4B25-2019 Project Report

Coursework Candidate Number: 5546C

1 Problem Solved

Radio Frequency Identification (RFID) is a way of tagging real-world items to allow identification without direct line of sight, which is required by alternate systems such as barcodes. Passive RFID relies on small electronic tags which are powered purely from incoming electromagnetic (EM) radiation - if the power density is too low, the tag will not be powered and will be unable to be read. Thus a key measurement taken when diagnosing RFID systems employed in commercial and research contexts is the RF power density at locations throughout the space tags are desired to be read within. Current options to do this are detailed below, however it is clear that there is a need for a mobile power measurement device. My 4B25 project provides a low-cost, portable embedded system approach that enables a user to measure the power density in a 1MHz to 8GHz frequency band (with smaller bandwidths selectable with the use of an appropriate filter), allowing quick diagnosis of RFID deployments, or indeed any application where power is the key statistic.

2 Stakeholders

Within the Engineering Department, Dr Michael Crisp leads a research group investigating novel uses of RFID, such as multi-reader scenarios and my own Master's Project on mapping the RF Field inside a room. In the wider wireless research field, the next generation of Wi-Fi technology employs beamforming - directing higher RF power towards a user, to combat the otherwise high drop-off of power with distance at high frequencies. In a research context a handheld power measurement device would help for quick diagnosis of whether such systems are functioning as expected

Outside academia, Dr Crisp has co-founded a company, PervasID, who provide industry-leading RFID detection systems for commercial purposes such as stocktaking. RFID is already employed by others to protect high value retail items, and for identifying shipping containers & cars in some toll stations. In a commercial context such a device would be useful in checking deployments to ensure tags will be read in all required locations.

3 Current State of the Art

From my work in the Research group, I have identified the current methods used to characterise the power of RF fields as follows:

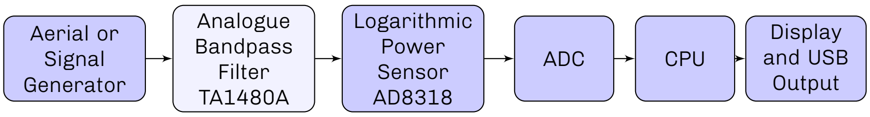
Reading a known RFID tag - If a tag is known to work, checking a reader antenna is able to read it in multiple locations is a basic diagnosis tool that there is the desired coverage. This however depends on the used tag's sensitivity, which can vary heavily due to antenna design and complexity of tag function (e.g. wireless sensing requires higher power to activate & read correctly). The data provided by this test is binary; whether the power is over the tag's required threshold - no data can be retrieved of how close the power is to the boundary and indeed the threshold of a tag itself can prove very difficult to measure.

Spectrum Analysers - The most common method employed in the research lab is to use an RF Spectrum Analyser to check the power received by an aerial. Although high in accuracy, configuring them to calculate power measured over a specific bandwidth can be difficult, they are invariably high cost, and most spectrum analysers in laboratory applications are too large to be deployed in a mobile situation. Mobile spectrum analysers do exist, but are very high in price and thus not amenable to widespread use.

Software-Defined-Radio - SDRs provide a low-cost alternative to provide spectrum-analyser functionality through computer-based processing of RF samples, however commonly employed chips such as the RTL2832U measure power relatively and require calibration to provide absolute measurements (a task I am performing as part of my Master's Project). One benefit of computer processing is the application of complex filtering, however such applications limit SDR usage on small portable computers with data instead being streamed to a computer for analysis, effectively making such a solution not truly portable.

Handheld RF Power Meters - There are RF Power Meters available for purchase, however models such as the Keysight V3500A retail for over $2,000, with cheaper options on Amazon ranging generally retailing for around $100-300, although some very cheap "EMF Meters" are available for $̃15. Although expensive options are likely to be highly accurate, their expense is restrictive. Cheaper options come with the risk of poor calibration & performance, thus there exists a use for a low-cost device that can be shown to be accurate over relevant frequencies.

4 My Approach



The final implementation's structure is shown in the flowchart above (filter is light as not used in testing, but would work for RFID band). I used an AD8318 Logarithmic Power Sensor for my project as it covers a 1MHz - 8GHz operating range and I was able to purchase a development board on Amazon for £15. This removed the need for a custom PCB involving complex RF considerations. The board came with an integrated 5V regulator, so must be supplied with a voltage over 6V. I chose to power it using a variable power supply in the laboratory at 7V, but also was able to power the whole system successfully from a 9V battery as the FRDM KL03 can be powered via internal regulation of voltage supplied to the VIN GPIO pin (J3 - 8). The output of the sensor is an analogue voltage proportional to the logarithm of the RF power measured at the SMA connector input, nominally -25mV/dBm. My initial testing with a signal generator input found that the voltage output by the sensor was 0.81V at its minimum and 2.02V at its maximum, thereby not exceeding the 3.3V supply voltage for the ADC, and thus requiring no conversion. Using the `adc_16` driver provided in KSDK1.1, I initialised the ADC input on PTB0, and wrote a function to return the raw ADC reading as an integer. I integrated this with the WARP `printAllSensors` function so that readings could be taken using the WARP menu & collected with JLinkLogger. I improved my display driver, adapting an Adafruit driver for the SSD1331 to implement a font allowing `char` printing, and separate functions to convert `int` and `float` values to strings. After the characterisation discussed below, I implemented a function to convert raw ADC readings to a true power reading which is printed to the screen, with the functionality wrapped in an `#ifdef` statement as including floating point computation caused the program to exceed the `.text` region on compilation.

5 Results

I used JLinkLogger to collect 51339 measurements across 13 different power levels (at least 2000 measurements per level). My measurement setup took the output of a signal generator at 865.9MHz, splitting it down two matched cables (measured to be 0.08dBm different, neglected in further calculations), measuring one output with my embedded system and one with a spectrum analyser reporting peak power (bottom right). The measurements & Python analysis are included in my fork of the Warp firmware. From -5dBm to -50dBm the standard deviation of ADC values was below 9, at -55dBm and below the measurements were substantially noisier, shown by the raw measurement plot and larger errorbars (min & max values) for the line of best fit, thus they were excluded from the fit. The measurements for each power level individually passed a 5% 2-sided χ^2 Hypothesis test for a Normal fit, fits are plotted for the noisiest values in the bottom left. We expect the noise to be Gaussian as these low values approach the noise floor, commonly modelled in RF channels as such.