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Miniature Antenna for IoT Devices Using LoRa Technology

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***Abstract*—In this paper, the way to design different shapes of miniature antenna for LoRa devices are presented. With dimension of $0.06\lambda\times0.1\lambda$, the proposed antennas are printed on 34×80×0.8 mm^3 FR-4 board . The simulation and experiment results show a good agreement with expectations of the electrical small antennas that operate at 868 MHz frequency band. Moreover, the changeable geometry of the designs while keeping a good performance proves that miniature antennas can be created to be more appealing as logos or figures.**

Keywords: miniature antenna, LoRa, Internet of Things

I. Introduction

Nowadays, the modern world is becoming connected, not only in term of human being but also artificial machines. This tendency has led to a technology so-called Internet of Things or IoT in technical communities. Just same as connecting peoples, there should be a mechanism of communication for connecting objects.

Several standards such as Bluetooth, Wi-Fi, 3G, 4G exist and each technique has its own pros and cons. To evaluate qualities of a system, the three main criteria are: how far it can transmit, how much power it consumes and how fast it can transfer data. Taking three issues into account, 3G and Wi-Fi have high data rate and both can cover a large area, yet they require large amount of power [1] [2]. Bluetooth, in reverse, can yield high power efficiency, but it can only function in few meters away [3]. Machine-to-machine (M2M) communication need both to be long range and low cost of power for working in long time, it can adapt with low data rate also. Therefore, a novel solution is proposed, that is LoRa technology.

Lora system is a Low Power Wide Area Network (LPWAN) specification aiming at supporting IoT in large areas. It is a proprietary spread spectrum modulation scheme which is provided by Semtech and has many advantages over conventional mechanisms, including low power, high robustness, long range capability and so on [4]. LoRa's working frequencies are 433MHz, 868MHz in Europe and 915MHz in American [5]. Besides, a narrow bandwidth of about 5MHz could be expected thanks to small amount of traffic and low data rate. Nevertheless, low carrier frequency also means a large antenna's size.

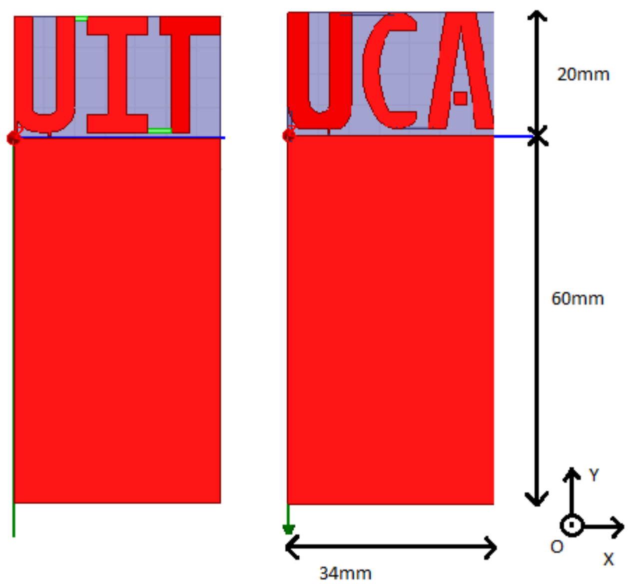

Fig. 1. UIT and UCA antenna designs

To make IoT devices be cheap, compact and have high mobility, its sizes must shrink down. A miniature antenna is defined when each dimension of antenna have to be less than or equal 0.1λ [6]. For instance, with frequency of 868MHz of LoRa band, if the radius of the virtual sphere circumscribing the antenna is lower than 17mm, the antenna will be classified as miniature. Such requirement in term of sizes is not totally impossible to design but still be challenged while efficiency will be reduced significantly. On bright side, miniaturization of an antenna can increase quality factor, thereby narrowing bandwidth [10] and reducing interference affects, which is an important characteristic of IoT antennas.

In this research, two LoRa antennas are designed and examined at 868MHz. Their sizes fit inside a rectangular of 0.06λx0.1λ. They are called UIT and UCA antennas, named after University of Information Technology and Universite Cote d'Azur to represent their cooperation helping this work done. The antennas can serve as radiation components of LoRa devices. Concretely, these devices are used to monitor environment information inside a 12-floor building of University of Information Technology.

Next section of the paper will discuss about some previous researches, then third section shows antenna design and simulation results. Meanwhile, the fourth section is for testing fabricated products and finally, then the fifth section is for electronic circuitry. Finally, the last part will resume the research and mention about its orientation.

II. Previous works

Though LoRa is a technology with high prospect, there are not many researches about its antenna. It is one of the most critical part of communication devices, which decides quality of systems. Laboratoire d'Electronique, Antennes et Telecommunications, or LEAT, is one of the most dynamic organization contributing to the development of LoRa Technology. They also supported this research with experiences and experiments. A design of miniature antenna is taken into account from F. Ferrero and L. Lizzi of L.E.A.T. It has the geometry of an Inverted F Antenna working in LoRa 868MHz [7]. Considering there is no limit in LoRa bandwidth, their antenna has acceptable UNB. The antenna in [7] also achieved multi-band, the other is Global Positioning System (GPS) band of 1.575GHz.

To specify conditions of electrical small antenna geometry, R.W. Ziolkowski and A. Erentok have made a summary in [8]. Their research concentrated on effects of meta-material. Another research was made by Gareth A. Conway by William G. Scanlon to examine the design of 868MHz band antenna for Wireless Medical Vital Monitor device. Besides, it is also a micro-strip antenna, which is compact and low-profile.

Meanwhile, several other works to qualify LoRa system operation were also conducted. For example, Juha Petajajarvi et al have tested range and channel attenuation model of LoRa systems in reference [9]. Together with other researches, they determined the wonderful prospect of this technology.

III. Antenna Design

Two antennas will serve as logos for the device. For this purpose, micro-strip antenna is highly recommended. Obviously, the function of a miniature antenna now becomes more flexible, it is no more a sole radiator, but also a decoration. The antennas designed based on geometry of a IFA or Inverted F Antenna [10]. One of the most important criteria of an IFA is its length. As long as the antenna length equals to a quarter wavelength, it will properly function well. However, the lower the frequency is, the harder the process is due to long length. Following that criteria, designs of antenna can be tuned into almost whatever shapes desired. Still, there are several adjustments before designs can work properly. Two designs are shown in Fig 1. Higher part of device PCB is for antenna, while electrical circuit and components are embedded to lower ground.

The proposed antennas are designed by following steps:

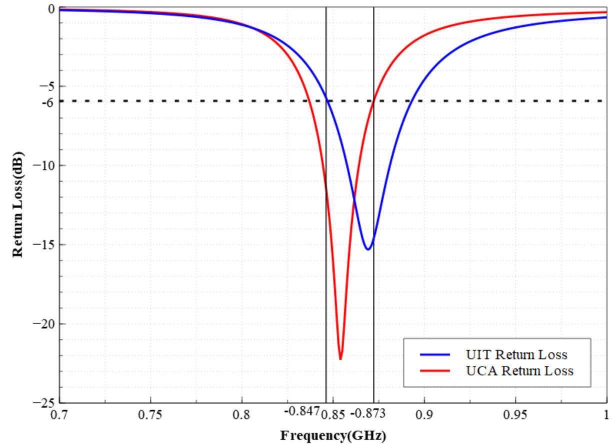

Fig. 2. Return Loss of UIT and UCA antennas

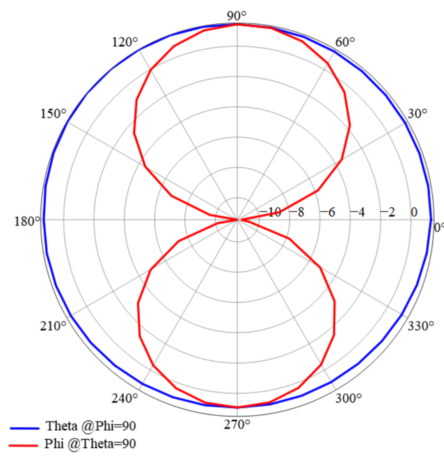

Fig. 3. Radiation pattern

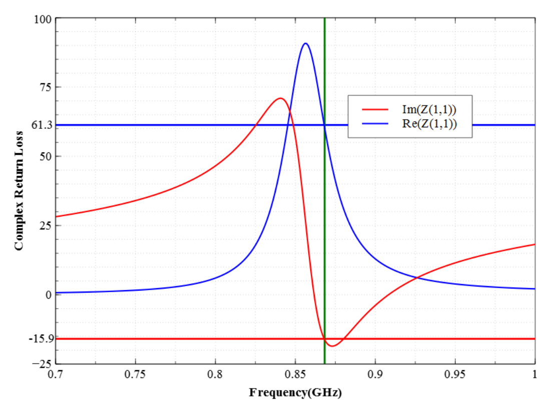

Fig. 4. Z parameters of UIT antenna

- Calculating antenna's length from preferred working frequency. In this case, an approximately-90-mm micro-strip line antenna should be obtained.

- Letters are put to fit the available space and connected by some less visible plates, so that the length of antenna is calculated by summing lengths of letters and plates.

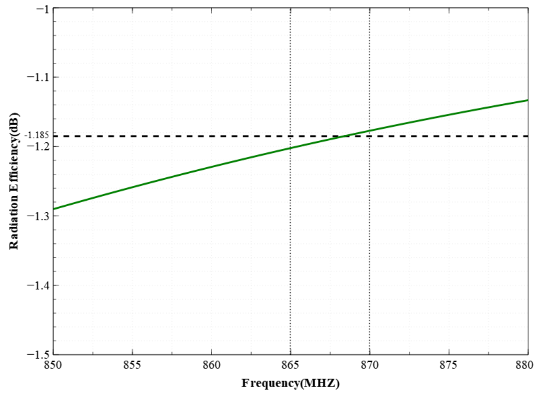

Fig. 5. Radiation efficiency of UIT antenna

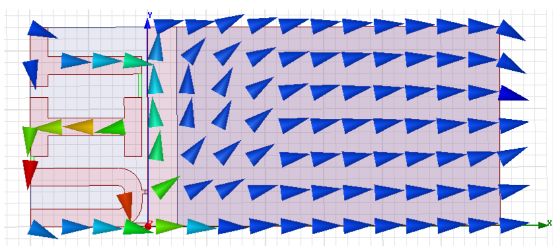

Fig. 6. Current distribution of antenna and ground

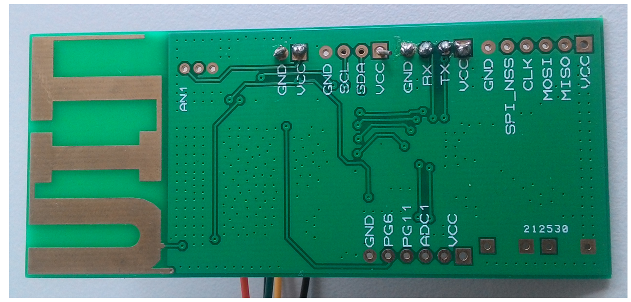

Fig. 7. UIT antenna prototype version 1: antenna layer view

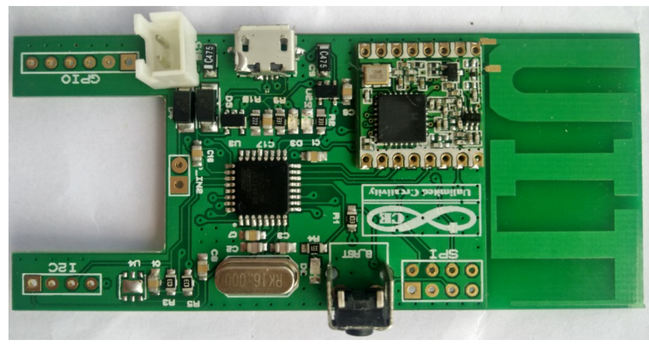

Fig. 8. UIT antenna prototype version 2: electronic circuit view

- Finally, with the nearly formed antenna, there should be some optimizations taking place before the design can perform properly.

For instance, UIT antenna achieved its length by connecting part of letter U, full length letter I and T together with two junctions. The distances between each two letters are both 2mm. Height of each letter is 19mm fitting inside available space. Both of UIT and UCA antenna designs were simulated and analyzed using High Frequency Structural Simulation (HFSS) from Ansys. However, to make this paper brief, simulation results of only UIT design is considered.

1) Reflection coefficient - S11: From Fig. 2 , a centered frequency of 868MHz is observed thanks to the length calculated in first step. When 10dB specification is concerned, a total bandwidth of 23MHz is achieved from 857MHz to 880MHz.

2) Matching condition: UIT antenna has reached maximum total gain of 0.721dB while maximum directivity is 1.91dB. Therefore, antenna efficiency is -1.19dB, in Fig. 5 good enough for electrical small antenna. Antenna impedance is nearly 50 Ohm at 868MHz, as shown in Fig. 4.

3) Gain total and Radiation pattern: The simulation has shown a vertical radiation pattern in Oyz plane. Besides, the design can yield maximum total gain of 1.55dB as in Fig. 3.

4) Current distribution: In Fig. 6 the current run through UIT antenna is observed. Along the length of antenna, the current is minimized at the end of letter T, while maximized at the short. This once again proves the resonance expected to have a quarter-wavelength equal to the length from end of letter T to the short. In addition, chassis wave mode usually should be noticed because 90 percent of energy radiated from PCB as antenna operates in low frequency (under 900MHz). However, in this situation, PCB sizes are fixed and not in full-wave or half-wave mode so chassis effect will be neglected.

IV. Prototype and Measurement Analysis

In this following Fig. 7 and Fig. 8 , the UIT antenna is presented with full circuitry. This prototype will further be used to develop LoRa system in University of Information Technology.

As can be seen in the figure, we added an thin plate at the end of UIT antenna. From our experience, it will be very useful for tuning during measurement. As the resonance is predicted to be lower in practice due to the fabrication problem, the final plate can be cut easily to reduce antenna length and reach higher frequency. Besides, the connection bridges and final plate are nearly invisible in order to beautify the antenna shape. Results of both UIT and UCA antennas are to be shown in Table I with and without tuning, in comparison with a long monopole and a short monopole.

From observation, after conducting some cuts, the antennas' performances turn better. With tunned UCA antenna, maximal gain received is 0.71 dBi, meanwhile UIT can transmit 0.8 dBi. Therefore, they are better than a short monopole while still not good as long monopole. The same thing happens to both antennas' efficiencies. After modification, UIT and UCA antenna can get -1.3dB and -1.39db efficiency, respectively.

V. Electronic Circuitry

UIT board is named after UIT University and that name also resembles UIT logo on top of it, which is actually an antenna.

TABLE I
MEASUREMENT RESULTS

Configuration	Raw Gain Max (dBm)	Efficiency (dB)	Efficiency	Gain Max (dBi)
Short Monopole	-17.4	-1.8	0.66	0.3
Long Monopole	-15.7	-0.1	0.98	2
UCA without cut	-19.2	-3.6	0.43	-1.5
UCA with cut	-18.21	-2.61	0.55	-0.51
UCA with cut plastic	-16.99	-1.39	0.73	0.71
UIT without cut	-19.3	-3.7	0.42	-1.6
UIT with cut 1	-17.5	-1.9	0.65	0.2
UIT with cut 2	-16.9	-1.3	0.74	0.8

This board covers an area of 81 x 35mm. It is designed for LoRa system developers. Hence, it is expected to yield efficient and robust performances while maintaining lowest price as possible.

To assure these properties, micro-controller Atmega328p is utilized together with LoRa module RFM95, which is in charge of transmitting and receiving data within LoRa band. Micro-controller functions at frequency 8MHz and has the input voltage of 3.3V, thereby consuming effectively low power. While developing UIT board, we can observe that it can be very useful if this board can use also input voltage 220V from electrical grid in Vietnam. Therefore, in the second version of UIT board, a large slot was made at the bottom of the board, as can be seen in Fig. 8. In this slot, a power adapter will be placed, it can transform an input voltage of 110-220V into output voltage 5V and output current 0.5A. Furthermore, a small circuit is added to make sure that this board can receive the high voltage to supply electric circuit while charging a Lipo battery at the same time without any problem.

In UIT broad, there are some input pins using different communication interfaces like SPI, I2C, GPIO, UART to help developer can have a wider range of choices upon their strength and available tools. Meanwhile, temperature and humidity sensors are integrated for getting data and linked directly to the board. To work with this board, developers are suggested to program on Atmel Studio or Arduino IDE, upload codes directly through micro-USB port.

VI. CONCLUSION

In this paper, two antennas are presented, both work with 868MHz for building a LoRa system. Two antennas are especially designed to be logos for University of Information Technology and University Cote d'Azur, where authors are working at. While modifying the antennas' geometries, some useful calculations should be done at first to make sure that antennas' performances are still good enough. After designing and calculating in simulations, two antenna prototypes are fabricated for measurements. Eventually, measurement results show that both antennas are functioning quite well with some modifications due to the differences between simulation and measurement. Table I shows that proposed antennas are better than a simple short monopole; meanwhile, they are slightly not good as a long monopole.

The circuitry integrated in ground plane of UIT board is also presented. Recently, LoRa module RFM95 is utilized thank to its power efficiency and simplicity in programming. With the functioning prototypes, further researches to build a LoRa system in University of Information Technology will be realized.

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