SIMULATIONS OF CHIRP SPREAD SPECTRUM FOR LEO SATELLITE COMMUNICATION

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Abstract

IoT service using low-earth orbit (LEO) satellite is considered as one of the most important key technologies to realizing global coverage. There are some candidate technologies to implement satellite IoT services: LoRa, Ingenu, Sigfox, etc [1-2]. Among them, LoRa, using chirp-spread spectrum (CSS), has the advantage of robustness against Doppler frequency offset. In this paper, we design the link level simulator for performance evaluation of CSS in LEO satellite communications. Considering LEO satellite channel model, we analyze the packet error rate (PER) for various spreading factors (SF) and frequency offsets. Simulation results show that CSS has robust performance under the severe Doppler frequency offset conditions.

1. Transmitter design

In this paper, we use CSS as a modulation scheme [3]. Let e_{SF} denote the spreading factor. e_{SF} bits are modulated to a CSS symbol which is called a chirp. A chirp is a sinusoidal signal which frequency increases or decreases over time. The desired information for signal transmission is represented by the cyclic shift of the chirp signal. Let T be the symbol duration. Mathematically, chirp is expressed as

$$p(t) = \begin{cases} \cos\left(2\pi t\left(f_0 + \mu\left(t - \frac{T}{2}\right)\right)\right), & 0 \le t \le T, \\ 0, & otherwise, \end{cases} \tag{1}$$

where μ is sweep rate which is defined as BW/T and f_0 is a center frequency. The chirp signal corresponding to time shift a is given by

$$p_a(t) = \begin{cases} \cos\left(2\pi t\left(f_0 + \mu\left(t + a - \frac{T}{2}\right)\right)\right), & 0 \le t \le T - a, \\ \cos\left(2\pi t\left(f_0 + \mu\left(t + a - \frac{3T}{2}\right)\right)\right), & T - a < t \le T. \end{cases} \tag{2}$$

Structure of the transmission packet is shown in Fig. 1. The transmission packet is composed with preamble field, sync field, header field, payload field, and cyclic redundancy check field.

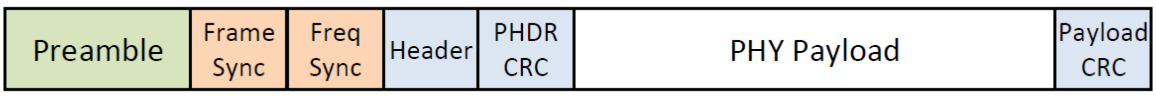

Figure 1. Packet structure

Preamble consists of 8 chirps with no cyclic shift. For frame sync symbol, we use 2 chirps with no cyclic shift the same as in the preamble. We use 2 chirps which frequency continuously decrease in the frequency sync field. Maximum payload length varies from 2 to 255 bytes. Each CRC field is 2 bytes long. As a channel code, we use the extended Hamming code with rates 4/4, 4/5, 4/6, 4/7, and 4/8.

2. LEO satellite channel model design

For LEO satellite, the Doppler frequency at a user can be parametrized by maximum elevation angle, satellite altitude, and relative position of a satellite and a user [4]. The Doppler frequency shift exists only for the visibility duration of satellite. As the maximum elevation angle increases, the visibility duration of satellite and the maximum Doppler frequency shift also increase. From the user point of view, the following instructions have been implemented in the simulator.

1. Select random number of users by Poisson probability distribution
2. Select a user's random position
3. For each user, compute the maximum elevation angle, relative latitude, relative longitude
4. Calculate Doppler frequency shift experienced by each user

3. Receiver design

Figure 2 shows the block diagram of the receiver.

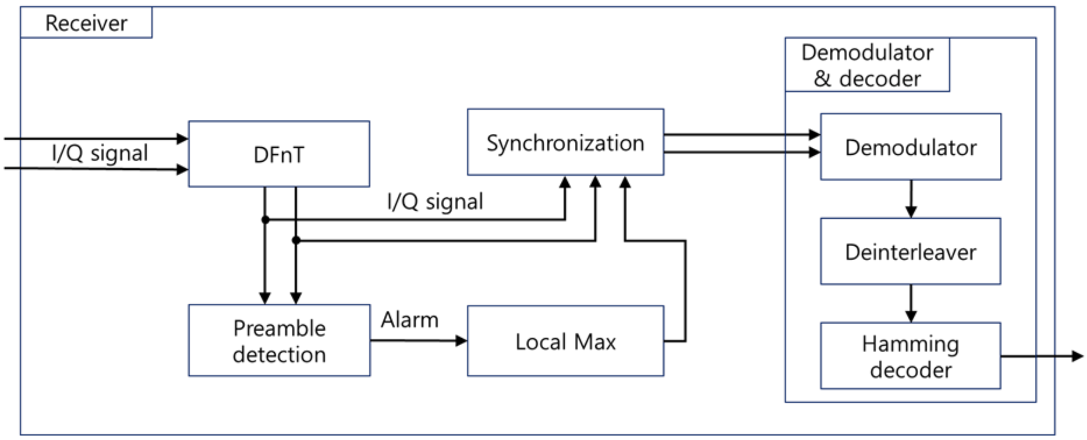

Figure 2. Receiver block diagram

Samples of received signals are processed by discrete Fresnel transform (DFnT) to find CSS signal [3]. After DFnT processing, the preamble detector tries to find 8 consecutive chirps with no cyclic shift in the received signal. If preamble detector decides there exists CSS packet in the received signal, DFnT samples enter to synchronization block to compensate timing delay and Doppler frequency offset. Synchronization block estimates timing delay and frequency offset using frame sync and frequency sync field followed by preamble. After synchronization, the receiver performs the demodulation and decoding processes.

4. References

[1] U. Raza et al, "Low Power Wide Area Networks: An Overview", *IEEE Communications Surveys Tuts.*, vol. 19, no. 2, pp. 855-873, 2nd Quarter 2017.

[2] S. Cioni et al, "On the satellite role in the era of 5G massive machine type communications," *IEEE Network*, vol. 32, no. 5, pp. 54-61, Sep. 2018.

[3] X. Ouyang et al, "Chirp spread spectrum toward the Nyquist signalling rate-Orthogonality condition and applications", IEEE signal process. Lett., vol. 24, no. 10, pp. 1488-1492, Oct. 2017.

[4] I. Ali at al, "Doppler characterization for LEO satellites," *IEEE Trans. Commun*., vol. 46, no. 3, pp. 309-313, Mar. 1998.

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