Joint CFO and IQ-Imbalance Compensator for Narrow-Band Wireless System

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***Abstract*—In direct conversion (DC) receiver, IQ imbalance (IQI) and carrier frequency offset (CFO) deteriorate bit error rate (BER) performance. In this paper, we present a joint CFO and IQI compensator using specific two preamble patterns for narrow band wireless receiver. We have verified the efficiency of compensation algorithm with BER characteristic by computer simulations.**

I. Introduction

A DC receiver architecture enables the design to be small, low power and low cost. However, it often suffers from degradation of BER due to CFO and IQI. A lot of compensation algorithms have been proposed. However, these algorithms are designed for a specific transceiver architecture and often do not apply to other architectures. One of the algorithms for compensating CFO and IQI was proposed in [1]. However, aside from narrow estimation range, the algorithm is unstable at CFO values near 0Hz. In this paper, we propose a joint CFO and IQI compensation algorithm for ARIB STD T61 which is a Japanese standard for narrow-band wireless system. The proposed algorithm overcomes the problem of the conventional algorithm and extends CFO estimation range by using two preamble properly.

II. CFO and IQI

Equation (1) shows received baseband signal $\hat{x}(t)$ influenced by CFO and IQI.

$$\hat{x}(t) = \{e^{-j2\pi\Delta ft}x(t)\}\frac{1}{2}(1+\alpha e^{-j\phi}) + \{e^{j2\pi\Delta ft}x^*(t)\}\frac{1}{2}(1-\alpha e^{j\phi}) \quad (1)$$

$x(t)$ represents baseband signal generated in transmitter and it is shown as $x(t) = x_I(t) + jx_Q(t)$. $x_I(t)$ and $x_Q(t)$ represent in-phase component and quadrature component of $x(t)$, respectively. The α and ϕ are gain and phase imbalance between in-phase and quadrature component respectively. Δf is the CFO parameter.

III. CFO and IQI Compensation Scheme

In equation (2), $\hat{S(t)}$ represents compensated signal.

$$\hat{S}(n) = \{\mathrm{Re}[\hat{x}(n)]w + j\mathrm{Im}[\hat{x}(n)]\}\, e^{j2\pi\Delta\tilde{f}nT_s} \quad (2)$$

Our system uses cyclic preamble signals for estimating CFO and IQI parameters. In [1], system estimates CFO parameter by using one preamble pattern. However, in this way, system can not estimate those parameters when CFO is certain value [1]. So, we use two preamble patterns. Equation (3) shows algorithm for estimating CFO parameter. N represents number of symbols contained in one cyclic of preamble signals. η represents a sign of CFO. System decides suitable preamble pattern from η which is decided by imaginary component of autocorrelation of received preamble signals.

$$\Delta\tilde{f} = \frac{\tan^{-1}[(\mathbf{a}^T\mathbf{b})^{-1}\eta\sqrt{(\mathbf{a}^T\mathbf{a})^2 - (\mathbf{a}^T\mathbf{b})^2}]}{2\pi T_s N} \quad (3)$$

where

$$\mathbf{a} = \begin{bmatrix} 2\hat{x}_I(n+N) \\ 2\hat{x}_Q(n+N) \end{bmatrix}, \mathbf{b} = \begin{bmatrix} \hat{x}_I(n) + \hat{x}_I(n+2N) \\ \hat{x}_Q(n) + \hat{x}_Q(n+2N) \end{bmatrix}.$$

Equation (4) shows algorithm for estimating IQI compensation parameter w. w is also shown as $w = \alpha e^{j\phi}$.

$$w = (\mathbf{c}^H\mathbf{c})^{-1}\mathbf{c}^H\mathbf{d} \quad (4)$$

where

$$\mathbf{c} = [\hat{x}_I(n)e^{j2\pi\Delta\tilde{f}T_sN} - \hat{x}_I(n+N)],$$
$$\mathbf{d} = [j\hat{x}_Q(n+N) - j\hat{x}_Q(n)e^{j2\pi\Delta\tilde{f}T_sN}].$$

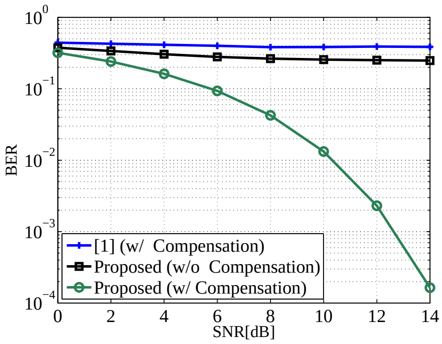

Fig. 1. BER characteristics of wireless system with DC receiver on AWGN channel. The system based on ARIB-STD T61 which is standard for narrow band digital telecommunication system

IV. Simulation

We use parameters α=1.5, ϕ=10[deg] and $\Delta f = 0$[Hz] in computer simulation. Figure 1 indicates that BER is under 10^{-3} for compensation system when SNR is 14 dB, and BER characteristic is improved from "Proposed (w/o Compensation)" and "[1] (w/ Compensation)".

V. Conclusion

In this paper, we have presented a new joint CFO and IQI compensation system and shown that our proposed algorithm is effective in BER performance. In the future, we will implement our system on FPGA.

References

[1] L. Lanante, M. Kurosaki, and H. Ochi, "Low complexity compensation of frequency dependent I/Q imbalance and carrier frequency offset for direct conversion receivers," in *Proc. IEEE international symposium on circuits and systems*(*ISCAS 2010*), Paris Frenche, May. 2010, pp. 2067–2070.