Half-Sinc Waveform Design for Narrowband IoT

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Abstract**—Narrowband Internet of Things (NB-IoT) is a cellular based IoT technique, which can send messages at a long distance using repetitive transmission and single tone frequency hopping. However, retuning of the RF front-end for each narrowband hop could cause frequency offset. Since each tone is shaped by a sinc pulse, when combining tones into a complete signal at the receiver, the side lobe of the sinc pulse would result in significant signal interference in the frequency offset condition. In this work, we propose a half-sinc (HS) waveform for uplink channels via cutting half band using the Hilbert transform to intentionally reserve a frequency offset protection gap. It is verified that the half-sinc waveform can tolerate up to 100% frequency offset via simulation and can practically remove the half side signal band in a software defined IoT platform.**

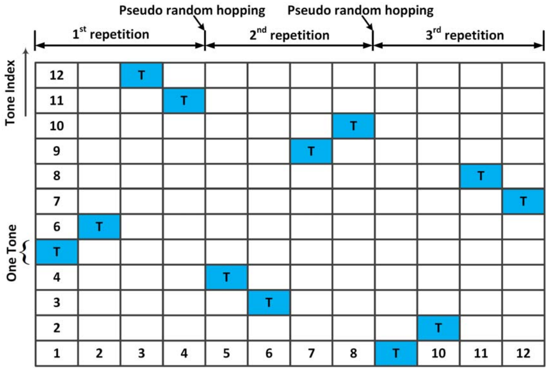
I. Introduction

Repetitive transmission [1] is employed in narrowband IoT to improve the probability to decode correctly transmitted signals. The repetitive transmission mechanism works together with frequency hopping [1] where single tones are transmitted at different frequencies to randomly avoid low quality channels. After the repetitive transmission, the tones at different frequencies, shown in Fig. 1, are aggregated at the receiver. However, due to imperfect RF retuning, frequency offset exists among different tones and the high side lobe of a since pulse shaped tone would cause interference to others.

This work proposes a half-sinc (HS) waveform using the Hilbert transform [2] where its half side signal band is cut and therefore a protection gap is reserved to avoid the frequency offset interference. The newly proposed IoT waveform is verified via simulation and experiment.

II. Half-Sinc Waveform Design

The typical single tone waveform, shaped by a sinc pulse, is illustrated in Fig. 2(a) where it occupies 15 kHz baseband bandwidth and shows high power leakage on both sides. Fig. 2(b) illustrates its one neighbouring tone spaced by 15 kHz. Following the same frequency hopping scheme in Fig. 1, two tones are aggregated in Fig. 2(c). If frequency offset exists, the orthogonality between adjacent tones is violated and signals would be interfered. Our proposed idea is to cut one side of the sinc pulse via using the Hilbert transform. The new signal waveform, after removing its mirror symmetric portion, is illustrated in Fig. 2(d) where the right side signal portion is removed. Its neighbouring tone waveform is shown in Fig. 2(e) with the removal of the left side portion. Following the same 15 kHz spacing, after aggregation in Fig. 2(f), a sufficient protection gap is reserved to tolerate the frequency offset.



12		T									
11			T								
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1	2	3	4	5	6	7	8	T	10	11	12

Fig. 1. Single tone frequency hopping illustration. The blocks labelled ‘T’ indicate randomly hopped symbol groups.

III. Modelling and Measurement Results

The removal of half side band in the half-sinc signal leads to a special constellation pattern shown in Fig. 2 where only real portion of the signal is effective. BER performance also verifies that the half-sinc signal has the same performance as the typical sinc signal. Various frequency offset ratios, ranging from 20% to 100%, are tested in Fig. 3 for the typical sinc and the half-sinc waveforms. Both BER curves and bar chart indicate that the proposed half-sinc waveform can tolerate all the frequency offset ratios while the typical sinc waveform is very sensitive to the frequency mismatch.

A software defined IoT platform [3] is used in Fig. 4 to verify the half-sinc waveform. Both the sinc and half-sinc waveforms are generated from the platform at 2.4 GHz carrier frequency with one signal copy sent back to the platform for signal recovery while the second copy for the spectrum analyzer. Practical results show that the half-sinc waveform can efficiently cut one side portion of the signal, which is approximately 50 dB out-of-band power lower than the typical sinc waveform.

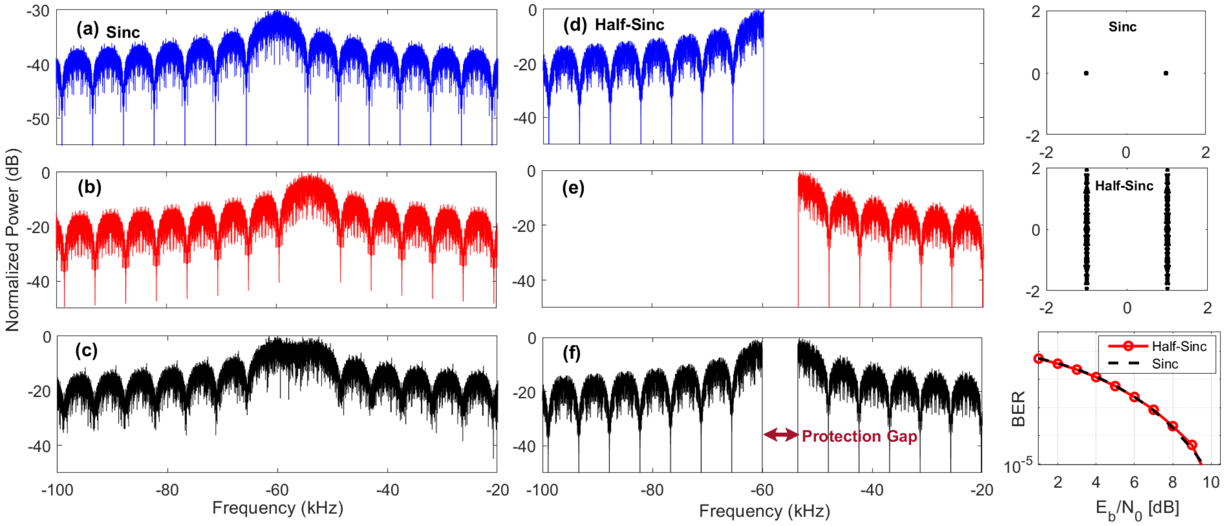

Fig. 2. Spectra comparison of sinc and half-sinc waveform. BPSK is used as a widely accepted format for IoT.

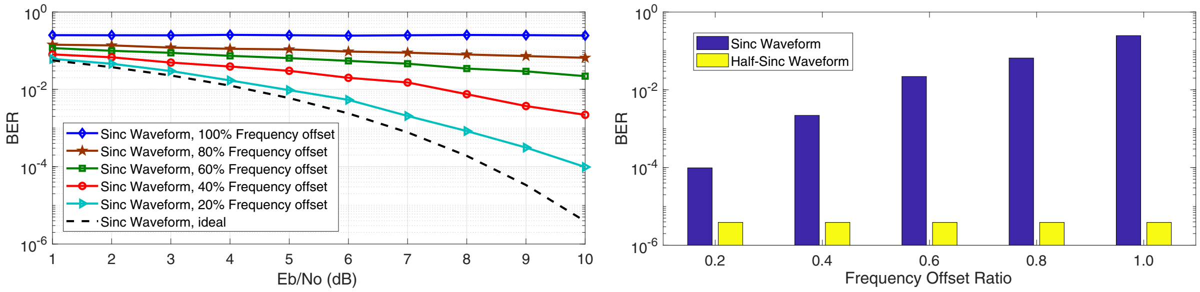

Fig. 3. Robust tolerance of frequency offset in the sinc and half-sinc waveforms.

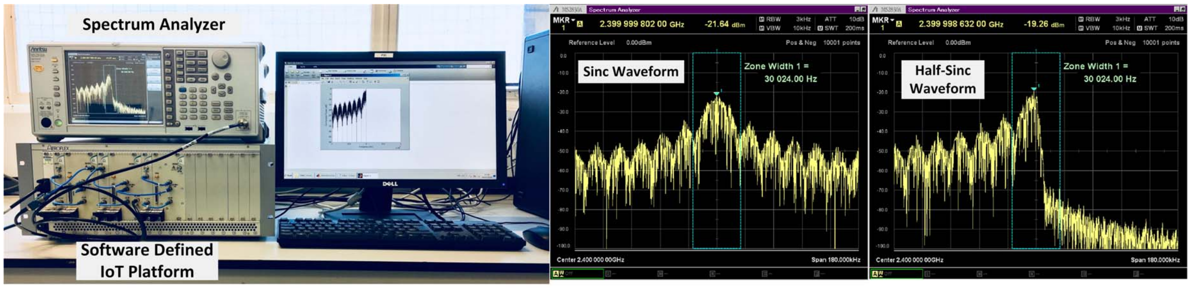

Fig. 4. Experiment validation on the half-sinc waveform with testbed setup and spectra comparison.

IV. CONCLUSIONS

This work proposed an efficient IoT waveform termed half-sinc (HS) waveform, which is robust to frequency offset than the typical sinc waveform. The Hilbert transform was used to cut the half side signal band. Results showed that the half-sinc waveform has the same BER performance as the typical sinc waveform while the half-sinc waveform has a robust tolerance to frequency offset up to 100%. A practical experiment verified the bandwidth truncation of the half-sinc waveform, which is approximately 50 dB out-of-band power lower than the typical sinc waveform. Therefore, half bandwidth is saved and it experimentally proved that the half-sinc waveform can potentially avoid frequency offset.

REFERENCES

[1] Qualcomm, "Paving the path to narrowband 5G with LTE Internet of Things (IoT)," Qualcomm Technologies, Inc, Tech. Rep.
[2] J. Proakis and M. Salehi, *Digital Communications*. McGraw-Hill, 2008.
[3] T. Xu and I. Darwazeh, "Non-orthogonal narrowband Internet of Things: A design for saving bandwidth and doubling the number of connected devices," *IEEE Internet of Things Journal*, vol. 5, no. 3, pp. 2120–2129, June 2018.