Compression Studies on LoRa Antenna Design for IoT Applications

Nurul Syahira Binti Nordin, Woo Ying Yee, Md Saeed Hasan Joarder, Badrul Hisham Bin Ahmad

Abstract: ***In this paper, a review on the LoRa antenna design for IoT application is studied. The expansion of the Internet of Things (IoT) has led the industry to develop new communication solutions, as current protocols are inadequate in terms of scope and energy efficiency to satisfy IoT requirements. Before studying antenna design, some background LoRa and IoT were discussed at beginning of the paper. LoRaWAN is an open LPWAN standard developed by LoRa Alliance and has main characteristics such as low energy consumption, long-range communication, builtin protection and GPS-free positioning. Besides, a comparison according to the method, resonance frequency, material, size of the antenna and the output is shown in the form of table. In addition, the strength and the weakness of each of the antenna design were discussed before the end of the paper.***

Keywords: LoRa, IoT, antenna design, resonance frequency.

I. INTRODUCTION

As the idea of the Internet of Thing (IoT) was introduced, the communication between machines and objects via internet has spread across the world. The concept of IoT has been implemented in the areas of smart cities, smart agriculture, industrial and others. Several types of technology have been developed for the purpose of wireless communication, such as Bluetooth, Wi-Fi, 3G, and 4G. However, every technology has its own pros and cons. A good communication system will have high data rate and low power consumption when transmitting the data from source to destination. Besides, a good communication system can also to have a large coverage area. Considering these characteristics, Wi-Fi and 3G able to provide high data rates, but the coverage is limited, and both technologies are high power consumption [1][2]. Instead, Bluetooth can produce higher power efficiency. However, it can only works in few meters away [3]. After few decades of development, wireless low power(LPWA) technology such as LoRa, Narrowband Internet of Things (NB-IoT) and TV White Space (TVWS) dominate the construction of global IoT networks. LoRa system is a wireless technology developed by Cycleo of Grenoble, France, and acquired by Semtech in 2012. LoRa system was built based on the industrial, scientific and medical fields [4]. LoRa network can cover a very large area with the function of multiple nodes. This system able to transmit and receive data within a range of 20km in line of sight condition. In addition, LoRa can be used up to 10 years without battery replacement. This feature able to provide the reliability to the system. However, LoRa system only able to transmit data up to 50kps [5]. Although the LoRa system only can provide low data rates, but it is proved to be sufficient for most of IoT applications. Since LoRa system is define as the physical layer of the protocol, it does not have network layer. Therefore, researchers had developed LoRaWAN as the upper layer of the network. LoRaWAN is media access control (MAC) layer. This layer will acts as a network layer protocol for managing communication between LPWAN gateways and end-node devices as a routing protocol that maintained by the LoRa Alliance [6]. In short, LoRaWAN is the communication protocol and the system architecture for the network, while the LoRa physical layer allows the long-range communication link. The LoRa device in the system are asynchronous and will transmit the data when there is a new data available to send. Data will be forward from one end node to multiple gateways which helps to send the data to the centralization network server. Once the server received the data, it will perform filtering duplicate data, security checks and manage the network. Finally, the received data will be forward to the application servers. For the operating system within the LoRa device such as operating frequency, data rate and power for all devices will be manage by LoRaWAN [7]. LoRaWAN uses license free sub-gigahertz radio frequency band at different country of the world. In Europe, LoRa operates at frequency 433MHz [8] and 868MHz. However, the operating frequency of LoRa system in the United States is 915MHz.

In this paper, few LoRa antenna design journal is studied and a review will be come out at the end.

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II. METHODOLOGY

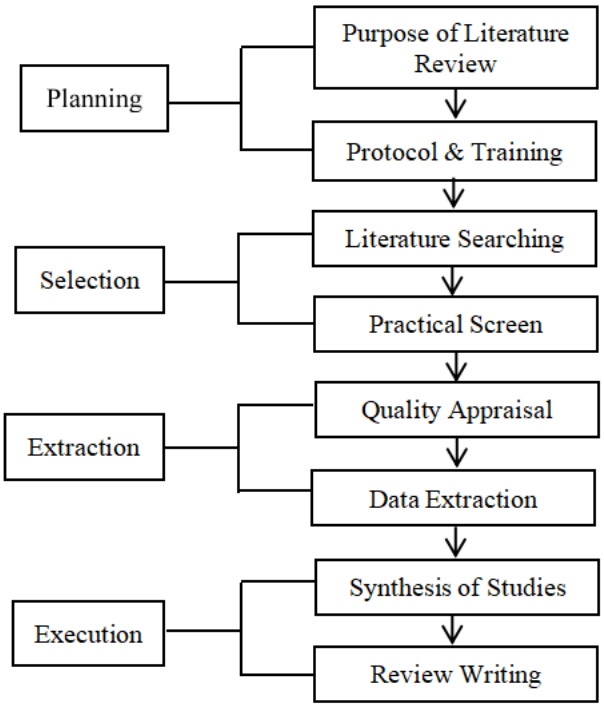

Fig. 1 Flow Chart of Systematic Literature Review Development.

As an anchor for an academic thesis or dissertation, the literature review is necessary to synthesize the understanding of researcher on their particular project, to test the rigorous research dedication of the researcher, justify future research, and act as the scholarly tradition and etiquette. Generally, the review was conducted by only 4 stages, which are planning, selection, extraction and execution. However, a standardize methodology which consisted of 8 steps as "Figure 1" are essential during conducting a systematic review for a review to be scientifically rigorous.

First, every researcher must know the purpose of the literature review. In this step, the purpose and the anticipated goal of the review must be clearly identified in order to explicit to its readers. As in all empirical work, the first step of a project should be to consider whether the methodology to be employed is the most appropriate one. Therefore, determining the purpose of the literature review would resolve the concern. Second, protocol and training is critical if the review was prepared by a group of researchers. All of the researchers must be completely clear and share the common consciousness about the detailed procedure to be followed. This requires both a written, detailed protocol document, and training for all reviewers to ensure consistency in the execution of the review. Third, searching for the literature begins the selection stage, which involved of searching for and the studies that will be include in the study, and eliminating several studies that do not meet the requirements. Hence, this step require researcher to be explicit in describing the details of the literature search, and needs to explain and justify how the comprehensiveness of the search was assured.

Forth, practical screen which also known as screening for inclusion must be undergone by researcher to eliminate the studies without further examination and keep those that considered for review. The studies that been eliminated must with practical reasons for non-consideration, and justification of comprehensive result that would provide the practical exclusion criteria.

Fifth, quality appraisal is the step after practical screening which used for exclusion screening. Quality of all studies will be focus in this step by explicitly spell out the criteria for judging which articles are of insufficient quality to be included in the review synthesis. The appraisal was divided into two groups, which are quantitative that used to test or confirm theories and assumptions while qualitative used to understand concepts, thoughts or experiences.

Sixth, data extraction of all literature will be performed through systematically extract the applicable information from each study for synthesis step.

Seventh, synthesis of studies to combine all studies by using appropriate techniques, whether quantitative, qualitative, or both in order to make comprehensive sense out of a large number of studies is carry out. At the end of this stage, a completely and polished synthesis of information will be generated to ease the review writing step.

The final step of the literature review is writing the review. The most important thing in the review writing is the process of the review development to be documented in sufficient detail.

III. RESULT

Table 1 Comparison between Different Antenna Design and Performance for LoRa [9].

Ref No	Size	Substrate used	Resonance frequency	Efficiency (dB)	Gain (dB)
Ref[9]	34*80*0.8	FR4	868 MHz	-1.39	0.8
Ref[10]	30*90*1.6	FR4	433 and 868MHz	-6(433MHz) -4.5(868MHz)	-4.1 -2.2
Ref[11]	125*20*1.6	FR4	410-441MHz	Not stated	-6 to -3.2 1dB
Ref[12]	45*42.5*0.8	FR4	868 MHz	Not stated	0.4

In journal reference [9], the miniature antenna was presented in two different designs which are UIT form and UCA form. The antenna was printed on FR4 in the dimension of 34mm*80mm*0.8mm. The antennas designed based on geometry of Inverted F Antenna (IFA). In order to ensure the antenna always work, the antenna length is always equal to a quarter of the wavelength. However, this design would face a problem when the frequency is lower. When the frequency is low, the harder the process due to the long length. In result, this journal only shows the simulation for the UIT design. The total bandwidth of 23MHz is achieved from 857MHz to 880MHz. Besides, the maximum total gain has reached 0.721dB while maximum directivity is 1.91dB.

On the other hand, the vertical radiation pattern in Oyz plane was presented with total gain of 1.55dB for the radiation pattern. From the journal of reference [10], a miniature antenna was design for coverage 433MHz and 868MHz. This antenna design in this journal used UCA design and printed on 30mm*90mm*1.6mm FR4 board. A lumped element was inserted between the feeding line and the UCA shape. Besides, a capacitor was placed between the "A" letter and the feeding line. The inductance parameter able to tune the resonance frequency at 433MHz. In order to tune the higher resonance around 868MHz, the capacitance will tune both 433 and 868MHz resonance. In short words, two resonance frequencies able to be achieved by controlling the inductance and capacitance value. From the result obtained from the study, the resonance frequency of 433MHz could be obtained as the inductor value is 22nH and the capacitor value is 0.8F. While inductor value is 23.1nH and capacitor value is 0.8F, resonance frequency of 868MHz could be obtained. The total efficiency at 433MHz is -5.8dB while total efficiency at 868MHz is -4.3dB.

Reference [11] presents a miniaturized printed inverted-F antenna (PIFA) with a LoRa sensor node, which is embedded on a circuit board with a size of 125mm*20mm*1.6mm. Since wavelength for the 410MHz is 732mm, it is nearly 6 times side of the PIFA antenna area. Therefore □/4 is used as the basic antenna structure. However, PIFA has an inherent nature of narrow bandwidth and its fractional bandwidth decreases further with the reduction of antenna height[13]. Therefore, this journal used the method of cutting slot on the ground in order to enhance the bandwidth of the PIFA by create another resonance. By cutting slots on the ground, the resonant frequency of the PIFA is reduced from around 450 MHz to 410MHz. Nevertheless, the voltage standing wave ratio (VSWR) generate by whole structure is less than 3, and the bandwidth was increase from 402.4 MHz to 441.6 MHz by adjusting the resonance of the slotted ground to a frequency neighboring with that of the PIFA.

In journal [12], a novel antenna that suit to LoRa was introduced. The size of the antenna is 42.5mm * 45mm * 0.8mm. By using wire patch antenna, it able to reduce the height of the dipole and the area of the ground patch while obtaining a dipole like radiation pattern. The proposed antenna base on wire-patch type has a symmetrical geometry with two short strips and a hollow patch. This hollow patch antenna come with some disadvantages of lower resonance frequency and narrow bandwidth compared to plain patch. A tunable capacitor was integrated at the end of the strip. This capacitor is used to help antenna to reach the desired resonance. Several values of the capacitor tested such as 0.7pF, 1.0pF, and 1.3pF. In this case, the capacitor value of 1.0pF is suitable for the resonance frequency of 868MHz. Besides, some of the parametric studies are made. The parametric studies included adjustment of the height and width of the antenna, size and others. In final, the journal obtained total gain is maximized in all direction, with value of approximately 0,63dB. In vertical direction, there is minimum gain transmitted. Therefore, when antenna is placed in parallel with human body surface, the effect is expected to be reduced significantly.

IV. DISCUSSION

The advantage of the studies in reference [9] is more than one antenna design was proposed. There were two types of antenna proposed and each antenna have difference gain. Besides, a thin plate was added at the end of the antenna 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. For the others three journal, the adjustment of the resonance frequency was done by using capacitor or inductor. Although the size of this antenna is very good for the portable devices which fit inside a very small volume, this design is not suitable for wearable devices because antenna efficiency can be reduced due to the vicinity of user hands coinciding with vertical pattern.

In the journal [10], the antenna design for the LoRa application able to cover both 433MHz and 868MHz within one design. This specification of the antenna able to make it different with others antenna. By introducing the lumped element and capacitor inside the USA design, the resonance frequency can be tune from 433MHz to 868MHz. This helps user to save their cost and more convenient when applying this antenna to the LoRa application. However, the size of the antenna is quite big compared to the previous one. Therefore, this antenna not able to apply at portable devices.

Based on journal in reference [11], this antenna design is applicable for the LoRa device within the frequency range of 410 to 441MHz. When compared with the other three designs, the result of this design can be regarded as ordinary antennas. This antenna only able to work under one LoRa frequency and the size of the antenna itself is consider as big. In addition, the gain value obtained by this design can also be obtained by other methods.

Last but not least, the antenna design by using wire-patch antenna able to provide better design in term of the size and obtaining better azimuthal polarization which reduce the effects from human body. Besides, the polarization of this antenna is circular, therefore, the loss from the polarization mismatch is minimized. However, the bandwidth of the antenna is become narrow due the hollow patch antenna was introduced. Besides, this antenna not able to have two different resonance frequency when applying in the LoRa application.

V. CONCLUSION

In this paper, a few journals related to antenna for LoRa application were reviewed. Each study has their own way or method to design the antenna by using LoRa. However, most of the antenna design only applicable for one resonance frequency. The resonance frequency can achieve by using tunable capacitor. For the antenna able to cover both 433MHz and 868MHz, the size of the antenna is not suitable for the portable devices. In conclusion, the design and the specification of the antenna always depend on the application.

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REFERENCES

1. H. Karjaluoto, “An Investigation of Third Generation (3G) Mobile Technologies and Services", May, 2014.
2. V. T. Conference, *2000 IEEE 51 st Vehicular Technology Conference*. 2000.
3. N. Todtenberg and R. Kraemer, “Ad Hoc Networks A survey on Bluetooth multi-hop networks”, *Ad Hoc Networks*, vol. 93, 2019.
4. B. Hammi, R. Khatoun, A. Fayad, and L. Khoukhi, “Internet of Things (IoT) Technologies for Smart Cities Internet of Things (IoT) Technologies for Smart Cities”, 2017.
5. R. G. P. V. K, “Agriculture Monitoring with Lora Based Wireless Sensor Networks”, vol. 7, no. 02, 2019, pp. 650–655.
6. M. Usmonov and F. Gregoretti, “Design and implementation of a LoRa based wireless control for drip irrigation systems Design and Implementation of a LoRa Based Wireless Control for Drip Irrigation Systems”, 2019.
7. D. Bankov, E. Khorov, and A. Lyakhov, “On the Limits of LoRaWAN Channel Access”, November, 2016.
8. J. Buckley *et al.*, “Compact 433 MHz antenna for wireless smart system applications Compact 433 MHz antenna for wireless smart system applications,” April, 2014, pp. 2013–2015.
9. L. H. Trinh *et al.*, “Miniature Antenna for IoT Devices Using LoRa Technology”, 2017, pp. 170–173.
10. F. Ferrero and S. Antipolis, “Dual-band LoRa Antenna : Design and Experiments”, pp. 243–246.
11. Q. Zhang and Y. Gao, “Embedded Antenna Design on LoRa Radio for IoT Applications”, pp. 2–4.
12. L. H. Trinh, T. Q. K. Nguyen, H. L. Tran, P. C. Nguyen, N. V Truong, and F. Ferrero, “Low-profile horizontal omni-directional antenna for LoRa wearable devices”, 2017, pp. 136–139.
13. H. T. Chattha, M. K. Ishfaq, Y. Saleem, Y. Huang, and S. J. Boyes, “Band-Notched Ultrawide Band Planar Inverted-F Antenna”, 2012.

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