IRJCS: International Research Journal of Computer Science
Volume 11, Issue 01, January 2024

ISSN: 2393-9842
https://www.irjcs.com/archives

On the Robustness to Doppler Rate of the Modified LoRa using two Spreading Factors

Jung Suk Joo
Dept. of Electronics Engineering,
Hankuk University of Foreign Studies, Korea
jjs@hufs.ac.kr

Publication History
Manuscript Reference No: IRJCS/RS/Vol.11/Issue01/JACS10081
Research Article | Open Access | Double-Blind Peer-Reviewed | Article ID: IRJCS/RS/Vol.11/Issue01/JACS10081
Received: 01, January2024 | Revised: 08, January 2024 | Accepted: 16, January 2024 | Published Online: 22, January 2024
http://www.irjcs.com/volumes/Vol11/iss-01/01.JACS10081.pdf
Article Citation: Jung(2024).On the Robustness to Doppler Rate of the Modified LoRa using two Spreading Factors. IRJCS::International Research Journal of Computer Science, Volume 11, Issue 01 of 2024 pages 01-05.
https://doi.org/10.26562/irjcs.2024.v1101.01
BibTeX Jung@2024Robustness
Academic Editor-Chief: Dr.A.Arul Lawrence Selvakumar, AM Publications, India

Abstract: In [1], we proposed a modified LoRa using two spreading factors (SF's) in order to independently set the frequency difference of adjacent LoRa symbols and the LoRa symbol period, and demonstrated that the use of two spreading factors could make it less sensitive to sampling frequency error while enabling low power transmission. In this paper, as an extension of [1], we will show that our scheme has also robustness to the Doppler rate through computer simulations.
Keywords: Modified LoRa using two SF's, LEO satellite, Doppler rate

I. INTRODUCTION

In recent years, the pace of development of internet of things (IoT) technology has been accelerating, and its application areas are continuously expanding. In particular, efforts are being made to mount IoT base stations on low earth orbit (LEO) satellites to support a wide area, and long range (LoRa) technology has been studied as a candidate for physical layer of LEO satellite IoT communications [2]-[4].

Because LEO satellites orbit at altitudes of less than 2,000 km above the ground, they have the advantage of lower power consumption and relatively shorter propagation delay than geostationary satellites. However, they suffer from Doppler shift and Doppler rate due to their fast movement speed [5]. Thus, it is very important to properly compensate the Doppler effects in communication systems using low-orbit satellites.

In [1], in order to independently set the frequency difference of adjacent LoRa symbols and the LoRa symbol period, we proposed a modified LoRa using two SF's, one of which is used in the transmission data generation process and the other in the LoRa modulation process independently. It has backward compatibility with the conventional LoRa, and is less sensitive to sampling frequency error while enabling low power transmission. In this paper, as an extension of [1], we will show that our proposed scheme has also robustness to the Doppler rate through computer simulations.

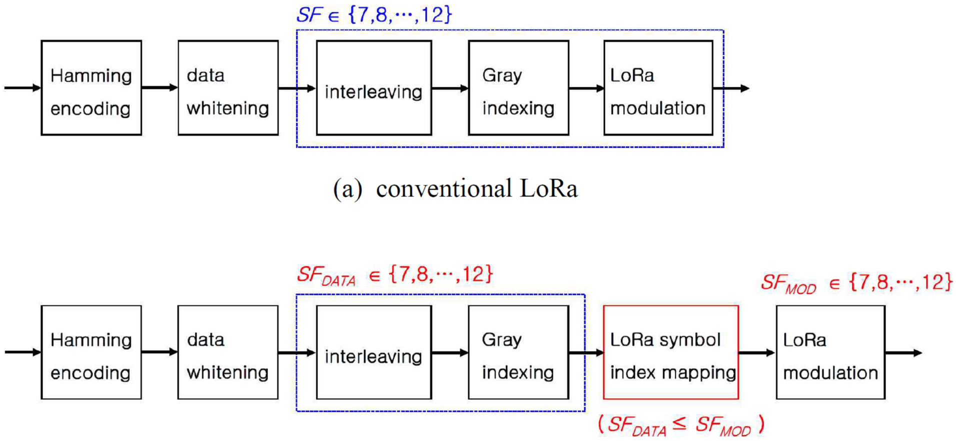
II. Modified LoRa using Two Spreading Factors [1]

In this paper, we consider the LoRa PHY structures described in [1], whose block diagrams are shown in Fig. 1. In the conventional LoRa, a spreading factor (SF) is used in both some parts of the transmission data generation process (specifically, interleaving and gray indexing) and LoRa modulation. Defining BW and SF as a system bandwidth and a spreading factor of the conventional LoRa system, respectively, a LoRa symbol carries SF bits information each time and is transmitted by changing the starting frequency of the base chirp signal according to the digital information. In order to transmit SF bits information at a time, 2^{SF} LoRa symbols should be defined, and their frequency functions can be expressed as

$$f_k(t) = \left(\frac{BW}{T_{sym}}\right)t + f_{o,k}, \qquad k = 0,1,\ldots,2^{SF}-1 \tag{1}$$

Where k is an LoRa symbol index; $f_{o,k}$ denotes the starting frequency of the k-th LoRa symbol; T_{sym} represents the LoRa symbol period.

Since BW is divided into 2^{SF} equal intervals and assigned as the starting frequency of each LoRa symbol, $f_{o,k} = -BW/2 + k\Delta f$ where the frequency difference of adjacent LoRa symbols is set at $\Delta f = BW/2^{SF}$. In addition, in order to ensure that LoRa symbols are orthogonal to each other in the symbol interval, the LoRa symbol period, T_{sym} is set to $1/\Delta f$ (that is, $T_{sym} = 1/\Delta f = 2^{SF}/BW$). In the modified LoRa (in Fig. 1 (b)), two spreading factors defined as SF_{DATA} and SF_{MOD} are used: SF_{DATA} only affects the transmission data generation process; SF_{MOD} only affects the LoRa modulation. Since information data is grouped by SF_{DATA} bits and mapped to LoRa symbols in the modified LoRa, $2^{SF_{DATA}}$ orthogonal LoRa symbols are defined and the frequency difference of adjacent LoRa symbols is set at $\Delta f = BW/2^{SF_{DATA}}$. On the other hand, the LoRa symbol period is independent of SF_{DATA} and is affected only by SF_{MOD}, and thus T_{sym} in the modified LoRa is set to $T_{sym} = 2^{SF_{MOD}}/BW$.



(b) modified LoRa using two SF's

Fig. 1 PHY layer block diagrams of the conventional LoRa and the modified LoRa using two SF's [1].

It was demonstrated in [1] that low-power transmission can be achieved while being insensitive to sampling frequency error, by setting SF_{MOD} greater than SF_{DATA} in the modified LoRa. As an extension of [1], we will show here that the modified LoRa using two SF's has also robustness to the Doppler rate.

III. SIMULATION RESULTS

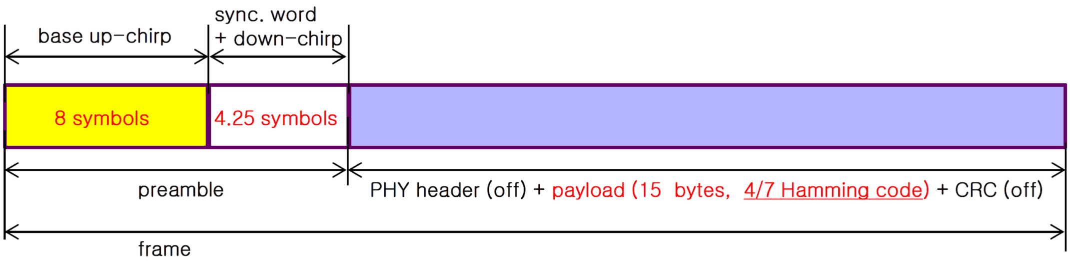
Since we consider the LEO satellite communication environment, it is assumed that the magnitude of the received signal is not distorted, and the influence of the Doppler effect is only taken into account here. Thus, the channel phase function $\theta(t)$ due to the Doppler effect can be expressed as follows [3].

$$\theta(t) = 2\pi\left(f_D t + \frac{\alpha}{2}t^2\right) + \theta_o \tag{2}$$

where θ_o is an initial phase, and f_D and α are the Doppler shift and the Doppler rate, respectively.

The LoRa PHY frame is composed of {preamble, PHY header, PHY payload, CRC} [6], and the frame structure used in the simulations is described in Fig 2 . The specific simulation parameters are as follows: center frequency is 915 MHz in ISM band; channel bandwidth, BW is set at 125 KHz; the length of PHY payload is fixed at 15 bytes; the code rate is set to 4/7—that is, (7,4) hamming code is used. In addition, using the notation of $SF = (SF_{DATA}, SF_{MOD})$ for the modified LoRa using two SF's, we fixed SF_{MOD} at 12 for low power transmission, while varying SF_{DATA} in $\{8,10,12\}$. Here, the modified LoRa of $SF = (12,12)$ is equivalent to the conventional LoRa of $SF = 12$. Note that as we reduce the value of SF_{DATA}, we can make the frequency difference of adjacent LoRa symbols be larger ($\Delta f = BW/2^{SF_{DATA}}$). In addition, we consider the LoRa interleaver in which zero bits are padded to fill it up. Since the Doppler shift, f_D of LEO satellites is very large due to the high moving speed of them, it should be estimated and compensated by using the preamble for reliable communications. Thus, in this paper, we assume perfect Doppler shift compensation, and only take into account the effect of Doppler rate, α in (2).

ISSN: 2393-9842
https://www.irjcs.com/archives



SF = (8,12) : 8 + 4.25 + 28 = 40.25 [sym] ➔ 1 frame = 1.32 sec
SF = (10,12) : 8 + 4.25 + 21 = 33.25 [sym] ➔ 1 frame = 1.09 sec
SF = (12,12) : 8 + 4.25 + 21 = 33.25 [sym] ➔ 1 frame = 1.09 sec

Fig. 2 Frame structure used in the simulations

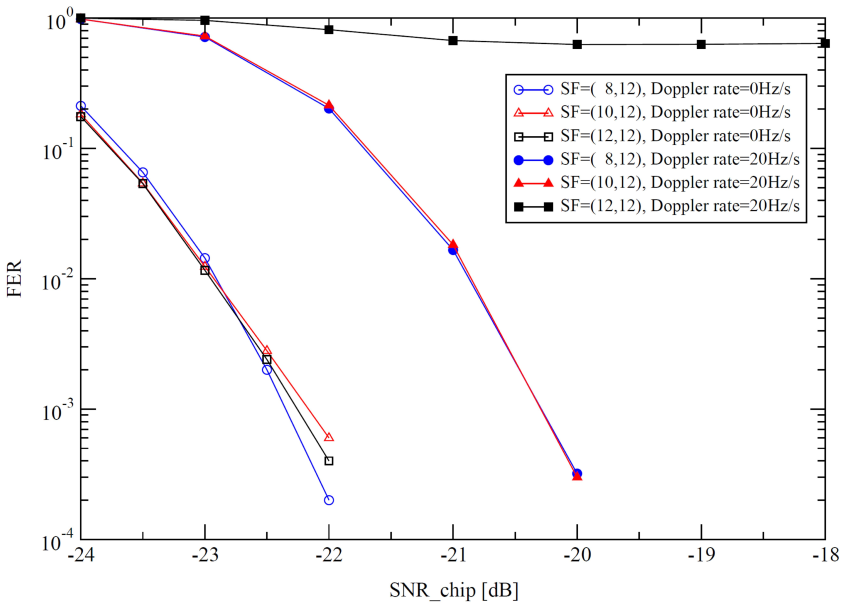


Fig. 3 FER Performance comparison for both cases of $\alpha = 0$ and $\alpha = 20$ Hz/s.

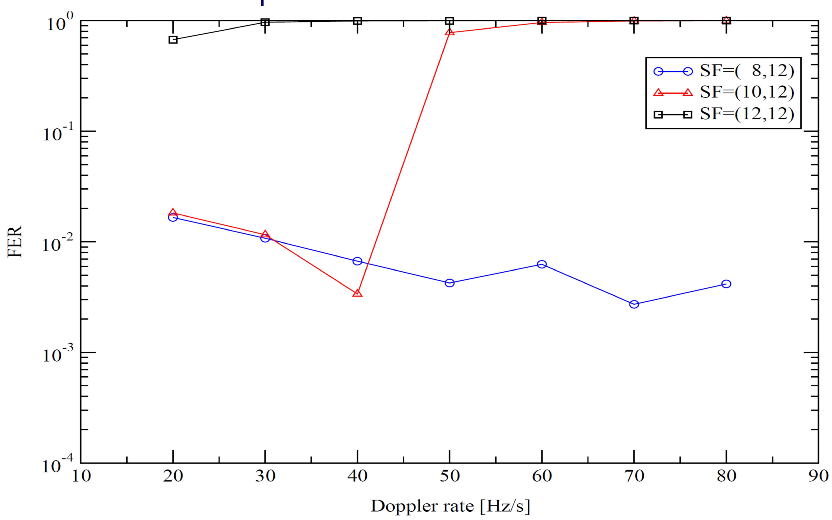


Fig. 4 FER Performance comparison according to Doppler rate (chip SNR = -21 dB).

Figure 3 shows frame error rate (FER) performance comparison between the conventional LoRa and the modified LoRa for both cases of $\alpha = 0$ and $\alpha = 20$ Hz/s. As expected, the conventional and the modified LoRa's revealed similar performance when the Doppler rate is zero. However, when the Doppler rate is 20 Hz/s, the conventional LoRa ($SF = (8,12)$ case) does not work—i.e., FER is almost one for all range of SNR.

On the contrary, both of the modified LoRa's ($SF=(8,12)$ and $SF=(10,12)$ cases) perform well. Figure 4 compares FER performances due to the Doppler rate, while the chip SNR was fixed at -21 dB. It can be seen from the results that the modified LoRa becomes more robust to the Doppler rate by reducing the value of SF_{DATA}.

IV. CONCLUSION

In this paper, as an extension of [1], we demonstrated through computer simulations that we could design the modified LoRa to be robust to the Doppler rate by adjusting SF_{MOD} and SF_{DATA}, since SF_{MOD} and SF_{DATA} determine, independently and respectively, the length of the frame and the frequency difference of adjacent LoRa symbols. Thus, we expect that the modified LoRa using two SF's could be useful for LEO satellite-based IoT applications.

ACKNOWLEDGMENT

This work was supported by Hankuk University of Foreign Studies Research Fund of 2023.

REFERENCES

[1]. J.S.Joo, "A modified LoRa using two spreading factors," Journal of The Institute of Electronics and Information Engineers, vol. 61, no. 2, Feb. 2024 (to be appeared, in Korean).
[2]. A.A. Doroshkin, A. M. Zadorozhny, O. N. Kus, V. Y. Prokopyev, and Y. M. Prokopyev, "Experimental study of LoRa modulation immunity to Doppler effect in CubeSat radio communications," IEEE Access, vol. 7, pp. 75721-75731, 2019. https://doi.org/10.1109/ACCESS.2019.2919274
[3]. G.Colavolpe, T.Foggi, M.Ricciulli, Y.Zanettini, and J.Mediano-alameda, "Reception of LoRa signals from LEO satellites," IEEE Trans. Aerosp. Electron. Syst,. vol. 55, no. 6, pp. 3587-3602, Dec. 2019. https://doi.org/10.1109/TAES.2019.2909336
[4]. L. Fernandez, J. A. Ruiz-de-azua, A. Calveras, and A. Camps, "Accessing LoRa for Satellite-to-Earth communications considering the impact of ionospheric scintillation," IEEE Access, vol. 8, pp. 165570-165582, 2020. https://doi.org/10.1109/ACCESS.2020.3022433
[5]. I.Ali, N.Al-dhahir, and J. E. Hershey, "Doppler characterization for LEO satellites," IEEE Trans. Communication., vol. 46, no. 3, pp. 309-313, Mar. 1998. https://doi.org/10.1109/26.662636
[6]. O.B.A. Seller and N. Sornin, "Low power long range transmitter," US Patent 9,252,834, 2016.