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A DUAL BAND COMPACT PIFA ANTENNA FOR INTERNET OF THINGS NETWORKS Sigfox, LoRaWAN and ZigBee

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ABSTRACT : In this paper, a planar inverted-F antenna (PIFA) for Internet Of Things (IOT) networks is studied. The proposed structure covers the 868MHz radio frequency band used by LoRaWAN, Sigfox, Z-Wave and ZigBee in Europe and the 2.4GHz radio frequency band used for Zigbee, Bluetooth and WiFi in all the world. The miniaturization in the antenna size is achieved by introducing a meandered microstrip line and the setup of a short line between the resonant element and the ground plane.

The antenna has compact size of 100x40x1.6mm³. The radiation patterns in the operating bandwidth are almost the same as the omnidirectional characteristics. The optimization of the antenna parameters was performed by CADFEKO, a Method of Moment (MoM) based solver.

Keywords: CADFEKO, Internet Of Things, LoRaWAN, Miniaturization, PIFA Antenna, SigFox, Wifi, ZigBee, Z-Wave.

1. INTRODUCTION

In the near future, and with the development of smart cities, the interconnection between objects becomes a great necessity. Internet of things (IoT) refers to the concept of extending Internet connectivity beyond conventional computing platforms such as personal computers and mobile devices. It is a concept that combines many technologies such as computing, sensing and networking. For companies embarking on IoT, choosing the most suitable communication network to connect their objects to the Net can become a Chinese puzzle. There are a lot of technologies, each of which has its own particularities in terms of energy consumption or price. Two major categories of networks exist on the market:

- Long-range and low-consumption networks (LPWAN : Low Power Wide Area Network), such as Sigfox, LoRaWan or cellular technologies (2G, 3G, 4G) are capable of transmitting data from one device to another over vast distances. They are used by companies that want to connect kilometers of infrastructure to the Internet or in smart cities projects for example.

- Short-range networks such as Wi-Fi, Z-Wave, ZigBee, and Bluetooth Low Energy allow to transfer data over short distances. They are widely used in home automation or in the consumer wearable market.

Sigfox is a proprietary network. In town, it has a range that can be greater than 10 kilometers, it can reach 30 or even 50 kilometers in the countryside. The devices consume very little energy to send their data on this network. However, for its low power consumption,

Sigfox can only carry very small amounts of data, between 10 and 100 bits per second maximum. Sigfox employs the differential binary phase-shift keying (DBPSK) and the Gaussian frequency shift keying (GFSK) that enables communication using the Industrial, Scientific and Medical ISM radio band which uses 868MHz in Europe and 902MHz in North America.

LoRaWan has a range that can be greater than 2 kilometers in town, it can reach 45 kilometers in rural areas. This protocol also has the advantage of being developed in a private network so that a company can manage it itself. Only 0.3 to 50 kilobits per second can pass through this network, which is (just like Sigfox) ideal for sensors periodically emitting a small amount of temperature data, geolocation, or pressure for example. LoRaWan uses radio frequency bands like 169 MHz, 433 MHz, 868 MHz in Europe and 915 MHz in North America.

Z-Wave is a wireless communications protocol used primarily for home automation. It is a mesh network using low-energy radio waves to communicate from appliance to appliance, allowing for wireless control of residential appliances and other devices, such as lighting control, security systems, thermostats, windows, locks, swimming pools and garage door openers. In open area, it has a range of 100 meters and it can only carry very small amounts of data. Z-Wave operates at 868 MHz in Europe, at 908.42 MHz in the North America and uses other frequencies in other countries depending on their regulations.

ZigBee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to

create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection. Hence, Zigbee is a low-power and low data rate. Zigbee operates in the industrial, scientific and medical (ISM) radio bands: 2.4 GHz in most jurisdictions worldwide; though some devices also use 784 MHz in China, 868 MHz in Europe and 915 MHz in North America and Australia, however even those regions and countries still use 2.4 GHz for most commercial Zigbee devices for home use. Data rates vary from 20 kb/s (868 MHz band) to 250 kb/s (2.4 GHz band) [1-6].

The growing demand to have small, compact, and economical wireless systems like those used in IOT, has increased the need to have small, low cost microstrip antennas [7-9]. The main limitations for this antenna was to create a miniaturized, low cost planar microstrip antenna, which could easily fit in every small available space. In order to get a low cost economical antenna, the use of extra passive lumped components like inductors and capacitors should be avoided. And the antenna should be matched without the use of additional matching network [8].

There are many techniques used to make antenna structures smaller, which include shortening the radiating part to the ground plane, capacitive loading, inserting slots as inductive loading, the use of PIFA technique [9-13] etc.

The purpose of this paper is the description of a PIFA antenna operating in two frequency bands used in the IOT Networks: The 868MHz band used by Sigfox, LoRaWan, Z-Wave and Zigbee and 2.4GHz band used by ZigBee and other wireless technologies like Wifi and Bluetooth.

2. ANTENNA DESCRIPTION

As shown in figure 1, the designed antenna is printed on a rectangular substrate having a permittivity relative of 4.4, a length L_s and a width W_s figure 1(c). The substrate is placed at a height h from the ground plane. The last has a length L_g and a width W_g . As shown in figure 1(b), the ground plane is not placed under the substrate. The antenna is fed by a microstrip line having a width of W_f . The shorting plate has a width W_{cc} is placed from the microstrip line by P_{cc} and from the edge of the substrate by L_{cc} (Figure 1(c and d)).

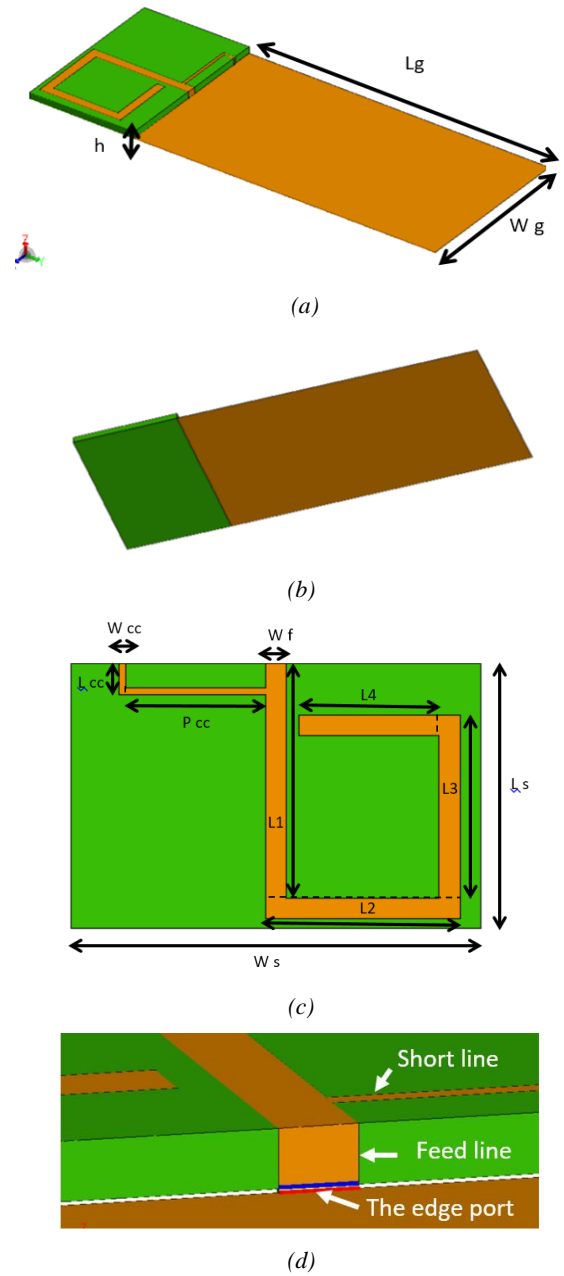


Fig.1. (a) 3-D geometry of the proposed antenna (b) rear view (c) Patch antenna geometry as seen from above (d) the feeding mode and the short line

3. ANTENNA PERFORMANCES

After a parametric study, the optimized parameters are summarized in table 1. The main parametric studies was the variation of the total length of the radiating element ($L_1 + L_2 + L_3 + L_4$), the variation of L_4 from 10 to 13.75 allows us to have the optimal value ($L_4=13.75\text{mm}$) which gives us a dual behavior (the 868 MHz and 2.4GHz bands) (figure 2).

Table. 1: Antenna parameters and their values

Parameter	Value (mm)	Parameter	Value (mm)
Lg	75	L3	18
Wg	40	L4	13.75
h	1.6	Wf	2.04
Ws	40	Pcc	15
Ls	26	Wcc	0.6
L1	23	Lcc	3
L2	19		

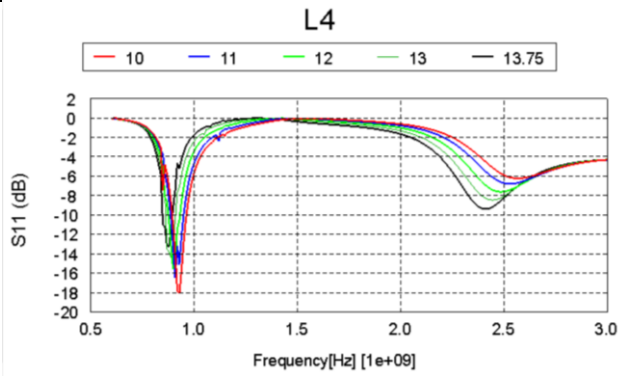


Fig.2. The effect of L4 values on the antenna behavior

When L4=13.75mm, another parametric study was performed. As shown in figure 3, when we vary the value of the shorting plate position (Pcc), we observe that when Pcc=16mm, we have a good impedance matching for the band of 2.4GHz and a bigger bandwidth.

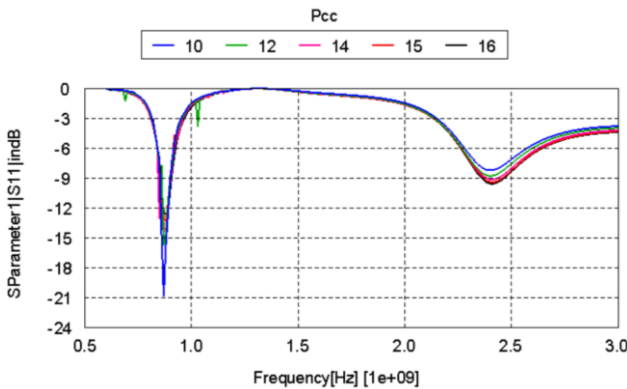


Fig.3. The effect of Pcc values on the antenna behavior

As shown in figure 4, the proposed antenna has two resonant frequencies in the range of 600MHz to 3.6GHz. The first resonance frequency is 868MHz and the second is 2.4GHz. To calculate the bandwidth for each resonance frequency, we consider -6dB as a limit for the reflection

coefficient S_{11} . So, the two -6dB bandwidth are respectively 70MHz (from 840MHz to 910 MHz) and 390MHz (from 2.26 GHz to 2.65 GHz). The maximum gains of the antenna vary between 1.9 and 2.1dBi for the first bandwidth and between 3.7 and 4.4 for the second one (figure 5).

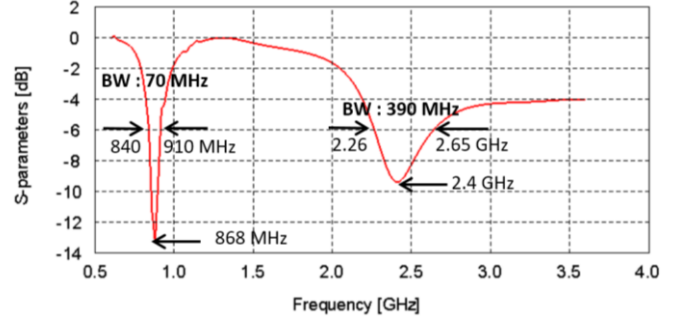


Fig.4. Simulated S_{11} versus frequency

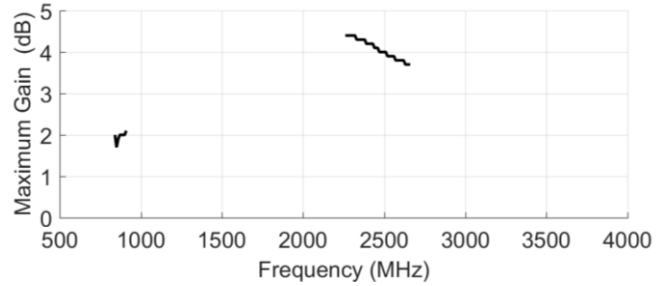
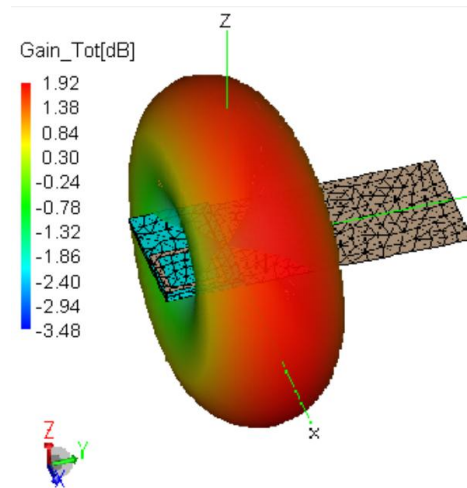
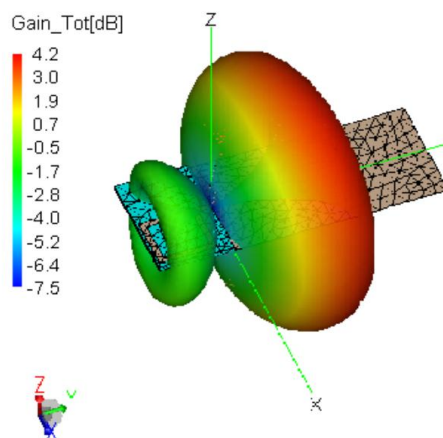


Fig.5. Simulated Maximum Gains versus frequency for the operational bands

Figure 6 shows the 3D gain pattern for the two frequencies 868MHz and 2.4GHz. We observe that the maxim gain for 868MHz is 1.92dBi and for 2.4GHz is 4.2dBi.



(a)Fr=868MHz



(b) $f_r=2.4\text{GHz}$

Fig.6. Simulated gain pattern for the two resonance frequencies (a) 868MHz and (b) 2.4GHz

The performances of this antenna make it a good solution for IOT networks such as Sigfox, LoRaWan, Z-Wave and Zigbee (868MHz band) and ZigBee (2.4 GHz band).

4.CONCLUSION

In this paper, a compact PIFA antenna for IOT networks application was proposed. The antenna has a small volume, an adequate gains which makes it suitable for use as an internal antenna. The simulated results show that the bandwidth of the proposed antenna covers the two important bands used in IOT networks: the 868 MHz band used in Europe by Sigfox, LoRaWan, Z-Wave and ZigBee networks and the 2.4GHz band used by ZigBee.

In the next work, fabrication and measurement should be done to confirm the simulated results. Also, more refinements should be done to cover other bands for the IOT networks.

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