# Reader Antennas for a Low-Cost Chipless RFID System

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*Abstract*— **This article presents the design and fabrication of two types of reader antennas as a proof of concept. One of them is a microstrip meander antenna, whereas the other one is a microstrip patch dipole antenna. Both are fabricated on a low-cost epoxi-based FR-4 substrate in a LPKF S103 prototyping machine. Besides that, several meander antennas were designed using other substrates. The simulated and experimental results indicate a suitable operating bandwidth, which is compatible to the Brazilian standardized range for RFID, and a broad directionality, which is adequate for the application.**

*Keywords*— **RFID, reader, microstrip antenna.**

## I. Introduction

Radio Frequency Identification (RFID) is a technology which allows the identification of tags based on radio frequency wave parameters. RFID is used in several applications, ranging from animal movement tracking in farms to the toll system in buses [1]. RFID is an enabler technology, which is prone to be used in a 5G scenario with Internet-of-Things.

The design of low-cost RFID systems usually comprises low-cost reader antennas and chipless tags. The use of chipless tags impose some constraints on the amount of data which may be transmitted between a tag and the reader. The tags designed in this project are described in [2].

The use of printed antennas and tags provide a system with portable and low-profile parts, which improve the overall flexibility of the system [1] [2]. Printed reader antennas have been proposed using different substrates and several designs, as in [3], where a loop antenna is printed on a Rogers RT5880 substrate.

The objective of this article is to present two types of reader antennas for a low-cost RFID system, and evaluate them as a proof of concept. One of them is a microstrip meander antenna, and the other one is based on a microstrip dipole design. The whole system with the proposed antennas is validated as RFID readers in an experimental setup. This work extends the research described in articles [4] and [5]. As far as we know, the design which is proposed in this article for the reader antennas is not found elsewhere in the literature. In comparison to [4] and [5], this article presents the fabrication of antennas, with a measurement campaign for characterizing one of the proposed microstrip meander antennas.

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Section II presents an overview of the main aspects of RFID systems. In Section III, the whole system comprising the proposed antennas is described. Simulation and experimental results are presented in Section IV, while Section V presents the main conclusions of this article.

## II. Radio Frequency Identification

RFID systems are composed of a transceiver known as the reader, and several responders in the environment, which are denominated tags [1]. Each tag contains a responding mechanism, which may present a chip. When a chip is present, it may store the identity information of the tag.

Our system is designed to operate with chipless contactless tags, which communicate to the reader by scattering back the transmitted waves [4]. Each tag backscatters the wave only in a certain frequency, which allows the identification of that particular tag based on the frequency.

The proposed reader is assumed to be inserted in an RFID gate, which is a term used to denominate an identification point in RFID systems for contactless tags [6].

Wire antennas present an undesired long length for low frequencies, which is a problem in terms of portability. To decrease its size, wire antenna design can assume the shape of a meander [7], such as in the Yagi-Uda and log-periodic meander design.

Few microstrip meander antennas have been described for RFID environment. In [8], Taconic RF-35 with dielectric constant of 3.5 is used as its substrate, operating in wireless mobile and in ISM (Industrial, Scientific and Medical) bands. In [9], a multiband meander antenna is designed to LTE applications. On the other hand, several microstrip antennas appear in the literature, such as [10].

## III. Proposed System

The overall system is intended to be an RFID gate, where tags are used to identify the users of the system. A diagram presenting the building blocks of the system is seen in Fig. 1. Baseband processing is performed by an Arduino platform, as shown in [11], in Portuguese.

Tags communicate to the reader without using contact, by backscattering. It is built with C-shaped and U-shaped structures printed on a Rogers RO6010 substrate, with dimensions 85.5mm $\times$ 54.0 mm and operating near 921 MHz [2].

The system is proposed to operate between 810 MHz and 915 MHz, which is the standardized high range of RFID, as defined in [12] by the Brazilian Agency of Telecommunications (ANATEL).

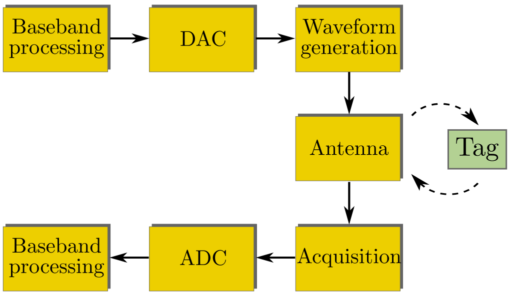


Fig. 1. Diagram representing the proposed system.

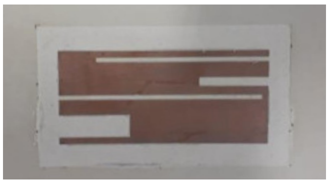

Fig. 2. Tag used in the system.

### A. *Proposed Reader Antennas*

In this article, microstrip meander antennas and microstrip dipole antennas are proposed. Antennas were designed using Roger's RO5880, Roger's RO6010 and the FR-4 substrate. After simulations, FR-4 is chosen for fabrication, since it is a low-cost epoxi-based substrate.

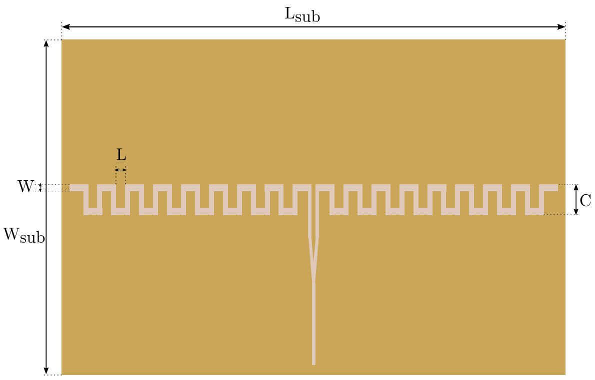


Fig. 3. Design of the M66CF meander antenna.

The proposed antennas are simulated in the ANSYS HFSS (High Frequency Structure Simulator) software. The $S_{11}$ parameter for the each considered design is compared in terms of an adequate fitting to the Brazilian ANATEL denominated high range for RFID [12].

Antenna parameters are considered in the simulation, such as the thickness of the substrate $h$, meander length $W$, meander height $C$, meander spacing $L$, and dielectric constant. All those parameters are chosen based on some optimization tools of the ANSYS HFSS.

Rogers' RT/duroid 5880 substrate is used with dielectric constant of 2.2, $\tan(\delta) = 0.001$ and 3.175 mm of thickness. By setting the values of the parameters $L$ and $C$, the parameter $W$ is modified to obtain a low value for the $S_{11}$ parameter at UHF band. Whenever $W$ is changed, a frequency shift occurs. When $W$ is increased, the resonant frequency decreases. Value $W = 2.2$ mm is selected, where the values of parameter $S_{11}$ are adequate in UHF bands. The selected value of $W = 2.255$ mm provides a slightly lower $S_{11}$ in UHF band.

Another feeding design is used with a Y junction, for the M66LF antenna. The coupling parameter LY is designed with a length $\lambda/4 = 81.97$ mm, which would be too large for the considered dimensions. Therefore, a submultiple $\lambda/36 = 9.11$ mm was chosen for the LY length. Rogers RT/duroid 6010 substrate is used to decrease antenna dimensions. Some substrate characteristic parameters are 2.5 mm of thickness, dielectric constant equals 10.2, $tan\,(\delta) = 0.0027$ and copper thickness of $35\mu$m.

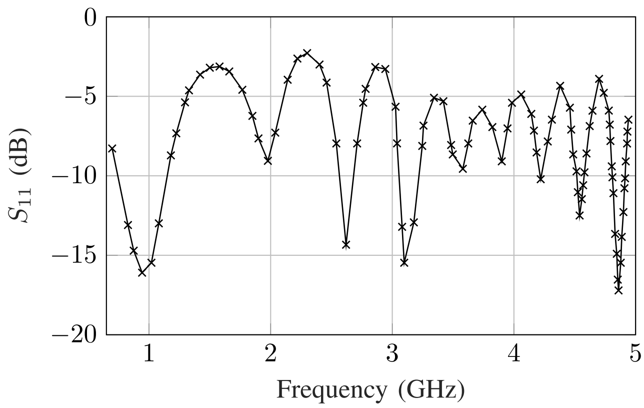


Fig. 4. $S_{11}$ parameter of M66LF antenna with $W = 1.09135$ mm. At 920 MHz, the $S_{11}$ value is $-15.5593$ dB. Bandwidth is found to be 109.2 MHz.

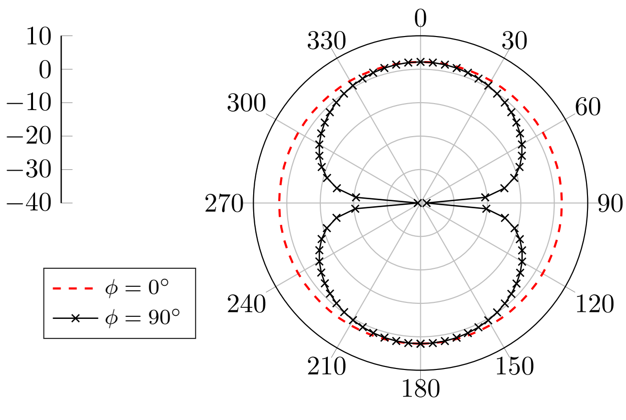


Fig. 5. Radiation pattern simulated for the dipole antenna.

## IV. Fabrication and Measurement Results

In this section, the experimental setup is addressed, with the designed waveform and the fabricated antennas. The waveform is generated in Labview using Matlab codes integrated to the Labview environment. The generated waveform is depicted in Fig. 6.

### A. *Fabrication*

The proposed antennas were fabricated in a LPKF S103 prototyping machine present in the Antennas and Propagation

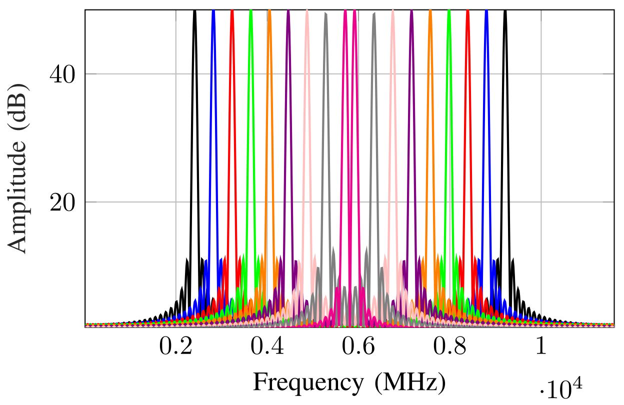


Fig. 6. Transmitted waveform generated in Labview. Frequency interval of $[2.4, 5.8]$ kHz and amplitude of $0.005$.

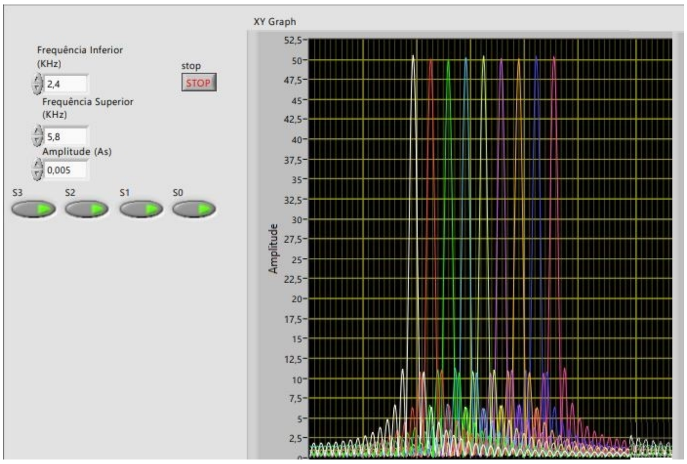


Fig. 7. Transmitted waveform generated in Labview. Frequency interval of $[2.4, 5.8]$ kHz and amplitude of $0.005$.

Lab (LAProp) at Universidade Federal Fluminense. The fabricated dipole antenna is presented in Fig. 8, while the fabricated meander antenna is depicted in Fig. 9. Afterwards, some parts of the circuit was corroded using ferric perchlorate.

For the dipole antenna, the angular half-power point of the fabricated antenna is simulated as $78°$, whereas 105 MHz is the measured bandwidth, centered at 915 MHz. The dimensions of the fabricated antenna are 22 cm $\times$ 6 cm.

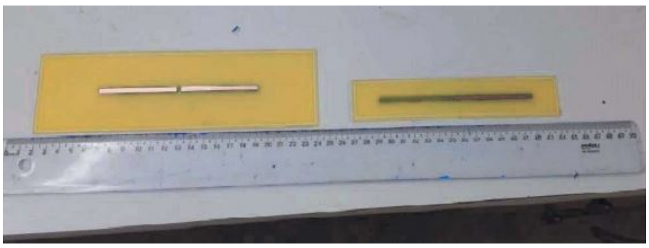

Fig. 8. Fabricated patch dipole microstrip antenna.

## *B. Measurement Results*

Measurement campaigns were performed in the Antennas and Propagation (LAProp) at Universidade Federal Fluminense. The objective of the campaigns was to evaluate the performance of the designed antennas.

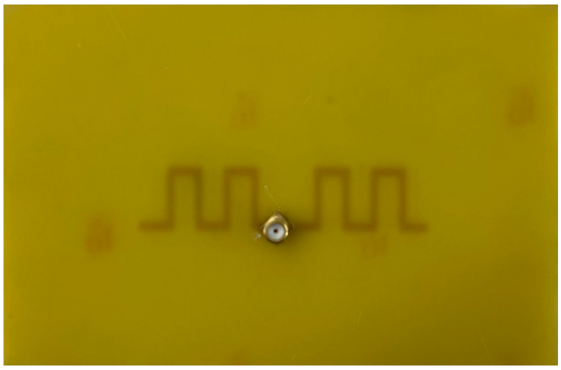

Fig. 9. Fabricated meander antenna.

Multiple sinusoids were created in a Labview development environment using MathScript. The generated waveform is equivalent to the overlap of signatures that should be transmitted by an RFID reader in operation.

D/A converter (DAC) used in the campaign is the DAQ NI USB 8212 board, which is compatible to Labview, with data convertion at a 250 kSa/s (kilosamples-per-seconds) rate. The RF mixer used is the Minicircuits ZFM 2000, with 2 inputs: the output of the DAC and the output of the signal generator Anritsu MG3700A. They are mixed and the output is used by the RFID reader.

In our campaign, the output is captured by the spectrum analyzer Anritsu MS2692A. The behavior of the ZFM 2000 mixer is similar to a dual-side band (DSB) modulator, which generates sinusoids both below and above the 921 MHz frequency of the signal generator.

In the first tested setup, the meander antenna of Fig. 6 was added to the rest of setup through a SMA RF PCB connector. This antenna was connected to the output of the mixer. An identical antenna was fabricated to simplify the validation of the whole setup. Tags displayed in Fig. 2 were positioned nearby to scatter the transmitted signal to the receiving antenna, as presented in Fig. 10. Fig. 11 shows the validation of the results. Meander antenna transmits the created waveforms, which is then scattered back by an RFID tag.

Some RFID tags were positioned nearby at 50 cm from the reader. Since the tag should be placed on the far field of the antenna, the Fraunhofer distance expression was calculated as $d_f = 2D^2/\lambda$, where $D = 22$ cm is the largest antenna dimension and $\lambda \approx 32$ cm is the central wavelength of the transmission, then $d_f = 25$ cm is the minimum distance for the measurements.

Afterwards, measurement setup was changed to add the dipole antennas to the system, as seen in Fig. 12. In Fig. 13, the results validate the setup with dipole reader antennas. The whole range of desired bandwidth lies inside the bandpass of the antenna.

Fig. 14 displays the simulated and measured results of the $S_{11}$ parameter for the patch dipole antenna. It is remarkable that the measured bandwidth is close to the simulated bandwidth, for the standardized high range of the Brazilian RFID

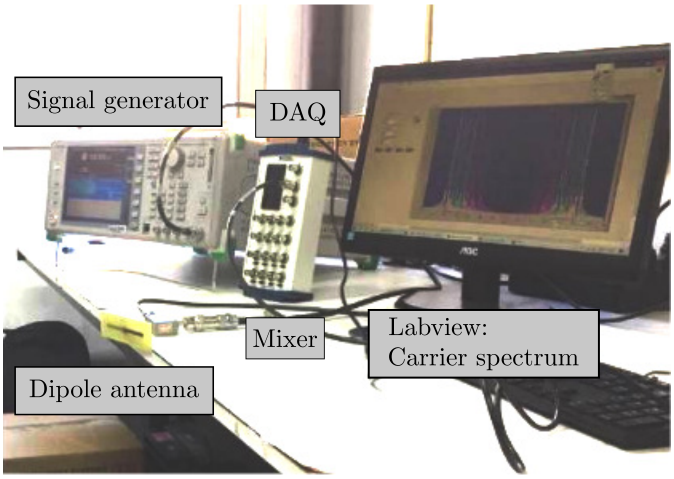


Fig. 12. Measurement setup for evaluating the patch dipole microstrip antenna.

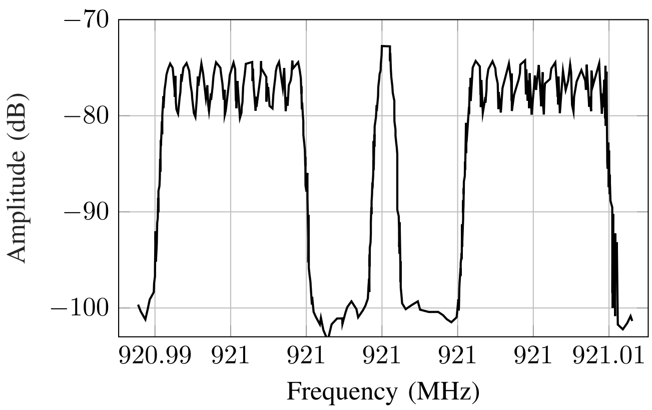


Fig. 13. Measurement results considering for evaluating the patch dipole microstrip antenna.

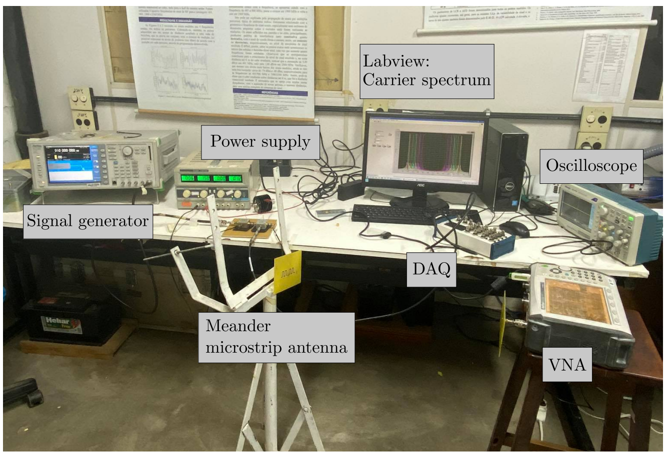


Fig. 10. Measurement setup for evaluating the meander microstrip antenna.

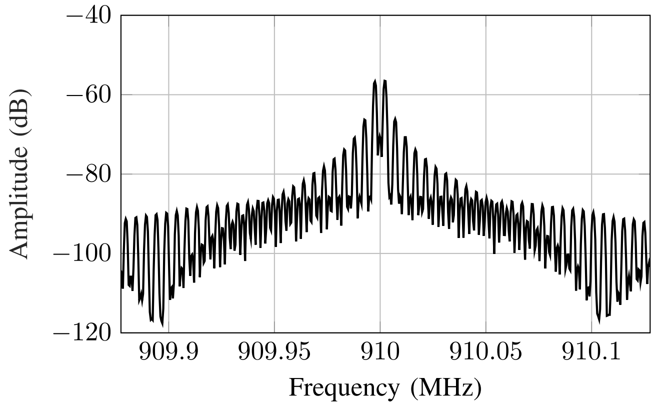


Fig. 11. Backscattered waveform in RFID Reader and meander microstrip antenna at the transmitter.

system, which lies inside the bandpass of the meander antenna.

## V. Conclusion

This article proposes microstrip meander and patch dipole antennas to be used as reader antennas for low-cost chipless RFID systems as a proof of concept. The proposed antennas were printed on a low-cost FR-4 substrate. The substrate was chosen after extensive research with Ansys HFSS simulations.

The proposed antennas presented an adequate performance for being used in the Brazilian standardized high range of RFID. The whole setup was experimentally validated by a measurement indoor campaign.

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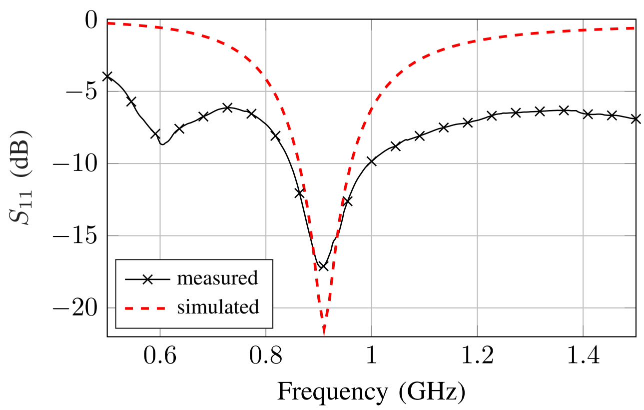


Fig. 14. Simulated and measured $S_{11}$ results for the FR-4 meander antenna.

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