.

阳普医疗科技股份有限公司出版
仅供阳普医疗内部使用。

MKDAPC-B68:202206

医学拾萃

IMPROVE REVIEW

阳普医疗科技股份有限公司
IMPROVE MEDICAL INSTRUMENTS CO.,LTD

地址：珠海市横琴新区环岛东路3000号ICC大厦南塔23层
服务热线：4001-300030
电话：+86 20-3231-2666
传真：+86 20-3231-2667
网站：www.improve-medical.com
邮编： 510530

IMPROVE REVIEW 医学拾萃 （标本处理系统篇 Pre-Analytical System）

二〇二二年六月刊 June, 2022