New potential of a direct printed LoRa antenna

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***Abstract*— In order to minimize the PCB (Printed Circuit Board) footprint of an IoT microtracker, we analyse the opportunity of deporting a LoRa antenna on the plastic case of the microtracker. This paper aims to compare an antenna conventionally manufactured on a PCB (FR4) and a printed antenna using jetting technology on a PC+ABS (Polycarbonate and Acrylonitrile Butadiène Styrène) polymeric substrate. The influence of the conductive ink, the antenna design and the substrate are underlined. Computational simulation is carried out. The LoRa antenna design is similar to the one used by [1].**

Keywords—LoRa; IoT; Jetting; Direct printing; Antenna.

I. INTRODUCTION

The increasing application field of the Internet of Things (IoT) involves new solutions of wireless communication. IoT devices collect and transmit data to an application for analysis, acting as a decision tool to improve a system. LPWAN (Low Power Wide Area Networks) is a wireless technology which consumes low power [2] with a high range. In this study, we will focus on a LoRa antenna embedded in a microtracker.

In the industry, PCB is a common substrate for electronic circuitry. It consists in the assembly of multilayers of copper and insulating materials, mainly fiber-reinforced epoxy. Wireless communication requires to integrate antenna on this PCB and conduct to geometric constraints regarding electronic circuit organisation. This work aims to explore an innovative way of producing antenna, relaxing PCB footprint constraints and adding functionality directly on the case, through a direct printing process.

II. METHODS AND PRINTING ANTENNAS

A. *Direct printing technique: jetting*

Several technologies of printed electronics, dedicated to conductive tracks circuitry, are used such as screen printing [3], flexography and jetting [4]. Jetting technique [5] combines versatility and adaptability. In our experiments, a conductive paste dispensing system is set on a 6-axis robot, thus allowing printed circuits on complex 3D-surfaces. The microdispenser plots drops at a selected frequency along the trajectory encoded in the robot. The purpose of this system is to print directly on the plastic case of the IoT device. This 3D direct printing technique is suited for any shape and allows the constructor to deport the antenna out from the PCB, to save space and to add new functions on the device [6].

B. *Simulation parameters*

In the present study, we use antenna in [1] which is a LoRa antenna adapted for microtrackers. A computational simulation study is first performed with CST software in order to evaluate the influence of conductive material and insulating substrate. A geometrical adaptation of the antenna design will be proposed. Afterward, our target is to produce this antenna using jetting printing process. We will analyse the process potential and the induced changes due to the printing technology.

The antenna conductive material is computed with the sheet resistance 30 mΩ/sq of the microparticle silver ink (Henkel). PC+ABS ($\varepsilon_{r\ PC+ABS}=3.49$) and FR4 ($\varepsilon_{r\ fr4}=4.3$) substrates are implemented for the same thickness of 0.8 mm. Printed silver lines are simulated with a thickness of 40 µm and a width of 600 µm.

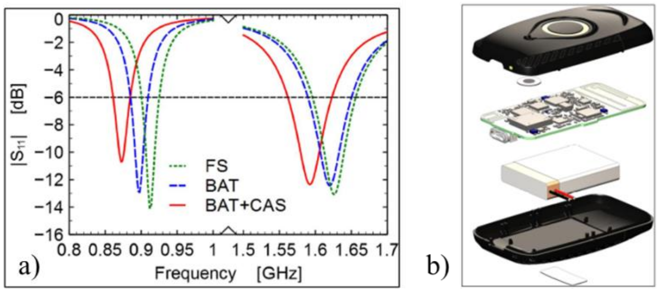

Fig. 1 : (a) Simulated S-parameter with battery (BAT), with battery and case (BAT+CAS), and free space (FS) [1](b) 3D view of the microtracker from [1]

C. *Antenna characteristics*

The reference antenna functions at two frequencies: 868 MHz for LoRa network and 1575MHz for the GPS function. The PCB substrate used is FR4 0.8 mm. The dual band antenna is set on a 400 mm^2 PCB area. In Fig.1, S-parameter is presented for 3 situations of the antenna: the antenna in free space, in a battery environment and in a battery and case environment. The 6dB-bandwidth obtained is 25 MHz for LoRa and 56 MHz for GPS. The efficiency for

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LoRa is -4 dB (40%) and -1.2 dB (75%) for GPS which is suitable for IoT application [1].

III. RESULTS AND ANALYSES

A. Computational simulation of the antenna

Using CST Microwave Studio software, we simulate the LoRa antenna performance with two constitutive materials and two different substrates (Fig. 2):

- Reference antenna using copper deposited on a FR4 substrate
- Identical antenna design using a silver ink (1.3×10^8 S/m) on FR4 substrate.
- Identical antenna design simulated with a silver ink on PC+ABS substrate
- A modified antenna design simulated with silver ink on PC+ABS

On the last simulation result, the antenna design is modified in order to compensate the offset induced by PC+ABS substrate. Each branch of the antenna creates a resonating frequency (Fig. 3a). By modifying their dimensions (Lengths d1, d5 and p1 are increased and, lengths d3 and the width of the lines are decreased), the offset is cancelled. Jetting technique allows the lines to be thin (about 600 µm). The geometrical optimisation allows the printed antenna on PC+ABS to resonate at 868 MHz and 1575 MHz. Simulation results are presented on Fig.2 and Fig.4, and main results are summarised in TABLE I. The results of the original antenna and the simulated printed antenna are compared. The realized gain for printing antenna is lower than the original antenna due to the conductivity of the silver. The realized gain for GPS frequency is higher than the original antenna. These gains are acceptable for IoT applications.

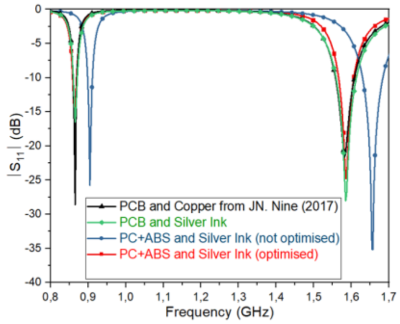

Fig. 2 : Simulation of the impact of the ink and substrate and optimisation of the antenna.

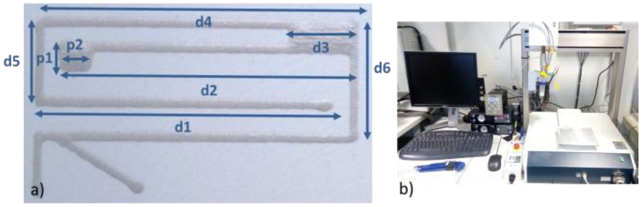

Fig. 3 : (a) Modified design of the antenna with silver ink on PC+ABS (b) Jetting system on the cartesian robot

TABLE I. Comparison of the simulation of the original antenna and the printing antenna

	Realized Gain (dB)		**Bandwidth for -6dB criteria (MHz)**	
	Optimized printed antenna on PC+ABS	***Original antenna on PCB***	***Optimized printed antenna on PC+ABS***	***Original antenna on PCB***
868 MHz	-6.495	-4	15	25
1575 MHz	-0.6074	-1.2	22	56

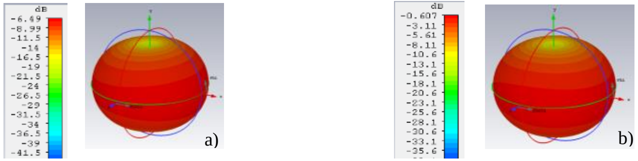

Fig.4: Plots of optimized antenna radiation patterns (a) at 868 MHz (b) at 1.575MHz

B. Experimental approach

The proposed antenna (Fig.3a) was printed with a microparticle silver ink presenting a conductivity of 1.3×10^8 S/m (Henkel). The ink was deposited with a piezoelectric jetting system (Vermes MDS 3200A) set on a Cartesian robot (Janome JR3304). Thermal curing was performed in an oven at 90°C during 30 min. Results will be compared with simulations in the near future.

IV. CONCLUSION

In this paper, the benefit of printing a LoRa antenna on plastic case is studied for an IoT wireless communication device. Simulations show an offset of S-parameter due to the modification of the substrate. A geometrical optimisation of the antenna is performed for printing on PC+ABS. The realized gain decreases compared to the PCB antenna because of the silver conductivity but it is acceptable for IoT application. After optimising the antenna, simulations present a functional LoRa antenna.

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REFERENCES

[1] J. N. Nine and S. Boudaud, “LPWAN as Enabler for Widespread Geolocation Solutions”. EmbeddedWorld2017, Germany, 2017.

[2] Q. Zhang and Y. Gao, “Embedded Antenna Design on LoRa Radio for IoT Applications”, 12th European Conference on Antennas and Propagation, London, p. 3, 2018.

[3] I. Kharrat, P. Xavier, T.Vuong, J.Duchamp, P. Benech, and G. E. P. Tourtollet, “Low-Loss Paper Substrate for Printed High Efficiency Antennas at 2.45 GHz”, IEEE Antennas and Wireless Propagation Letters, vol. 14, p. 1400-1403, 2015.

[4] D. H. N. Bui, T. P. Vuong, P. Benech, J. Verdier, and B. Allard, “Gain enhancement of suspended miniaturized antenna on high-loss paper substrate”, 2017 IEEE International Symposium on Antennas and Propagation USNC/URSI National Radio Science Meeting, p. 2163-2164, 2017.

[5] M. Singh, H. M. Haverinen, P. Dhagat, and G. E. Jabbour, “Inkjet Printing-Process and Its Applications”, Advanced Materials, vol. 22, n° 6, p. 673-685, févr. 2010.

[6] E. MacDonald and R. Wicker, “Multiprocess 3D printing for increasing component functionality”, Science, vol. 353, n° 6307, p. aaf2093-aaf2093, sept. 2016.