浙江大学

本 科 生 毕 业 设 计
开题报告

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所在学院： 计算机科学与技术学院

一、题目： 专业教室桌面控制系统

二、指导教师对开题报告、外文翻译和中期报告的具体要求：

指导教师（签名）：

年　　月　　日

毕业设计开题报告、外文翻译和中期报告考核

导师对开题报告、外文翻译和中期报告评语及成绩评定：

成绩比例	开题报告 占 (20%)	外文翻译 占 (10%)	中期报告 占 (10%)
分值			

导师签字 ____________

年　月　日

答辩小组对开题报告、外文翻译和中期报告评语及成绩评定：

成绩比例	开题报告 占 (20%)	外文翻译 占 (10%)	中期报告 占 (10%)
分值			

开题报告答辩小组负责人（签名）____________

年　月　日

目　录

本科毕业设计开题报告

1 项目背景

专业课程不同于通识课程，往往需要配合实验学习一些特定的知识。这些课程就需要在专业教室中进行。在专业教室中，会提供一些诸如示波器之类的设备，用于学生进行实践操作。但由于资源的限制，设备的数量往往不足以让所有学生同时使用，通常只能按照课程分批次地进行使用。

但是，并不是所有学生都会按照课程的时间到专业教室进行学习。由于各种各样的原因，有些学生会在没有课程的时候来到专业教室，占用教室中的资源。当然，还有许许多多类似的情况导致了目前专业教室混乱的现状。

想象一下下面的情景：一个学生匆匆赶到教室准备上课，却发现已经没有空余的设备可以使用了，只能在一旁干看着；有的学生遇到这种情况则会去别的教室寻找空位，从而可能导致另外一个学生没有设备可用；有的学生下课后仍然不离开教室，继续占用本应属于别的学生的资源；有的学生人离开了，设备却仍然开启着；教师看着一台台损坏的设备，却无从知道该设备最近的使用情况……

这种混乱的现状是我们所要改变的，我们希望专业教室能够变得有序并且是易于管理的。我们期望中的专业教室应该是这样的：上课的学生可以顺利地到指定的位置上上课，设备在学生离开后会自动断开电源，教师能够随时知道当前教室的使用情况，并且能够查看历史记录……

为了实现这样一个有序的专业教室，我们需要一个专业教室桌面控制系统。

2 目标和任务

我们要实现一个专业教室桌面控制系统,它应该具备以下功能:

- 对于学生:
  - 有课的学生能够顺利地进入教室使用设备。
  - 学生能够知道自己上课的具体位置、时间段及其他相关信息。
  - 学生只能在指定的位置上使用设备。
  - 学生离开后,该位置的设备会自动断电并且可以重新分配给其他学生。
  - 没有课的学生在有空位置的情况下,也能够临时进行使用。
- 对于教师:
  - 能够开设一门课程,然后让课程的学生可以在指定时间段进入教室。
  - 可以查看教室的当前和历史使用记录。
  - 在特殊情况下,可以强行分配位置给某个学生使用。

3 可行性分析

首先,简单地分析一下整个系统的构成,从硬件和软件两个角度进行分析。

在硬件环境上,首先需要一个读卡器能够读取学生校园卡的具体信息。然后,这个读卡器应该是与服务器通过某种方式连接在一起的,可以是广域网、局域网或者其他更有效的方式。读卡器可以把读到的信息传给服务器处理。服务器处理完数据后,需要有一个与服务器相连的屏幕显示相应的返回信息。最后,在教室的每个桌面上还需要有一个读卡器,能够读取学生的信息再次进行验证,并且有一个控制电源通断的模块根据服务器返回的内容控制电源的通断。

在软件环境上,首先需要搭建一个服务器,能够根据学生信息判断该学生

是否可以使用教室，并给出相应的反馈信息。然后电源通断模块上需要有相应的程序控制电源通断，并且提供延时断电的机制。最后，还需要一个后台管理软件。支持教师导入课程信息，查看使用记录以及强行开放某个位置的使用等功能。

从上面软件和硬件的分析上来看，要实现这样一个专业教室控制系统，主要涉及以下几个方面的内容：

- 从校园卡获取信息
- 将信息显示到屏幕上
- 控制电源通断
- 相应的控制程序
- 网络线路的布置

我们将针对上述内容一一进行可行性分析。

首先是从校园卡获取信息，这点可以通过已经被广泛应用的 RFID 技术实现。RFID 技术，即射频识别技术，目前已广泛应用于我们的生活。比如学校寝室的门禁系统、高速公路的收费卡等。因此，只要阅读一下相关的资料，实现从校园卡获取学生的具体信息是可以实现的。

然后是将信息显示到屏幕上，可以考虑采用 LCD 屏幕。在从服务器获取到信息后，通过相应的程序显示即可，技术上并没有太大的困难。

控制电源通断可以通过一个现有的电源模块来实现，嵌入式程序可以根据具体信息计算出通断的结果，给予模块相应的信号，即可控制电源的通断。

整个系统有比较多的控制程序，最主要的是服务器的程序和后台管理软件的程序，这两者可以采用 java 进行编写，另外一些嵌入式程序可以考虑采用 C 编写。

最后是整个系统的网络布线。获取学生信息和显示信息的屏幕只需要放在一处，可以采用以太网直接与服务器相连。而教室内部的读卡器如果每一台都直接与服务器相连的话，布线会比较麻烦，因此可以考虑采用一个通信机，读

卡器与通信机通过 485 网络交流，而通信机与服务器通过以太网进行连接。这样整个系统的布线也会相对容易一些。

通过对整个系统的详细分析，从技术角度上来看，系统是可以实现的。

4　初步技术方案和关键技术考虑

4 .1　初步技术方案

在可行性分析中，我们已经大致讲解了系统的实现，这里再总结一下。

首先，整个系统的构成是这样的：每个专业教室都应该有一个门禁系统，门禁系统由一个读卡器、LCD 屏幕和门禁构成，系统直接和服务器通过以太网连接在一起。然后在专业教室里，每张桌子上都有一个桌面机系统，由一个读卡器和一个电源控制模块构成，用于控制每个位置的电源通断。桌面机不直接与服务器进行通信，而是通过一个布置在教室中的通信机进行中转。桌面机和通信机之间通过 485 网络进行通信，然后通信机与服务器通过局域网进行通信。

门禁系统的考虑使用 C 编写控制程序，系统在获取到读卡器读取到的信息后，调用服务器的接口验证该学生信息。然后将服务器返回的信息经过处理显示到 LCD 屏幕上，并且控制门禁打开或者保持关闭。

教室内的通信机与服务器直接相连，主要用于消息的中转。需要将来自桌面机的消息转发到服务器，将来自服务器的消息转发到指定的桌面机系统。

桌面机控制程序也考虑采用 C 程序进行编写，在读卡器第一次读到卡的信息时，通过通信机到服务器进行验证，验证通过后即可以让桌面通电。之后只要卡的信息不发生改变，则不再到服务器进行验证。当校园卡离开读卡器，则启动延时断电机制 (继续保持通电一段时间，然后断开电源并通知服务器)。当再次读取到卡的信息后，重新到服务器进行验证。如果验证通过，则取消延时断电机制。

服务器程序采用 java 编写。需要有以下接口：

- 根据学生信息返回是否可以使用教室，如果可以，给出座位号和时间段。如果不可以，给出相信的错误信息。
- 导入课程信息的接口。课程信息应该包括课程名称，课程时间，课程教室，学生信息等。
- 查询历史使用记录。可以通过接口参数查询指定位置的历史使用记录，也可以查询某个时间段某个教室的使用情况。
- 强行开放某个位置。可以人为分配某个位置给某个学生，以应对临时状况。
- 设置延时断电机制的延时长度。
- 位置回收的接口。调用接口提示服务器某位置上的学生已经离开，位置可以重新用于分配。

最后，还有一个后台管理的软件，主要给教师或者管理人员使用。同样考虑使用 java 进行编写，功能与服务器提供的接口吻合。主要提供导入课程信息，查询历史使用记录和强行开放某个位置的功能。

4 .2　关键技术考虑

整个系统涉及到的技术还是比较多的，下面对其中的几个关键技术进行简单的分析：

1. 位置分配机制

   首先，对有课程的学生按到达顺序依次分配座位。

   如果除去上课的学生外，位置仍有空余，则可以将剩余的座位分配给没有课程的学生使用。这样可以方便之前由于各种原因错过课程的学生进行补课。

2. 延时断电机制

   为了方便学生临时离开，系统设计了临时断电机制。利用这个延时，学生可以出去接个电话或者上一趟厕所，之后回来可以继续之前的实验。

但是,延时的时长却是个不好控制的变量。目前,这个时长暂时被定位 5 分钟,但实际使用效果仍是未知的。为了能达到更好的体验,服务器提供了一个修改延时时长的接口,并且可以在后台管理软件中提供可视化的修改界面。这样,管理人员就可以根据使用情况,随时做出变更。

3. 位置回收机制

首先,最正统的位置回收方式应该是由座位上的程序主动调用回收的接口,告诉服务器学生已经离开。然后服务器把该位置重新加入分配列表中。

假如每个学生上完课后都能够准时离开,那么第一种回收机制就够用了。但是,有些学生可能下课后仍旧没有离开教室。而考虑到之后又有新的课程的情况,为了避免同一门课程的学生因此被分隔或者分配不到座位,系统还需要有一种强制回收座位的机制。这种机制执行的时候,由服务器直接通知座位上的程序断电,重新进行通电验证。从而提醒已经下课的学生离开教室。

当然,如果没有课程的学生仍旧想继续呆在专业教室,那么他们可以尝试重新刷卡。由于位置分配机制中有考虑到他们,只要位置仍有剩余,他们还是可以从多余的位置中分到一个继续使用的。

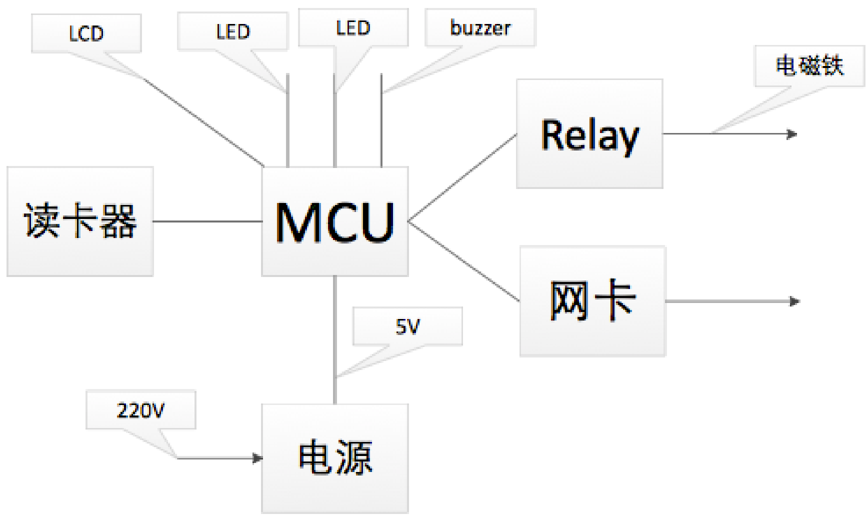
4. 设备详细关系图

图片简单说明:

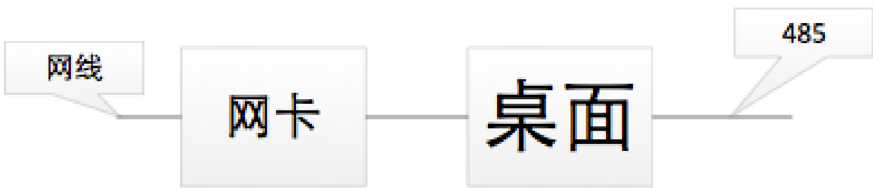
- MCU: 中央控制单元
- 485: 485 通信网络
- 读卡器: 射频识别模块,用于读取校园卡信息
- LCD: LCD 屏幕,用于显示文字信息
- Relay: 继电器,用于控制门禁和电源通断
- LED: 指示灯,分为红灯绿灯,用于表示系统状态

- buzzer: 蜂鸣器，用于提示系统状态

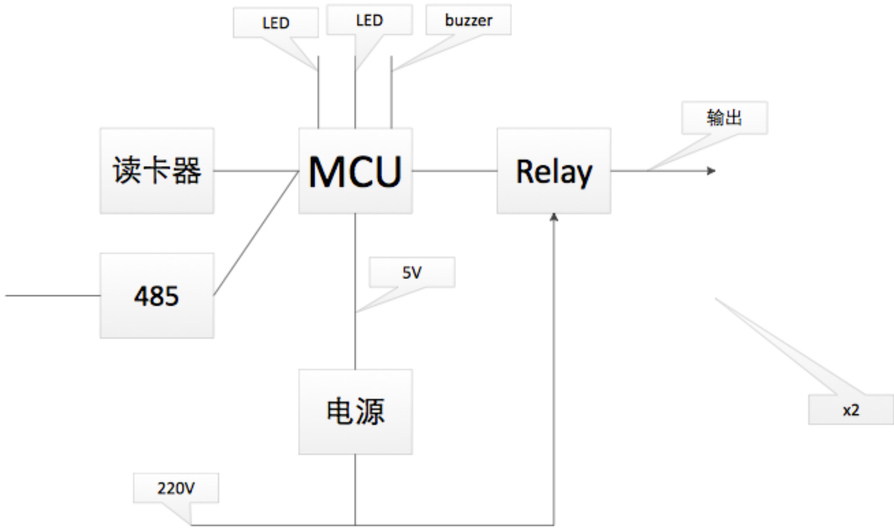
门禁机通过读卡器从校园卡读取到学生信息，然后从服务器获取到相应信息显示到 LCD 屏幕。其中，继电器用于打开门禁，红绿灯及蜂鸣器用于反馈学生的刷卡操作。



通信机仅用于 485 和以太网之间的通信，不做额外的处理，为了方便布线而设置。



桌面机通过读卡器获取学生的信息，与通信机通过 485 网络相连，然后有一个继电器用于控制电源的通断。另外，同样有红绿灯及蜂鸣器用于指示相应的状态。



5 预期工作结果

实现一个专业教室的桌面控制系统，具有以下功能：

- 一个门禁系统，学生在刷卡后，系统将服务器返回结果显示在一个 LCD 屏幕上，显示的信息包括姓名、课程、时间段、座位号等，也有可能是一段禁止进入的理由。同时，根据相应的情况，决定是否打开门禁。
- 一个桌面机系统，学生在到达指定座位后，把卡放在读卡器上，桌位的插座就会持续地供电。把卡从读卡器上拿走，桌面会继续供电一定时间，方便学生临时性离开教室。在延时时间内，座位会继续保留，学生可以随时回来。超过时间限制，座位会被重新分配。
- 一个教室内的通信装置，由于布线等问题，教室内每个桌面电源控制系统不直接和服务器通信，而是通过通信装置与服务器通信。通信装置负责中转消息。
- 一个服务端管理后台，提供开课、查询使用记录、强制分配座位使用权，调整延时断电时长等功能。

6 进度计划

2014/03/01 - 2014/03/14 了解课题背景，分析具体需求

2014/03/15 - 2014/03/21 查看课题相关文献、资料

2014/03/22 - 2014/03/27 完成开题报告

2014/03/28 - 2014/03/31 实现从校园卡获取学生信息

2014/04/01 - 2014/04/03 实现在 LCD 屏幕上显示对应的信息

2014/04/04 - 2014/04/07 实现程序控制电源通断

2014/04/08 - 2014/04/15 初步搭建服务器程序

2014/04/16 - 2014/04/23 实现座位分配系统

2014/04/24 - 2014/04/27 实现教室内的通信装置

2014/04/28 - 2014/05/01 完善桌面电源控制系统

2014/05/05 - 2014/05/08 初步实现管理后台

2014/05/09 - 2014/05/12 完善管理后台

2014/05/13 - 2014/05/16 实现程序整体功能

2014/05/16 - 2014/06/01 完成结题报告

本科毕业设计外文翻译

题目：通过快速成型对射频识别系统进行探索和评估

摘要：当前使用的射频识别 (RFID) 系统只包含了相当少的功能，然而未来的系统和人们生活中的应用却需要大量的通用功能，比如超大的通信距离，超快的数据传输速度，以及相当高的准确性等。为了达到这些更高的目标，现有的射频识别系统需要面临以下几个挑战：(1) 射频识别系统在各种频段下的兼容性，(2) 深入了解物理层系统参数对系统性能的影响，(3) 与射频识别相关的新颖无线技术的风险，(4) 处理越来越复杂的高性能射频识别系统。因此，设计者需要一个高度可配置，灵活，高性能的射频识别环境用来试验性地探索底层物理状况和评估新颖的射频识别技术及设计。这篇论文介绍了射频识别快速成型的概念，并且提供了一份关于系统模拟，论证和快速成型环境的调查报告。还给出了设置一个用于射频识别的快速成型系统的指南，并证明了它的实现。最后，给出了使用快速成型系统进行的几个典型的测试。

关键字：射频识别、测试、快速成型、实验、模拟

1. 背景说明

射频识别是一种快速出现的用以识别和跟踪物品的技术。相比较于其他识别技术，像磁条、条形码等，射频识别不需要任何可见的连接并且可以几乎同时地识别多个物品。它在识别和跟踪物品的应用领域是非常有前途的。甚至一部分这样的应用已经被实现了，比如文档的识别和跟踪（电子护照或者图书管理系统），过路费的收取，门禁系统，动物跟踪，生产流水线等。不过射频识别系统一般都是定制用于特定的工作场景的，通用的射频识别应用仍旧不被当前的射频识别设备所支持。这些应用包括了物流领域的那些应用，比如用于自动包裹跟踪服务，集装箱内物品的自动识别登记，对组装线上的产品的识

别，商店收银台对货物的自动识别，或者总的来说就是对整个供应链上的商品的跟踪。在这些应用中，射频技术可以大大提高物流效率。然而，现有的射频识别技术在可靠性、数据传输速度、超高频下的识别距离这些方面仍旧有所欠缺。在接下来的第 2 节中，我们介绍了射频技术普及所要面临的一些核心问题和挑战。通过射频识别系统模拟器，快速成型环境以及用现成组件搭建的实验装置能否解决这些挑战，我们将在第 3 节通过一份调查来讨论一下。第 4 节介绍了快速成型的概念以及它在快速系统评估方面的作用。第 5 节提供了一份快速成型环境下通用于数字基带和模拟前段的安装和实施方案，并且提供了我们的一个案例。第 6 节给出了在指定射频识别系统参数影响下系统的性能以及相互依赖关系。最后一节总结了一下这篇论文并且给出了一个关于未来研究的方向的观点。

2. 高性能射频识别技术所面临的挑战

2.1 对现有射频识别系统的兼容

一个通用的射频识别系统，可以分为识别器，标签和中间件。此外，我们还可以把系统分成有源、半有源和无源的系统。在无源射频识别系统中，标签可以从识别器发出的电磁场中获取到能量，从而用于发射标签上的数据。无源的射频识别系统消耗低，并且没有需要给电池充电的烦扰。在半有源和有源的系统中，识别器会通过后向散射或者负载调制获取标签发出去的数据。这些调制都是依靠吸收或者反射标签的能量来实现的。

由于使用的技术不同，不同的射频识别系统工作在不同的频率段：低频一般为 125kHz 或 134.2kHz，高频一般在 13.56MHz，无源标签通过一个感应耦合的元件与识别器配对在一起，然后通过负载调制的技术把数据传输给识别器。超高频系统工作在 860-960MHz，采用后向散射调制进行数据的交流。最后，射频识别现在已经被扩展到 2.4 和 5.8GHz。在这些系统工作的频段中，存在着许多不同的标准。

不同的射频识别技术，有源、半有源或者无源，加上不同的频率段和不同

的工作标准，从而产生了兼容性和互通性的问题。此外，区域无线电管理政策使得设计一个全球通用的系统变得更加复杂了。现今，射频识别设备往往是为一个特定的应用开发的，适配了一个特定的标准和频率。这让这些设备往往无法用于其他应用。解决这些兼容问题并设计一个适用于所有应用的设备是当前最重要的任务，并会推动未来的射频识别技术的发展。

2.2 系统参数的影响

然而现在的射频识别技术还不能支持这样一个通用的设备，特别是在原生物理层的性能上，仍旧落后于市场的需求。这样的一个通用系统会有以下典型目标：高可靠性，高数据吞吐量，大读出距离，在多标签环境下高效地通信，在不同环境下都能保持原有的性能和全部的功能，不受物品不同特性的影响等。为了提高原声物理层的性能，或者说提高射频识别技术的性能，我们需要更加详细地了解我们的设计目标与系统参数之间的关系。这些系统参数包括了硬件的配置，发射功率，调制模块和编码参数等。而且，我们需要知道设计目标之间的相互关系并作出一些权衡。在传输速度、读出距离、可靠性之间做出权衡是非常重要的。因此，我们需要设计一个灵活的测试环境，用来针对性地探索特定参数对系统的影响。这可以让我们从各个角度探索系统，或者在真实的场景中进行特定方向的测试。为了说明这个想法，我们在第 6 节提供了一份在给定的传输速度和发射功率下，对系统可靠性进行的一系列测试结果。

2.3 新技术的风险

一般来说，新推出的无线技术和一些概念，特别是射频识别技术，由于缺乏在现实场景下的安装和表现经验，很有可能会有许多不可预见的挑战。举个例子，可以考虑最近只在多天线接入的模型中被描述到的无线信道技术。对这类新技术基本物理过程了解的缺乏，导致了在射频识别中引入它们变得十分困难。因此，在试验配置的时候，有必要对这类新技术进行完整的评估和探索。在设计上取得越是大的突破，发现相应的概念或是设计错误后需要承担的代价也就越大。因此，在这些系统设计的时候就尽早进行探索可以极大地减少这

样的概念性错误。这点不仅适用于新算法的引用，同样适用于新硬件设备的设计。

2.4 处理不断增长的复杂性

为了实现未来射频识别设备的高性能需求，许多复杂的信号处理技术被提了出来。这些技术包括光束成形技术，多进多出技术，高阶调制方案，复杂的反碰撞算法，在识别器上的信道估计算法等。随着信号处理算法变得越来越复杂，实现方案自然也会随着变得越来越复杂。为了能够适应在原型实现上越来越严峻的挑战，无线系统的设计需要相应地变为快速成型。传统的设计方式需要花费大量时间并且没有提供在不同环境下探索整个新系统的可能。

2.5 需要实验测试配置

我们已经指出了通用射频识别设备的需求和优势。为了应对越来越复杂的高性能射频识别系统，比较各种各样的新式的设计，探索物理层的差异，并且设计出一种通用与所有设计的射频识别设备，研究者需要一个高度灵活可配置的测试环境。这样的一个实验平台，需要能够探索诸如二进通道这样的新提出的特性。还要能够实现在射频识别领域中加入多天线这样的新技术。

3. 关于射频识别测试环境的调查

4. 快速成型的概念

5. 双频射频识别快速成型平台的建立

6. 对射频识别系统参数的实验探究

7. 总结和对未来的展望

我们已经展示了未来应用会产生的那些具有挑战性的需求。那些应用需要高性能表现，比如高数据吞吐量，大读出距离，在多标签环境下的高读取率和高可靠性。为了达到这些需求，物理层和逻辑层都需要复杂的算法。这样的信号处理算法包括波束成形、多进多出射频识别系统、用于解决多标签应用中的碰撞的算法等。在逻辑层，复杂的协议对算法进行处理以用于防止碰撞或者估计标签群是当前研究的热点。此外，对于未来的射频识别应用来说，最重要

的是一种在识别器和标签上都支持多种频段的射频识别设备，从而实现一种设备适用于所有射频识别应用的美好愿景。

为了设计出这样一种通用并且高性能的射频识别系统，研究者和工程师需要一个高性能的测试和测量的环境。这个环境必须允许快速实现研究和设计出来的概念。此外，嵌入式系统设计者需要一个快速成型环境用于评估不同的实现方案。物理层和协议层的多个参数都会影响到整个系统的表现。为了再次提高射频识别技术的性能，我们有必要更详细地了解这些参数的依赖关系，同样也要对整个系统的参数和性能的关系有个整体的了解。

我们介绍了建立在我们实验室的双频快速成型环境的配置方法。尽管原型保证了一个逼真的测试环境，但可重现的测量结果告诉我们，过于简单的模型和模拟假设会轻易地把我们带到错误的结论上去。

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ORIGINAL ARTICLE

Evaluation and exploration of RFID systems by rapid prototyping

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Abstract Today's RFID systems exhibit relatively little functionality, while future systems and ubiquitous computing applications require an ample set of general purpose features, like wide communication ranges, high data rates, high reliability, and many more. In order to meet these high-performance goals, several challenges in state of the art RFID systems need to be managed: (1) the compatibility of RFID equipment, working according to different standards in various frequency domains, (2) the thorough understanding of the performance impact of physical layer system parameters, (3) the venture of novel wireless technologies in the context of RFID, and finally, (4) to deal with the increased complexity of high-performance RFID systems. Therefore, designers desire a highly configurable, flexible, and high-performance RFID environment to experimentally explore the underlying physical conditions and to evaluate novel RFID technologies and designs. This paper introduces the concept of rapid prototyping in RFID and provides a survey of system simulators, demonstrators, and rapid prototyping environments. A guideline for the setup for such a rapid prototyping system applicable for RFID is presented, and its implementation is demonstrated. Finally, some exemplary measurements carried out with this rapid prototyping system are presented.

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1 Introduction and motivation

These days, radio-frequency identification (RFID) is a very fast emerging technology for applications demanding identification or tracking of goods. In contrast to other identification technologies, such as the magnetic strip or the bar code, no line of sight connection is required to identify an item, and multiple goods can be inventoried almost simultaneously. Its potential for various applications in the field of identification or tracking of items is very promising [1, 2]. Several of such applications have already been realized [3], as for instance document tracking and identification (in electronic passports or automated library systems [4–6]), road tolling [7], access control applications, animal tracking or manufacturing line applications, just to name a few. While RFID deployments are often tailored to work in these specific scenarios, *generic* RFID applications are still not well supported by the available RFID equipment. These include applications in the field of logistics, as for instance automated parcel tracking services, automatic inventory of whole cargo containers filled with different goods, identification of products in an assembly line, automated identification of products of a customer at the cash desk in a shop, or in general tracking of goods throughout an entire supply chain. In these applications, logistic processes can be enormously facilitated and made more efficient by such a technology. However, the provided performance of current RFID technology lacks behind the demands on high reliability, high data rates, and large read-out ranges in the ultra high frequency (UHF) domain.

In the following Sect. 2, we identify some of the core problems and challenges of RFID to become ubiquitous in everyday's life. The potential to handle these challenges by RFID system simulators, rapid prototyping environments, and experimental setups by off-the-shelf components is discussed in a survey in Sect. 3. Section 4 introduces the concept of rapid prototyping and its strength in rapid system evaluation. Section 5 provides a setup and implementation guideline for both, digital baseband and analog frontends in rapid prototyping environments, and exemplarily shows our setup. Section 6 presents experimental results on the impact of selected RFID system parameters on the system performance and the mutual dependencies of these performance measures. The last section summarizes the paper and gives an outlook to future research directions.

2 Challenges of high-performance RFID technology

2.1 Compatibility of present-day RFID systems

In a basic RFID system, we distinguish between RFID readers, RFID tags, and the RFID middleware. Furthermore, we distinguish between active, semi-passive, and passive RFID systems. In passive RFID systems, the tags receive the energy needed for processing from an electromagnetic field, which is provided by the reader. Passive RFID systems have the advantage that the tags are low cost and that they do not need to be recharged if their battery is empty. In both, semi-passive and passive systems, data transmission from the tag to the reader is achieved by a backscatter or load modulation. These modulations rely on the principle of either absorbing or reflecting power at the RFID tags [8–11].

In addition to the different technologies in use, RFID systems are operated in various frequency bands: In the low-frequency (LF) domain at 125 kHz or 134.2 kHz and in the high-frequency (HF) domain at 13.56 MHz, passive tags are coupled with the reader via a dominantly magnetic field (inductive coupling) and transmit information to the reader by a load modulation technique. UHF systems operate in the band of 860–960 MHz, where the RFID tags apply backscatter modulation for communication. Finally, RFID is currently being extended to the bands at 2.4 and 5.8 GHz. In each of those many frequency bands, several different standards have emerged.

The different RFID technologies, whether active, semi-passive, and passive, together with the various frequency bands and the variety of RFID standards lead to compatibility and interoperability issues of today's RFID systems. Furthermore, regional radio regulation policies complicate the design of a system that is globally functional. Currently, RFID equipment is often developed to support one specific application well suited to a certain frequency domain following one particular standard. This makes the equipment often unsuitable for other RFID applications. The challenge of untangling these compatibility issues and designing a *one fits all* RFID equipment hence is of major interest and will drive future RFID technologies.

2.2 Influence of system parameters

Today's RFID technology, however, is not yet ready for such a general purpose RFID equipment and, especially the raw physical layer performance, lacks behind the market demands. Typical goals for such a general purpose system are high reliability, high data throughput, large read-out distance, efficient communication in multi-tag scenarios, full performance in various different environments, and full functionality, independent of the characteristics of the objects the tags are attached to [12–15]. In order to further push the raw physical layer performance or RFID technology forward, detailed understanding of the dependency of these design goals on various system parameters is essential [16]. Such system parameters include hardware configurations, transmit power, or modulation schemes and encoding parameters. Moreover, in-depth knowledge about the mutual impact of the design goals and the available trade-offs is fundamental. Important issues are, e.g., trade-offs between data rate, read-out distance, and reliability. Thus, we face the challenge to design a flexible test environment to experimentally explore the impact of certain system parameters. This allows to explore the system in all its aspects and to conduct tests and measurements in realistic scenarios of particular interest. In order to illustrate this idea, we provide measurement results on the impact of the selected data rate and the transmit power on the system reliability in Sect. 6.

2.3 The venture of novel technologies

Newly introduced wireless technologies and concepts in general, and RFID technology in particular, potentially hide unforeseen challenges due to a lack of experience on implementation and behavior in realistic scenarios. Consider, for example, the wireless channel in RFID systems, which only has recently been described by models for multiple antennas in [17–19]. The lack of detailed understanding with the underlying physical processes of such novel technologies hampers their introduction to RFID. Therefore, a thorough evaluation and a detailed exploration of these novel concepts are strongly desired in an experimental setup. With an advanced progression in the design, the penalty of discovering a wrong design decision or an error in the drafted concept dramatically increases [20].

Hence, an exploration of the envisioned system *early* in the design process strongly reduces the risk of such a conceptual error. This is true for the introduction of new algorithms (like beamforming [21] or anti-collision algorithms [22, 23]), as well as for new hardware designs.

2.4 Dealing with increased complexity

In order to meet the high demands on technological performance for future RFID equipment, complex signal processing techniques are envisioned. Such techniques include beamforming or multiple-input–multiple-output (MIMO), higher-order modulation schemes, complex anti-collision algorithms, or channel estimation algorithms at RFID readers. With the rising complexity of the signal processing algorithms, also the complexity of the implementation increases naturally. To keep up with this growing challenges in implementing prototypes, the design paradigms have changed toward rapid prototyping in wireless systems [24]. Conventional design methods are often time-consuming and do not offer the possibility to explore the new system in different configurations.

2.5 Required experimental test setups

The demands and advantages of a general purpose RFID equipment have been pointed out. In order to tackle the increasing complexity of high-performance RFID systems, to rate various system architectures and implementation variants of novel RFID designs, to fully explore the physical characteristics of RFID systems and their parameters, and to design one-fits-all RFID equipment, researchers aim for a highly flexible and configurable test environment. Such an experimental platform is, for example, required to explore the characteristics of the RFID dyadic channel, which has only recently been explored and modeled [25–28]. Another example is the establishment of multiple antenna technology in the field of RFID [18, 29, 30].

On the one hand, simulators offer the required flexibility to explore the system in various configurations; however, the validity of results strongly depends on realistic assumptions and modeling [31]. Test environments composed of off-the-shelf components allow for experimental setups and measurements on the other hand. However, access to desired parameter settings is often not available, such that the system can only be explored in a limited range of configurations. Additionally, the performance of the available equipment must be accepted. In between those two extremes, rapid prototyping environments provide a high degree of flexibility and allow to experimentally explore RFID systems in various aspects. Following the concept of rapid prototyping, high-level simulation code is consistently mapped to more detailed descriptions and is eventually also executed on a hardware platform [32–34]. The focus is rather on a rapid than on an optimized implementation of an algorithm in order to get access to experimental system evaluation at an early stage of the design process. Therefore, the targeted hardware platforms are in general composed of easily configurable components, such as digital signal processors (DSPs), field-programmable gate arrays (FPGAs), microcontrollers, and analog-to-digital converters (ADCs) as well as digital-to-analog converters (DACs). This allows for a system exploration in both, simulation and measurement. The drawback compared with simulation environments is the longer development time and the time to initially prepare the target hardware. However, once the hardware and the associated design flow are set up, the evaluation of all the aspects of the desired system innovation is fully supported. Another drawback comes with hardware restrictions, which may limit the full potential of experiments, for example, bandwidth restrictions or the accuracy of oscillators. Therefore, usually very high-performance hardware platforms are selected for rapid prototyping environments. Finally, the rapid configuration of the hardware platform out of high-level description clearly depends on the support of electronic design automation (EDA) software. While data-flow-oriented algorithms are well supported for such an automatic mapping, control flow-oriented code is poorly suited for such tools. A more detailed description of the rapid prototyping concept is provided in Sect. 4.

3 Survey on RFID test environments

In the following, a survey of state of the art setups for RFID system exploration is given. We compare system simulators, test environments by off-the-shelf components and rapid prototyping environments.

3.1 System simulators

Several powerful RFID simulation environments have been reported recently: Typical questions of research here include the evaluation of a single component of the RFID equipment, like RFID tags [35–37], readers [38], or antennas and analog parts [39, 40], physical and logical layer simulation and its impact on the performance of the RFID system in different frequency domains [36, 41–44]. Simulators further call attention to multi-tag and multi-reader environments [45–52]. The potential of generating misleading facts because of inaccurate modeling of underlying physical conditions (like the wireless channel or tag characteristics) has been discovered in [31]. Hence, in order to realize more realistic scenarios and to cross-verify the simulation assumptions, an approach of validating simulation results by commercially available RFID equipment or rapid prototyping environments is followed.

3.2 Test environments by off-the-shelf components

Researchers validate simulation results with measurement data generated by off-the-shelf RFID components [41, 53] or a controlled environment composed of prototypes, commercially available RFID components and measurement equipment [54]. Moreover, several groups reported on measurement results by off-the-shelf RFID equipment: Pentilla et al. [14] study the impact of fast-moving objects in RFID systems and Bertocco et al. [55] provide benchmarks on multi-tag and long-range system performance, while Nikitin et al. [56] show experimental tag localization results. This approach, however, has the disadvantage that the designers do not have full access to all the parameters of interest in their measurement equipment. Researchers cannot deploy novel signal processing concepts on the physical layer. Furthermore, only experiments with already existing equipment can be carried out, while novel concepts cannot be directly evaluated by measurements. The researcher must accept the provided performance of the available equipment.

3.3 Rapid prototyping environments for RFID

Following the concept of rapid prototyping, simulation code is consistently mapped to embedded devices. Its functionality is examined both in simulations and in a measurement environment. This approach is followed for instance in the study by [35, 37, 57, 58] for RFID tags or in [42, 59] for RFID readers. Furthermore, the approach of an automatic generation of hardware modules out of high-level descriptions, as it is common practice in chip design [60], is demonstrated on the example of encoding and decoding units in RFID [61, 62]. Untangling standard compatibility issues and automating the design flow for a multi-standard active RFID tag are addressed in the study by [63]. The setup of a generic measurement and test platform based on LabVIEW is shown in [64]. Compared with the previously described approach of employing commercially available RFID components, this approach has the advantage that designers can explore the novel system rapidly in experiments. Access to various configuration parameters is fully available.

Examples of automated design flows for the design of RFID tags have been shown by the Graz University of Technology (http://www.iti.tugraz.at) and by the RFID center of excellence at the University of Pittsburgh (http://www.engr.pitt.edu/SITE/rfid). The first group reports on a cosimulation framework of system level (Matlab and Simulink) and hardware description languages (HDL) for RFID tag architectures [37]. The Pittsburgh group shows a design flow for active RFID tags based on a microprocessor or custom hardware processor, out of a high-level C code description [58].

4 Rapid prototyping concept

This section first provides a detailed description of the rapid prototyping concept in general and the differentiation to other design concepts. Second, specifics for the application of rapid prototyping to RFID are identified.

We have seen the demand for flexible test and measurement environments to develop in the field of RFID. Often, prototypes are pre-studies for the final product. They are demonstrators to show the feasibility of such a product as well as for marketing purposes for future products. Such prototypes often include the entire functionality of the final product [65], and thus, in particular for highly complex systems, their development may be as challenging and time-consuming as the development of the final product itself. Especially, the advantage of an exploration of the system on an *early* design stage is not supported.

Hence, *rapid prototyping* seeks to accelerate the design process in several ways:

1. In order to realize a highly configurable setup, most of the signal processing tasks are accomplished in the digital domain on easily reconfigurable components rather than on custom printed circuit boards (PCBs) with analog components (e.g., filters, modulators and demodulators, encoders). Essentially, the entire baseband processing on both transmitter and receiver side is realized by digital components, which strongly facilitates a rapid (re-) configuration and allows for an exploration of implementation variants. An analog frontend is required for further tasks as frequency up- and down-conversion, power amplification, carrier suppression, signal conditioning, or antenna matching.
2. The concept of rapid prototyping aims to include only what is of specific interest instead of the entire functionality in the prototype. This could, for example, be certain signal processing algorithms that are newly introduced, like a synchronization and decoding concept [62]. A certain evaluation and measurement concept is developed, and thereafter, the required functionality for that specific measurement is designed.
3. Similarly, the focus is not pointed toward a very resource-efficient implementation, but rather toward a demonstration of the feasibility of the implementation

and the functionality. Certain structures of interest can also be optimized in terms of hardware resource consumption and certain implementation details. Different receiver architectures or the influence of fixed-point variables [66] can be investigated, if this is of specific interest; however, this is not the primary goal for the overall design. Furthermore, form factors and assembly issues are usually of secondary interest [65].

4. Therefore, easily configurable and rather over sized hardware platforms are utilized instead of custom PCBs equipped with optimized application-specific integrated circuits (ASICs) and analog components. Due to the use of powerful platforms, the designers do not need to bother about certain implementation details or especially resource-efficient implementations, but can concentrate on the implementation of the algorithms [67]. Typical platforms are composed of a set of DSPs, FPGAs, microcontrollers, and ADCs/DACs. These platforms are not designed for a specific application, but suitable for a wide range of different implementations.
5. Finally, the electronic design automation (EDA) industry offers several tools to automate and speed up the design process (e.g., Matlab/Simulink, Synopsys, System Generator for DSP, Altera Quartus and DSPBuilder, Coware, or LabVIEW, just to name a few). Following a rapid prototyping approach, algorithms are designed on a high level of abstraction (for instance in Matlab/Simulink or SystemC) and are subsequently modified to more detailed descriptions. The process of stepping from one level to the next more detailed level of description is highly automated [68]. This on the one hand speeds up the design process, while on the other hand ensures consistency between the various description layers.

With these design acceleration concepts, rapid prototyping meets the demands for an early exploration and evaluation of wireless systems also in experimental setups. Compared with other communication environments, differing characteristics of RFID systems are identified, which demand specific signal processing algorithms and thus influence the rapid prototyping of RFID systems:

1. The RFID reader needs to supply the passive RFID tag with power while it backscatters information to the reader. This provision of power supply by a carrier signal results in a strong leakage of this energy-supplying carrier into the receiver. This undesired leaking carrier can be up to a factor of 90 dB stronger than the desired receive signal [69, 70]. Thus, passive tags demand reader architectures for handling the inherent carrier leakage from the transmitter to the receiver. This is true for the development of both analog frontends and digital receiver structures.
2. Employing passive tags results in limited processing capabilities on tags and hence requires complex signal processing algorithms to be accomplished on RFID readers. The required interaction between the reader and the tag for computing a sophisticated transmission scheme is not available with low complexity tags. For example, such advanced transmission schemes require a feedback information for channel estimation from the tag to the reader, to realize multiple antenna transmit schemes at the reader. This feedback information, however, cannot be processed on the tags, such that signal processing algorithms for RFID need to be designed to meet with the imbalance of processing capabilities between readers and tags.
3. The wireless channel shows a fundamentally different structure to the typical cellular mobile wireless channel: due to the backscatter modulation of passive tags, the uplink communication channel coefficient consists of the reader-to-tag and tag-to-reader channel. Thus, the link quality is affected by the forward and the backward channel coefficient simultaneously. The tag realizes a pinhole in this dyadic channel from the transmitter to the receiver of the RFID reader [18, 27]. In contrast to other wireless systems, where a point-to-point connection from Device 1 to Device 2 may be considered, the sole consideration of an isolated tag-to-reader channel is not useful in the context of RFID.

5 Setup of a dual frequency RFID rapid prototyping platform

The following section provides a setup and implementation guideline for rapid prototyping environments and introduces the established setup in our laboratory. Due to the aforementioned imbalance of processing capabilities in RFID systems, we focus on rapid prototyping for RFID readers.

5.1 Design flow

To illustrate the rapid prototyping concept, we show the highly automated design flow for the RFID rapid prototyping system, which we have established in our laboratory. Our setup [59] is shown in Fig. 1. This design flow is decomposed into three layers, namely the link layer model, the physical layer model, and finally, the rapid prototype. The link layer and physical layer model serve as simulation layers for the protocol processing and the signal processing, respectively. The link layer model is coded in C++ and SystemC and supports several RFID standards [71–73]. The physical layer is modeled in Matlab/Simulink and serves as a refinement of the link layer model. In addition to the link layer model, it evaluates modulation and encoding settings, effects of channels, or specific details of the receiver architectures. Finally, on the rapid prototype, real-time measurements are conducted to verify both protocol and signal processing.

Two different frequency domains, namely the HF domain at 13.56 MHz and the UHF domain at 868 MHz are supported in measurements by two exchangeable radio-frequency (RF) frontends. A third frontend at 2.4 GHz is currently in preparation. The results of the two simulation layers, like the impact of different RFID system parameters (like protocol parameters), distinct receiver architectures, different environmental conditions, or hardware configurations (like single or separated receive and transmit antennas), is cross-checked, and assumptions for simulations are validated.

The various layers in the design flow do not only work as stand-alone simulations, but are strongly interconnected to each other. For example, generated sequences from the link layer model can serve as an input to the transmitter in the physical layer model, and samples of tag sequences that are captured on the FPGA of the prototype during real-time measurements can serve as a simulation input for the receiver on the physical layer model.

The automation of the design flow is achieved by the following process: The code of the RFID reader on the link layer model is directly embedded on the DSP on the rapid prototype, and the code from the physical layer model is automatically converted to VHDL and embedded on the FPGA of the board, by Simulink to VHDL conversion tools. This conversion is either provided by the HDLCoder toolbox of Matlab or the System Generator of Xilinx. These tools are well suited for data-flow oriented blocks (like filters), but unfortunately do not well support designs with a strong control-oriented part (like finite state machines). Such blocks are coded in traditional hand-written VHDL code. The automatically generated blocks are then embedded in this hand-written VHDL framework. This consistent and automated evaluation process ensures a rapid configuration of the prototype.

With this approach, various signal processing architectures have been rated to each other, e.g., receivers using envelope demodulators and I/Q demodulators with different signal detection schemes, or different synchronization units [42, 62]. Measurement results on exploring the performance trade-offs in RFID systems are shown in Sect. 6.

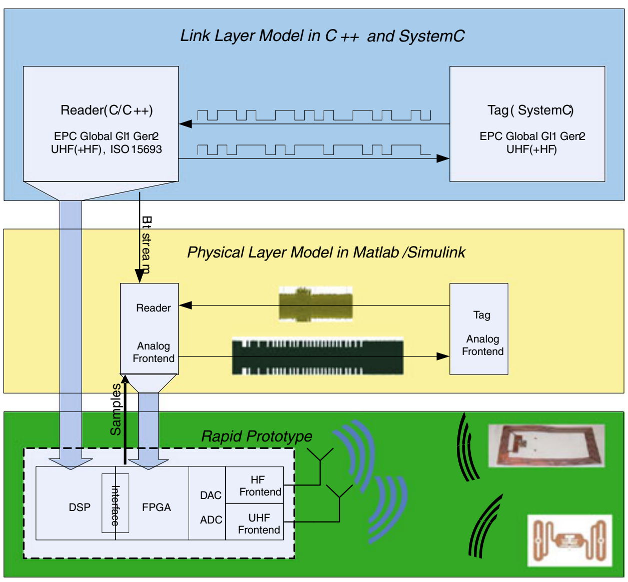

Fig. 1 Design flow of our RFID prototyping system [59]

5.2 Digital baseband

In the following, we present the realization of the digital part of the reader. The digital baseband section has been designed to be highly modular and easily parameterizable. A modular design ensures the easy exchange of certain blocks, as for example, modulators, demodulators or filters and thereby rating various architectures and algorithms. In order to explore the influence of certain system parameters, it is necessary to provide access from an application to change these parameters. In microcontrollers and DSPs, these parameters are reflected by variables, while in FPGAs, these parameters are stored in registers that are accessible from the controlling software.

Our digital baseband processing part consists of the following modules (also see Fig. 2):

– Protocol processing naturally needs to be accomplished on digital components (i.e., DSPs as in our realization or microcontrollers). In order to support a wide range of RFID applications and to tackle compatibility issues, our rapid prototyping system supports multiple protocols in the HF and UHF frequency domain.

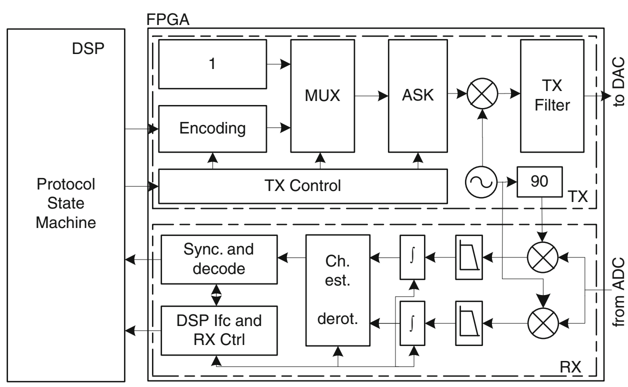

Fig. 2 Digital architecture for RFID reader prototyping

- Transmit signal generation: For the realization of a flexible setup, we generate the transmit signal in the digital domain on the FPGA. All parameters of interest affecting the shape of the transmit signal are accessible via registers, for instance, data rate, encoding, modulation, and filter parameters.
- Modulation: Amplitude shift keying (ASK) with adjustable modulation depth is supported in the transmitter.
- Encoding and decoding: Several encoding types are standardized, including Pulse Interval Encoding and one-out-of-four encoding in the downlink, and FM0, various Miller and Manchester subcarrier encodings in the uplink communication. Major interest is on rating various decoding algorithms on subcarrier or FM0 encodings [43, 74]. We have realized a correlator-based structure that enables maximum likelihood sequence decoding [62].
- Up- and down-conversion: Depending if the digital to analog interface is realized in baseband or at an intermediate frequency, up- and down-converters are required. An interface at an intermediate frequency has the advantage of realizing I/Q demodulation in the digital domain just requiring one ADC for sampling the receive signal, and decreasing the distortion of I/Q imbalance, with the drawback of a higher required sampling rate.
- Filtering: Digital filters with given parameters have been realized rapidly with the assistance of high-level filter design tools (filter and design analysis toolbox of Matlab). Additionally, matched filters for the rectangular-shaped uplink modulation signal are designed as moving average filters.
- Signal detection: One of the biggest challenges in RFID reader receivers is the detection of the receive signals, due to the following facts: First, the receive signal is strongly impaired by a leaking carrier signal, due to the required energy supply of passive tags. Second, the receive signal has a high dynamic range, depending on the reader to tag distance, the multipath fading as well as on the backscatter efficiency of the tag. Eventually, noise can severely degrade the detection performance, which is especially an issue in industrial environments. Therefore, the tag modulation signal can be located basically anywhere in the I/Q plane of the reader receiver, demanding a leakage filter and a channel estimation algorithm for proper signal detection [75].
- Synchronization: Finally, synchronization is a major issue in wireless communications in general, and, due to the wide tolerances in the backscatter link frequency (BLF, proportional to backscatter symbol rate [72]), in particular in RFID. We have evaluated different structures, utilizing the properties of the encoding formats and correlator structures [43, 62, 76]; our results are presented in the study by [77].

5.3 Analog frontends

This section discusses the requirements and design strategies of analog frontends for RFID systems. In general, the analog frontend often is the bottleneck during the implementation of rapid prototyping environments. Such frontends can be off-the-shelf frontends or ordered developments or simply self-built. In the following, we discuss the pros and cons of these:

- The simplest and fastest way to acquire such a frontend seems to buy an off-the-shelf frontend. Unfortunately, such devices will hardly be available years before a system like RFID or a technology like MIMO are established on the market. Additionally, such analog radios show low flexibility. Alternatively, a frontend can be ordered by a manufacturer especially designed for the actual demands. This is typically a very cost-intensive way for the small number of analog frontends usually required for a rapid prototyping environment. Furthermore, each adaptation to the frontend implemented by a manufacturer will cause additional costs. Finally, commercially available products can be adopted, like the frontend of an off-the-shelf reader can be used. This approach, however, requires detailed documentation about the PCBs, which is usually not available. A further drawback is that frontends are often integrated in a system-on-chip solution, making a realization of this approach impossible. Moreover, the achievable quality of this solution for research and design purposes of new technologies is questionable.
- The second possibility is to self-build the required analog frontend. In this case, different realizations are possible:

    1. One design strategy is to employ single chip solutions. The drawback of this approach is that highly integrated consumer radio-frequency front-end chips are designed to just meet the minimum requirements of a specific final consumer product. For research purposes, often a significantly better performance is required. Additionally, such chips are not available for upcoming or future standards. Especially for RFID reader chips as from Impinj, WJ Communications or austriamicrosystems, the analog frontends are directly combined with the digital baseband and no modifications are possible.
    2. An implementation with only discrete components like transistors and diodes requires a very high radio-frequency design effort and causes

development delay. Additionally, the overall circuit design will be of very high complexity.

3. Therefore, a radio-frequency frontend of a rapid prototyping environment should be developed with available state-of-the-art components with lower integration level (e.g., mixers, amplifiers, filters) but with much better performance than the single chip solutions. Also the radio-frequency design effort is then significantly lower compared with an implementation with discrete components [78]. The challenge is to implement and possibly to adapt later on, a high-performance radio-frequency frontend supporting future standards with todays technology in a rapid way. Nevertheless, the availability of components, especially of frequency selective parts, is crucial in the design process of a prototype since these systems usually are designed years before a standard is defined or first products are launched.

The architecture of the self-built rapid prototype frontend has to ensure maximum flexibility and best performance at a short development period. Clearly, a trade-off between flexibility, performance, and development time has to be found. In contrast to optimized frontends for communication systems, the rapid prototyping approach requires three main functions, namely frequency conversion, amplification, and filtering. To realize such a frontend, two main architectures (and a lot of varieties) are possible, the direct conversion and the heterodyne approach [79, 80]. For UHF RFID reader frontends, different architectures, in most cases for integrated circuits, have been reported for example in the study by [81–85].

Especially in passive and semi-passive RFID systems, the isolation between transmitter and receiver is a key issue for the reader frontend. Best isolation is achieved by applying either a circulator or directional coupler together with a single reader antenna (monostatic setup) or by making use of distinct, spatially well-separated transmit and receive antennas (bistatic setup). Several approaches for increasing the isolation of the transmitter and the receiver are proposed in [69, 81, 86–88].

Figure 3 illustrates our frontend concept for an RFID reader in the UHF frequency domain. Both transmitter and receiver are based on a low intermediate frequency (IF) to RF concept combined with a two-stage frequency conversion. Therefore, two local oscillator signals are required, which can be provided by standard laboratory signal generators. For the improvement of transmitter–receiver isolation an additional module, the carrier compensation unit (CCU) is added for canceling the self-interference or direct coupling at the receiver [69]. A microcontroller unit is part of the system concept for monitoring and control purposes

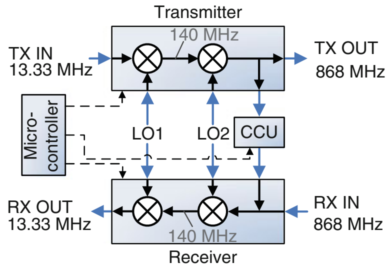

Fig. 3 Simplified block diagram of our established UHF reader rapid prototyping frontend

as well as for possible communication with the rapid prototype for further applications. For operation in rather static scenarios with little environmental changes, the microcontroller is not required as the various multipath components of the carrier leakage do not change significantly. In that case, it is sufficient to calibrate the CCU once for proper isolation. The UHF frontend can be directly interlinked with the digital baseband board at an intermediate carrier frequency that is well supported by the ADC sampling frequency (13.33 MHz in our setup). As stated above, the I/Q down-conversion to the baseband is finally achieved in the digital domain.

The frontend performs as a linear transponder and is therefore not limited to the modulation schemes, which are presently standardized for RFID. The frontend can be used in a shared transmit and receive antenna scenario as well as in a separate transmit and receive antennas scenario. In the single antenna RFID reader scenario, a circulator or a directional coupler can be employed to provide decoupling between transmitter and receiver. The CCU is designed for a further improvement of transmitter–receiver isolation in both shared antenna or separate antennas, configurations.

6 Experimental exploration of RFID system parameters

To illustrate the concept of rapid prototyping in the context of RFID, we show its strength in rapid system exploration. An exemplary measurement in our laboratory illustrates how simplistic modeling in simulations can lead to wrong results.

As discussed previously, thorough understanding of influencing parameters affecting performance goals (such as high reliability or high data rates), as well as the available trade-offs, is essential in order to further improve RFID technology. An exemplary question of interest is the influence of transmit power (P_{TX}) and backscatter link frequency (BLF, proportional to data rate) on read-out reliability, reflected by the received energy per bit to noise power spectral density ratio E_b/N_0 of the RFID reader on the one hand and by the errors in the communication on the other hand. The receive E_b/N_0 is expected to follow the form:

$$E_b/N_0 = c\frac{P_{TX}}{\mathrm{BLF}}\frac{1}{N_0}. \tag{1}$$

It is proportional to P_{TX} and inverse proportional to BLF, as with an increasing symbol period (proportional to 1/BLF) the time for accumulation of energy for one bit increases, assuming a constant receive power in backscatter communication systems ($E_b = P_{RX}/\mathrm{BLF}$, with P_{RX} denoting the receive signal power). The proportionality constant c in (1) includes all losses of the system, such as the channel attenuation. The selection of the parameters BLF and P_{TX} just serves as an example. In principle, the influence of all parameters of interest can be evaluated. For the measurements, the following setup as shown in Fig. 4 was applied [89].

Throughout the measurement, the same single tag was employed [90]. Hence, the results are typical but it is expected that a set of tags leads to slight variations in measurements. The digital receiver calculates an estimate of the receive E_b/N_0 and computes the packet error ratio (PER) of the receive sequences, which is the ratio of successful read-outs to total read-out trials. The tag was periodically interrogated with the same sequence for 10^4 times for each measurement point, before the input parameters (transmit power P_{TX} and backscatter link frequency BLF) are updated. Figure 5 depicts the applied interrogation sequence. It requests the unique identifier (electronic product code (EPC)) from Class 1 Generation 2 UHF RFID tags [72] after a reset period. A packet error is counted if any error occurred during the read-out of the EPC code. This communication includes the two packets transmitted from the reader to the tag (22 and 16 bits) as well as the reception of the two replies of the tag (16 and 128 bits), as indicated in Fig. 5. Note that this reflects the raw physical layer performance, as no retransmissions are executed if the cyclic redundancy check (CRC) of the EPC code fails. The evaluation result is a compound of the performance of the tag and the reader, meaning that the

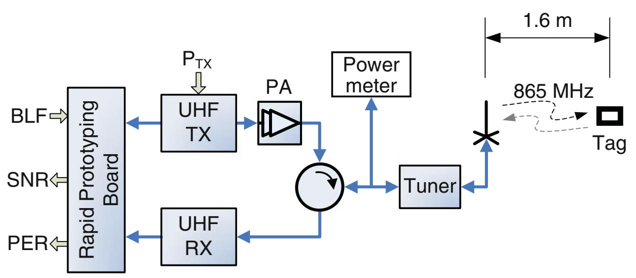

Fig. 4 Measurement setup for testing influence of certain parameters on the overall performance

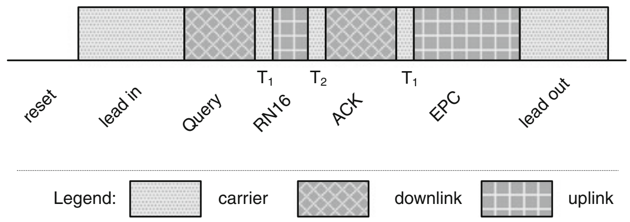

Fig. 5 Interrogation sequence in measurements according to [72]

components are not verified individually, but the overall *system* behavior.

6.1 Results

Figures 6 and 7 exhibit the dependency of E_b/N_0 and the PER on the backscatter link frequency and the transmit power as a parameter. The received E_b decays with rising BLF as expected, due to the following reasons (Fig. 6): With increasing data rates, the energy per bit naturally decreases, as due to the shorter bit duration less energy per bit is received. Finally, higher data rates also lead to higher tolerances in the backscatter link frequency according to [72], complicating the accumulation of energy per bit and the synchronization in the digital receiver.

Due to the E_b/N_0 decrease, the PER consequently rises with increasing BLF (Fig. 7). A saturation of the PER at around 10^{-3} is observed. Taking into account that a correct EPC code read-out includes the correct reception of 16 + 128 bits at the RFID reader and the expected functionality at the tag, this saturation is reasonable.

The various curves in the plots correspond to the different transmit power levels. It is observed that, at small transmit power levels the tag does only establish communication at low data rates. The reason for that behavior is the higher-energy consumption of the tag at higher data

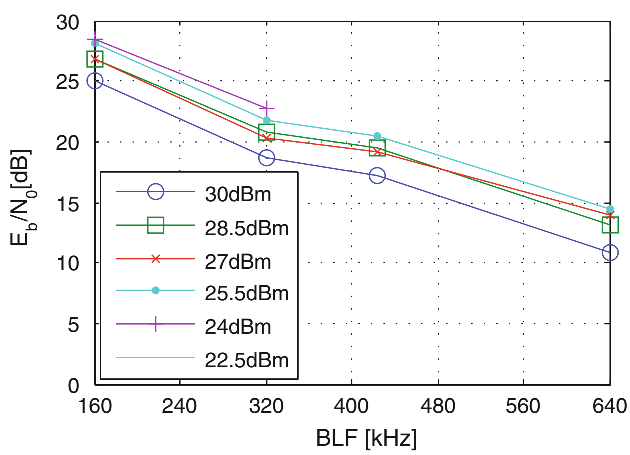

Fig. 6 Dependency of E_b/N_0 at the receiver on backscatter link frequency and transmit power

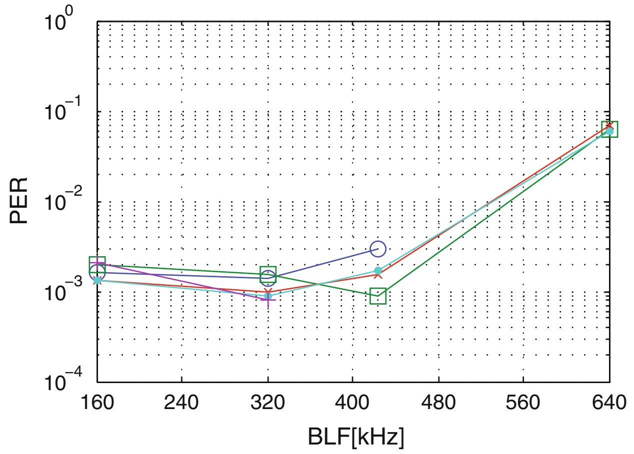

Fig. 7 Dependency of packet error ratio on backscatter link frequency and transmit power

rates, due to higher switching frequencies. Observing the receive signals of the reader on an oscilloscope indicates such an explanation, as the tag does not receive sufficient power to backscatter its entire response sequence. The response is only transmitted in some fraction, showing the tag is running out of energy and the communication is aborted. Additionally, it is observed that with rising transmit power neither the E_b/N_0 nor the PER can be increased. At a certain point, at which the tag receives sufficient energy for processing, the communication works with hardly any error. Additionally provided energy does not lead to an increase in receive E_b/N_0 at the reader receiver anymore. That behavior results from the following: at a certain level of provided energy, the tag cannot store any additional energy in its capacitors and need to drain it off, even if it is in the absorb state. Hence, with an increase in the provided energy above the saturation of the tag, the modulation efficiency of the tag is decreased (a similar result has also been shown in [91]). Additionally, with higher transmit power, the phase noise of the transmitted carrier of the RFID reader increases. Due to the leakage into the receiver, an increase in receive noise power is observed.

The measurement results show that the expected model of $E_b/N_0(\mathrm{BLF}, P_{\mathrm{TX}})$ as described in (1) does not fit well with the actual behavior. Thus, a more realistic model is proposed:

$$E_b/N_0 = c\frac{P_{\mathrm{TX}}^{-\alpha}}{\mathrm{BLF}^{\beta}}. \tag{2}$$

By fitting the measurement data of Fig. 6, the two coefficients α and β are determined as $\alpha = 0.51$ and $\beta = 2.12$. We applied the least squares method of the Matlab curve-fitting toolbox to obtain three-dimensional fitting, resulting in a root mean square error (RMSE) of 0.86 dB.

7 Summary and future research directions

We have shown the challenging demands originating from potential applications for today's and future RFID systems. These applications call for high-performance goals, such as high data throughput, large read-out distances, high access rates in a multi-tag environment and high reliability. In order to meet these demands, sophisticated algorithms on both the physical and the logical layer are required. Such signal processing algorithms for example include beamforming and MIMO RFID systems or algorithms for collision resolution in a multi-tag application. On the logical layer, complex protocol processing algorithms to handle anti-collision or estimation of the tag population are currently hot research topics. Furthermore, RFID equipment supporting several frequency domains on both readers and tags [92, 93], realizing that the vision of a one-fits-all RFID solution is of major importance for future RFID applications.

In order to design such a general purpose and high-performance RFID system, researchers and engineers need a high-performance test and measurement environment. Such an environment must permit a rapid realization of research and design concepts. Furthermore, embedded systems designers desire a rapid prototyping environment in order to rate several implementation variants. Several different parameters on both the physical and protocol layers affect the overall system behavior. For a further increase in the performance of RFID technology, detailed understanding of these dependencies is essential, as well as a thorough exploration of the interconnection of system parameters with design goals.

We introduce the setup of a dual frequency rapid prototyping environment, which we established in our laboratory. Exemplary measurement results reveal that simplistic modeling and simulation assumptions can easily lead to erroneous conclusions, while a prototype guarantees realistic test environments.

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References

1. Michahelles F, Thiesse F, Schmidt A, Williams JR (2007) Pervasive RFID and near field communication technology. IEEE Pervasive Comput 6(3):94–96
2. Hodges S, McFarlane D (2005) Radio frequency identification: technology, applications and impact. Auto-ID Labs White Paper Series 1

3. Roberts CM (2006) Radio frequency identification (RFID). Comput Security 25(1):18–26
4. Satpathy L, Mathew AJ (2006) RFID assistance system for faster book search in public libraries. In: Proceedings of the CHI '06 extended abstracts on human factors in computing systems, Montreal, pp 1289–1294
5. Molnar D, Wagner D (2004) Privacy and security in library RFID: issues, practices and architectures. In: Proceedings of the 11th ACM conference on computer and communications security, Washington, DC, pp 210–219
6. Gormish M (2005) Interaction between paper and electronic documents. In: Proceedings of DocEng '05: ACM symposium on document engineering, Bristol
7. Blythe P (1999) RFID for road tolling, road-use pricing and vehicle access control. IEE Colloquium on RFID Technology (Ref. No. 1999/123)
8. Finkenzeller K (2004) RFID handbook, 2nd edn. Wiley, New York. ISBN 0-470-84402-7
9. Rao KVS (1999) An overview of backscattered radio frequency identification system (RFID). In: Proceedings of the microwave conference, 1999 Asia Pacific, vol 3, pp 746–749
10. Stockman H (1948) Communication by means of reflected power. Proc IRE 36(10):1196–1204
11. Nikitin PV, Rao KVS, Martinez RD (2007) Differential RCS of RFID tag. Electron Lett 43(8):431–432
12. Floerkemeier C, Lampe M (2004) Issues with RFID usage in ubiquitous computing applications. In: Lecture notes in computer science, pervasive computing, volume 3001/2004, pp 188–193. Springer, Berlin. ISBN: 978-3-540-21835-7
13. Nikitin PV, Rao KVS (Jul. 2006) Performance limitations of passive UHF RFID systems. In: Proceedings of the IEEE antennas and propagation society international symposium, pp 1011–1014
14. Penttila K, Sydanheimo L, Kivikoski M (Apr. 2004) Performance development of a high-speed automatic object identification using passive RFID technology. In: Proceedings of the IEEE international conference on robotics and automation, vol 5, pp 4864–4868
15. Mohammed N, Sivakumar M, Deavours DD (2009) An RFID tag capable of free-space and on-metal operation. In: Proceedings of the IEEE radio and wireless symposium, San Diego
16. Nikitin PV, Rao KVS (2009) Effect of gen2 protocol parameters on RFID tag performance. In: Proceedings of the IEEE international conference on RFID
17. Griffin JD, Durgin GD (2007) Link envelope correlation in the backscatter channel. IEEE Commun Lett 11(9):735–737
18. Griffin JD, Durgin GD (2008) Gains for RF tags using multiple antennas. IEEE Trans Antennas Propag 56(2):563–570
19. Kim DY, Jo HS, Yoon H, Mun C, Jang BJ, Yook JG (2010) Reverse-link interrogation range of a UHF MIMO-RFID system in nakagami- m fading channels. IEEE Trans Ind Electron 57(4):1468–1477
20. Janka RS (2002) Specification and design methodology for real-time embedded systems. Kluwer Academic Publishers, Dordrecht
21. Angerer C, Langwieser R, Rupp M (Sept. 2010) Direction of arrival estimation by phased arrays in RFID. In: Proceedings of the third international EURASIP workshop on RFID technology, Spain
22. Bueno Delgado MV, Angerer C, Vales Alonso J, Rupp M (2010) Estimation of the tag population with physical layer collision recovery. In: Proceedings of the third international EURASIP workshop on RFID technology, Spain
23. Angerer C, Langwieser R, Rupp M (2010) RFID reader receivers for physical layer collision recovery. IEEE Trans Commun 58(12):3526–3537
24. Rupp M, Mehlführer C, Caban S, Langwieser R, Mayer LW, Scholtz AL (2006) Testbeds and rapid prototyping in wireless system design. EURASIP Newsl 17(3):32–50
25. Kim D, Ingram MA, Smith WW (2003) Measurements of small-scale fading and path loss for long range RF tags. IEEE Trans Antennas Propag 51(8):1740–1749
26. Lázaro A, Girbau D, Salinas D (2009) Radio link budgets for UHF RFID on multipath environments. IEEE Trans Antennas Propag 57(4):1241–1251
27. Griffin JD, Durgin GD (Apr. 2009) Multipath fading measurements for multi-antenna backscatter RFID at 5.8 GHz. In: Proceedings of the 2009 IEEE international conference on RFID, pp 322 –329
28. Mayer LW, Wrulich M, Caban S (2006) Measurement and channel modeling for short range indoor UHF applications. In: Proceedings of European conference on antennas and propagation (EuCAP), Nice
29. Nikitin PV, Rao KVS (2007) Performance of RFID tags with multiple RF ports. In: Proceedings of the IEEE antennas and propagation society international symposium, pp 5459–5462
30. Angerer C, Langwieser R, Maier G, Rupp M (2009) Maximal ratio combining receivers for dual antenna RFID readers. In: Proceedings of the IEEE MTT-S international microwave workshop series on wireless sensing, local positioning and RFID, Cavtat
31. Kin SL, Mun NL, Cole PH (March 2006) Operational considerations in simulation and deployment of RFID systems. In: Proceedings of the 17th international Zurich symposium on electromagnetic compatibility, Singapore, pp 521–524
32. Belanovic P, Knerr B, Holzer M, Sauzon G, Rupp M (2005) A consistent design methodology for wireless embedded systems. EURASIP J Appl Signal Process 2005(16):2598–2612
33. Belanovic P, Holzer M, Micusik D, Rupp M (2003) Design methodology of signal processing algorithms in wireless systems. In: Proceedings of the international conference on computer, communication and control technologies, pp 288–291
34. Holzer M, Knerr B, Belanović P, Rupp M (2006) Efficient design methods for embedded communication systems. EURASIP J Embed Syst 2006(1):21–38
35. Derbek V, Steger C, Weiß R, Wischounig D, Preishuber-Pfluegl J, Pistauer M (2007) Simulation platform for UHF RFID. In: Proceedings of the design, automation and test in Europe—conference and exhibition, Nice
36. Derbek V, Steger C, Kajtazovic S, Preishuber-Pfluegl J, Pistauer M (2005) Behavioral model of UHF RFID tag for system and application level simulation. In: Proceedings of the IEEE international behavioral modeling and simulation workshop, pp 60–63
37. Janek A, Steger C, Weiss R, Preishuber-Pfluegl J, Pistauer M (2008) Functional verification of future higher class UHF RFID tag architectures based on cosimulation. In: Proceedings of the IEEE international conference on RFID, Las Vegas, pp 336–343
38. Mayordomo I, Roc Berenguer, Valderas D, de No J, Guruceaga I, Gutierrez I (2007) A passive RFID system design and analysis focused on reader performance. In: Proceedings of the conference on design of circuits and integrated systems, DCIS 2007
39. Beroulle V, Khouri R, Vuong T, Tedjini S (2003) Behavioral modeling and simulation of antennas: radio-frequency identification case study. In: Proceedings of the international workshop on behavioral modeling and simulation, pp 102–106
40. Grosinger J, Mayer LW, Mecklenbräuker C, Scholtz AL (2009) Determining the dielectric properties of a car tire for an advanced tire monitoring system. In: Proceedings of the IEEE vehicular technology conference, Anchorage
41. Floerkemeier C, Pappu R (2008) Evaluation of RFIDSim—a physical and logical layer RFID simulation engine. In: Proceedings of the IEEE international conference on RFID, Las Vegas
42. Angerer C, Holzer M, Knerr B, Rupp M (2008) A flexible dual frequency testbed for RFID. In: Proceedings of the 4th international conference on testbeds and research infrastructures for the development of networks & communities, Innsbruck

43. Mutti C, Wittneben A (Sept. 2007) Robust signal detection in passives RFID systems. In: Proceedings of the first international EURASIP workshop on RFID technology, Vienna, pp 39–42
44. Han Y, Lin Q, Min H (2006) System modelling and simulation of RFID. AutoID Labs White paper. http://www.autoidlabs.org
45. Engels DW, Sarma SE (2002) The reader collision problem. In: Proceedings of the IEEE international conference on systems, man and cybernetics, vol 3
46. Vogt H (Oct. 2002) Multiple object identification with passive RFID tags. In: Proceedings of the IEEE international conference on systems, man and cybernetics, vol 3
47. Knerr B, Holzer M, Angerer C, Rupp M (June 2008) Slot-by-slot maximum likelihood estimation of tag populations in framed slotted aloha protocols. In: Proceedings of the international symposium on performance evaluation of computer and telecommunication systems, Edinburgh, pp 303–308
48. Floerkemeier C (2006) Transmission control scheme for fast RFID object identification. In: Proceedings of the pervasive computing and communications workshops, Pisa
49. Knerr B, Holzer M, Angerer C, Rupp M (2010) Slot-wise maximum likelihood estimation of the tag population size in FSA protocols. IEEE Trans Commun 58(2):578–585
50. Kin SL, Mun nL, Grasso AR, Cole PH (Jan. 2006) Synchronization of RFID readers for dense RFID reader environments. In: Proceedings of the international symposium on applications and the internet workshops, Phoenix
51. Bueno-Delgado MV, Vales-Alonso J, Gonzalez-Castano FJ (2009) Analysis of DFSA anti-collision protocols in passive RFID environments. In: Proceedings of the 35th annual conference of the IEEE industial electronics society (IECON), Porto
52. Bueno-Delgado MV, Vales-Alonso J, Angerer C, Rupp M (2010) A comparative study of RFID schedulers in dense reader environments. In: Proceedings of the IEEE international conference on industrial technologies, Vina del Mar
53. Egea-Lopez E, Bueno-Delgado MV, Vales-Alonso J, Garcia-Haro J, Martinez-Sala AS, Costas-Rodriguez S, Gil-Castineira F, Lopez-Bravo C, Gonzalez-Castano FJ (2007) On the implementation of a multi-reader radio frequency identification (RFID) architecture. In: Proceedings of the IEEE international symposium on industrial electronics, pp 2562–2566
54. Hawrylak PJ, Ogirala A, Cain JT, Mickle MH (2008) Automated test system for ISO 18000-7—active RFID. In: Proceedings of the IEEE international conference on RFID, Las Vegas, pp 9–18
55. Bertocco M, Dalla Chiara A, Gamba G, Sona A (2009) Experimental analysis of UHF RFID impairments and performance. In: Proceedings of the IEEE instrumentation and measurement technology conference
56. Nikitin PV, Martinez R, Ramamurthy S, Leland H, Spiess G, Rao KVS (2010) Phase based spatial identification of UHF RFID tags. In: Proceedings of the IEEE international conference on RFID
57. Jones AK, Hoare R, Dontharaju S, Tung S, Sprang R, Fazekas J, Cain JT, Mickle MH (2007) An automated, FPGA-based reconfigurable, low-power RFID tag. Microprocess Microsyst 31(2):116–134
58. Jones AK, Dontharaju S, Tung S, Mats L, Hawrylak PJ, Hoare RR, Cain JT, Mickle MH (2008) Radio frequency identification prototyping. ACM Trans Design Autom Electron Syst 13(2):1–22
59. Angerer C, Knerr B, Holzer M, Adalan A, Rupp M (2007) Flexible simulation and prototyping for RFID designs. In: Proceedings of the first international EURASIP workshop on RFID technology, Vienna, pp 51–54
60. Knerr B, Holzer M, Belanovic P, Sauzon G, Rupp M (2004) Advanced UMTS receiver chip design using virtual prototyping. In: Proceedings of the IEEE international symposium on signals, systems and electronics, Linz
61. Tung S, Jones AK (April 2008) Physical layer design automation for RFID systems. In: Proceedings of the IEEE international symposium on parallel and distributed processing, Miami, pp 1–8
62. Angerer C, Rupp M (2009) Advanced synchronisation and decoding in RFID reader receivers. In: Proceedings of the IEEE radio and wireless symposium, San Diego
63. Jones AK, Hoare RR, Dontharaju SR, Tung S, Sprang R, Fazekas J, Cain JT, Mickle MH (2006) A field programmable RFID tag and associated design flow. In: Proceedings of the 14th annual IEEE symposium on field-programmable custom computing machines, Napa, pp 165–174
64. Nikitin PV, Rao KVS (2009) LabVIEW-based UHF RFID tag test and measurement system. IEEE Trans Ind Electron 56(7): 2374–2381
65. Rupp M, Burg A, Beck E (2003) Rapid prototyping for wireless designs: the five-ones approach. Signal Process 83(7):1427–1444
66. Belanovic P, Rupp M (2005) Automated floating-point to fixed-point conversion with the fixify environment. In: Proceedings of the 16th IEEE international workshop on rapid system prototyping, pp 172–178
67. Kaiser T, Wilzeck A, Berentsen M, Rupp M (2004) Prototyping for MIMO systems—an overview. In: Proceedings of the XII European signal processing conference, Vienna, pp 681–688
68. Vasilko M, Machacek L, Matej M, Stepien P, Holloway S (2001) A rapid prototyping methodology and platform for seamless communication systems. In: Proceedings of the 12th international workshop on rapid system prototyping, Monterey, pp 70–76
69. Lasser G, Langwieser R, Scholtz AL (2009) Broadband suppression properties of active leaking carrier cancellers. In: Proceedings of the IEEE international conference on RFID, Orlando
70. Mayer LW, Langwieser R, Scholtz AL (Sept. 2009) Evaluation of passive carrier-suppression techniques for UHF RFID systems. In: Proceedings of the IEEE MTT-S international microwave workshop on wireless sensing, local positioning and RFID, Cavtat
71. EPCGlobal (2006) EPC Global HF Air Interface Version 2, Document Version 0.1
72. EPCGlobal (2008) EPC radio-frequency identity protocols class-1 generation-2 UHF RFID, Version 1.2.0. http://www.epcglobalinc.org
73. ISO/IEC (2000) ISO/IEC 15693, identification cards—contactless integrated circuit cards—vicinity cards
74. Liu Y, Huang C, Min H, Li G, Han Y (2007) Digital correlation demodulator design for RFID reader receiver. In: Proceedings of the wireless communications and networking conference (WCNC 2007), Kowloon, pp 1664–1668
75. Angerer C (2008) A digital receiver architecture for RFID readers. In: Proceedings of the IEEE 3rd international symposium on industrial embedded systems, Montpellier, pp 97–102
76. Huang C, Min H (2006) A new method of synchronization for RFID digital receivers. In: Proceedings of the 8th international conference on solid-state and integrated circuit technology, 2006. ICSICT '06, Shanghai, pp 1595–1597
77. Angerer C (2010) Design and exploration of RFID systems by rapid prototyping. PhD thesis, Vienna University of Technology. http://publik.tuwien.ac.at/files/PubDat_187386.pdf
78. Langwieser R, Lasser G, Angerer C, Rupp M, Scholtz AL (2008) A modular UHF reader frontend for a flexible RFID testbed. In: Proceedings of the 2nd international EURASIP workshop on RFID technology, Budapest
79. Laskar J, Matinpour B, Chakraborty S (2004) Modern receiver front-ends. Wiley, New York
80. Poberezhskiy YS, Poberezhskiy GY (2005) Flexible analog front ends of reconfigurable radios based on sampling and reconstruction with internal filtering. EURASIP J Wireless Commun Netw 2005(3):364–381

81. Curty JP, Declercq M, Dehollain C, Joehl N (2007) Design and optimization of passive UHF RFID systems. Springer Science+Business Media, LLC, New York. ISBN 0-387-35274-0
82. Choi K, Eo Y, Jung S, Kwon I, Lee HB, Kim Yj (2007) A fully integrated CMOS RF transmitter for UHF mobile RFID reader applications. In: Proceedings of EuRAD 2007: European radar conference, Munich, pp 369–372
83. Kipnis I, Chiu S, Loyer M, Carrigan J, Rapp J, Johansson P, Westberg D, Johansson J (2007) A 900 MHz UHF RFID reader transceiver IC. In: Proceedings of ISSCC 2007. Digest of technical papers. IEEE international solid-state circuits conference, pp 214–598
84. Ying C, Fu-hong Z (2008) A system design for UHF RFID reader. In: Proceedings of ICCT 2008: 11th IEEE international conference on communication technology, Hangzhou, pp 301–304
85. Xiaohua W, Xiaoguang Z, Baisheng S (Aug. 2007) Design for UHF RFID reader and selection for key parts. In: IEEE international conference on automation and logistics, pp 2913–2916
86. Penttilä K, Sydänheimo L, Kivikoski M (2006) Implementation of Tx/Rx isolation in an RFID reader. Int J Radio Frequency Identification Technol Appl 1(1):74–89
87. Kim W-K, Lee M-Q, Kim J-H, Lim H-S, Yu J-W, Jang B-J, Park J-S (2006) A passive circulator with high isolation using a directional coupler for RFID. In: IEEE MTT-S international microwave symposium digest, pp 1177–1180
88. Langwieser R, Lasser G, Angerer C, Fischer M, Scholtz AL (May 2010) Active carrier compensation for a multi-antenna RFID reader frontend. In: Proceedings of the IEEE international microwave symposium, Anaheim
89. Angerer C, Langwieser R (2009) Flexible evaluation of RFID system parameters using rapid prototyping. In: Proceedings of the IEEE international confenerence on RFID, Orlando
90. Impinj (2005) Impinj Monza EPCglobal Generation 2 RFID, Datasheet
91. Mayer LW, Scholtz AL (2008) Sensitivity and impedance measurements on UHF RFID transponder chips. In: Proceedings of the second international EURASIP workshop on RFID technology, Budapest
92. Missoni A, Klapf C, Holweg G (2007) Dual frequency comprehensive transponder with inverse load modulation. In: Proceedings of the first international EURASIP workshop on RFID technology, Vienna, pp 5–8
93. Missoni A, Klapf C, Pribyl W, Guenter H, Holweg G (2008) A triple-band passive RFID tag. In: Proceedings of the IEEE international solid-state circuits conference, San Francisco

浙江大学毕业设计

本科学生中期报告

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项目名称：	专业教室桌面控制系统
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1　项目概况

学校的专业课程，需要用到一些特殊的实验设备。这时候，就需要让学生到放置了这些设备的专业教室上课。但是专业教室不同于一般的教室，管理员们不希望没有课程的学生随意进出教室，更不希望学生胡乱使用那些设备。他们希望使用状况是可控的，并且可以对设备的使用情况进行查询。因此，他们需要一个专业教室的桌面控制系统。

这个系统应该包含如下功能：

- 门禁系统

门禁系统用于控制学生的进出。学生可以在门禁系统上刷校园卡来尝试进入，系统会对学生权限进行判断。然后分配座位给学生并让他/她进入，或者拒绝学生进入，继续让门保持锁定。

- 桌面电源控制系统

桌面电源控制系统用于控制桌面上设备电源的通断。每一个位置都有一个独立的控制系统。学生在门禁系统获得授权后，可以在对应座位上使用校园卡让系统通电。其余状态下，设备一直保持断电状态。

- 后台管理程序

后台管理程序用于对课程、教室、使用情况等进行管理。管理员可以通过后台管理程序录入新的课程，导入学生列表，增加新的教室等，当然，也可以删除相应的课程、教室、学生。

为了实现这么一个系统，我需要完成以下工作：

- 门禁系统
  - 读取卡号
  - 控制门锁
  - 在 LCD 屏幕上显示提示信息 (分配的座位或者不能进入的提示)

- 桌面电源控制系统
  - 控制电源通断
  - 延时断电机制
- 出于布线考虑而设置的通信系统：在桌面电源控制系统和服务器之间转发消息
- 服务器程序：根据卡号返回通断信息和相应的提示信息
- 后台管理程序
  - 教室管理功能
  - 课程管理功能
  - 使用记录查询
  - 临时开放功能
  - 卡号登记功能

2 工作成果及水平

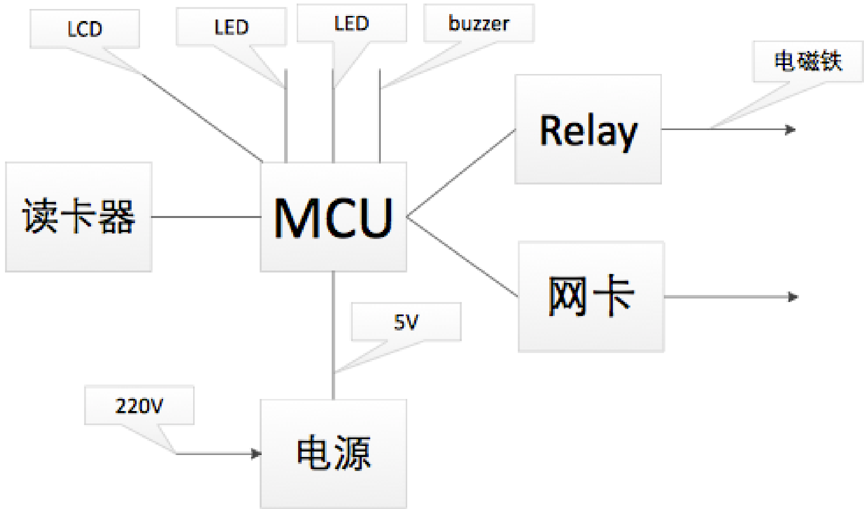
目前为止，已经完成了系统主体的功能。在学生端，完成了用 arduino 控制的门禁机、通信机和桌面机的控制程序。在服务端，实现了服务器程序和后台管理软件。具体介绍如下：

- 门禁系统：

门禁系统采用一块 arduino nano 的板子作为中央控制单元 (MCU)。这样可以方便地用 C 语言进行编程，实现对连接在板子上其余模块的控制。

门禁系统的工作逻辑是这样的：首先，arduino 板子上连有一个 RFID 的读卡模块，可以读取到校园卡的卡号。同时，板子上连接着一块网卡，使系统与服务器通过局域网相连。中央控制单元在获取到卡号后，通过局域网把卡号发送到服务器，然后从服务器获取到结果。板子上还连有一个 LCD 屏幕和一个继电器，控制程序把从服务器获取到的信息显示到 LCD 屏幕上，并且根据结果，

通过继电器控制门锁的开关。另外,板子上还连有两个 LED 灯(一红一绿),一个蜂鸣器,用于响应用户的刷卡动作和提示系统的状态。



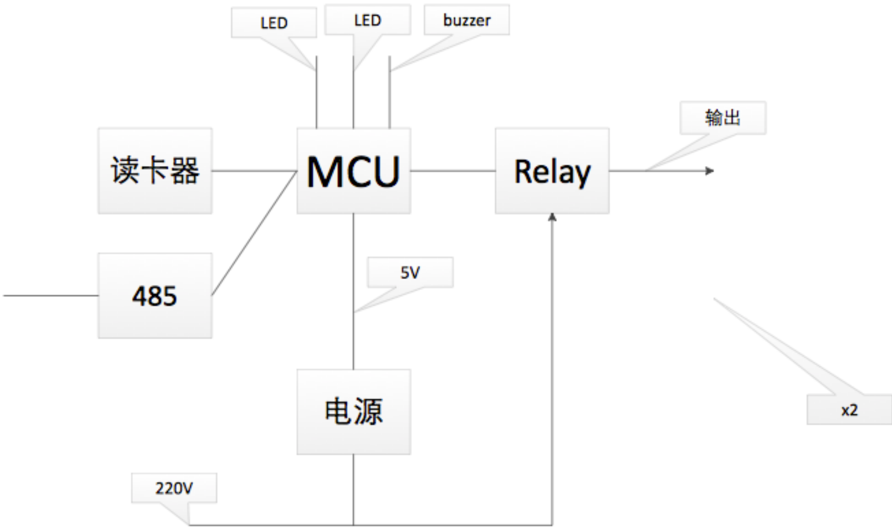
• 通信系统:

通信系统是为了方便布线而设置的。假如没有通信系统,每一个桌面电源控制系统就需要直接通过局域网与服务器相连。但这样在布线上就会十分麻烦。为了使布线更加简单,我们就在教室建立了一个通信机,通信机与服务器通过局域网相连。而桌面电源控制系统和通信机则通过 485 串口相连。

通信系统同样使用了一个 arduino 的板子作为中央控制单元,并且连接了一个网卡和一个 485 串口。控制程序所做的事情就是接收 485 串口的消息,通过局域网发给服务器;接收局域网的消息,通过 485 串口发送给桌面机。

• 桌面电源控制系统

桌面电源控制系统由 arduino nano 中央控制单元和连接在上面的 RFID 读卡器、485 串口、继电器、LED 灯、蜂鸣器构成。



系统用于控制桌面总电源的通断。当学生把卡放置在读卡器上后,读卡器会从服务器获取结果,从而通过继电器控制电源的通断。同时,读卡器会不断读取卡号判断卡是否保持一致。如果卡发生了改变,则会重新从服务器进行通断的判断。

系统还提供了延时断电机制。当卡被拿走后,系统会继续供电 5 分钟。如果卡没有在这个延时周期内重新放回,系统就断开电源。这为学生临时离开桌面提供了可能。

• 服务器程序

整个系统除了学生端的门禁、通信、桌面系统,还需要有服务端的程序响应请求。服务器在 4321 端口开启 socket 监听。当服务器接收到 socket 消息后,会根据 IP 地址和来源标示判断出消息的来源。然后根据卡号判断学生能否进入教室,并返回相应的结果。

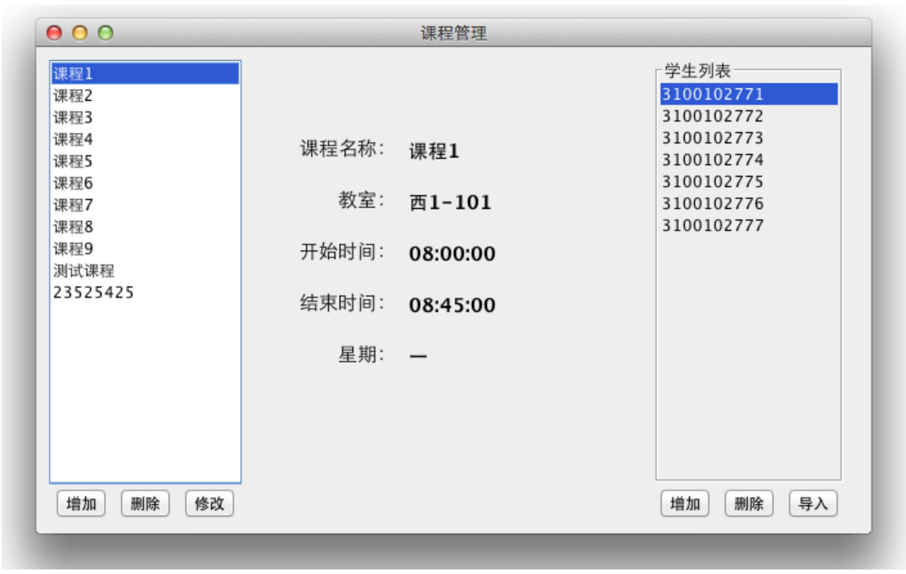
服务器判断逻辑包括:卡号是否与学号绑定,学生是否在当前时间有课程,学生是否被临时允许进入,分配座位让其使用等。

- 后台管理程序

管理人员需要对教室、课程、学生等进行管理,自然不会是让他们直接操作数据库。因此,我们还需要一个后台管理软件,通过它可以管理教室、增删课程、导入学生、查看使用记录、临时开放位置、绑定卡号等。目前,除了使用查询功能还在开发优化中,其余功能都已经完成了。

教室管理功能提供了教室的增加、删除和修改功能。每一个教室都有教室名称、教室座位总数、门禁机 ip 和通信机 ip 这 4 个属性需要设置。教室名称用于识别教室,一般来说应该是独一无二的。教室座位数应该与布置在教室内的桌面电源控制系统数量一致,这样就可以顺利进行座位的分配。另外两个 ip 则是为了服务器在收到 socket 消息的时候对教室进行识别。

课程管理功能提供了课程的增加、删除、修改和学生管理功能。每一门课程除了课程名称外，还应该分配一个教室用于上课，然后设置好课程的上课时间。另外，课程可以增删或者导入上课学生的学号，这样学生在对应教室刷卡后就能够顺利进入教室。



临时开放功能是让管理员能够临时开放一个教室给指定学生使用一段时间，只要输入学生学号，指定教室和开放时间，该学生就能前往教室临时使用教室。卡号登记功能则是为了在学生卡号和学号之间建立绑定关系。因为读卡器只能够读取到校园卡的卡号，而不知道学生的学号；而课程教室一般只有学生学号列表而不知道学生的卡号。因此需要卡号登记系统把两者进行关联。

3 项目收获

在做毕业设计之前，我对 Java 也有过一些了解，但更多的只是在语法方面的。这次使用 Java 写了一个完整的后台管理程序，不管是在语言方面还是设计模式上面都有了很大的收获。在编写程序的时候，我使用了 MVC 的设计模式，然后还使用单例模式，这些原本仅停留在接触层面的知识这次在实际运用中，我理解得更深刻了。

在编写程序的时候，我也遇到过不少问题，而且很多是现有书籍中也没有讲得透彻的概念。在使用搜索引擎解决这些问题的同时，更是增强了我自我学习的能力。

我觉得在这一过程中，我最大的收获不是在语言方面的，而是通过自学完成一整个项目的经验。

4 对工作建议

在完成毕设的过程中，我深深的觉得实践才是学习编程的最好方法。因此，以后我自己可以通过多做一些实际的项目来提高自己的编程水平。

另外，我觉得学校可以适度地提高课程大程的难度，这样同学们可以在课程中就得到更好的锻炼。

5 其他