Process Noise Parameters of Beamforming Green Nodes

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Abstract—**Signals arrive out of phase at the intended receiver from collaborative beamforming (CB) nodes due to the instability in the output frequency signals of the universal software radio peripheral's (USRP) local oscillator (LO). These nodes including the target must synchronize their oscillator frequencies for coherent signal reception. In order to do this, frequencies and phases of the signals should be estimated in software defined radio (SDR) and smoothen with nonlinear filters such as the extended Kalman filter (EKF). The process noise parameters of the NI USRP-2920 nodes will have to be calculated and used with the EKF process noise covariance matrix. These nodes are green communication hardware devices where most of the hardware units are now software defined. This article uses the direct spectrum method to obtain the phase noise values at various frequency offsets of the NI USRP-2920 in order to calculate the power spectral density of fractional frequency fluctuation. By applying the power-law noise model to this obtained value, the generated white frequency noise and random walk frequency noise values are $q_1=1.93\times10^{-21}$ and $q_2=5.86\times10^{-18}$, respectively.**

Index Terms—**Collaborative beamforming, phase noise, process noise parameters, universal software radio peripheral.**

1. Introduction

Two or more antenna devices can simulate a virtual array by transmitting a common message jointly to the desired receiver. This phenomenon is otherwise recognized as collaborative beamforming (CB)[1]. Implementation of CB which is a green wireless communication has the advantages of longer directional transmission range, thereby reducing the number of intermediate nodes, per node radiation due to multiple relay nodes as this radiation affects human[2], and redundancy and energy sharing (making the network energy-efficient) among participating individual nodes in the ratio of $1/N$ (N is the number of participating nodes)[3].

Experimental/practical synchronization of sensor node signals in wireless sensor networks (WSN) has been at the forefront of research for more than a decade. WSN CB implementation was reported in [4] and [5] where the local oscillators (LO) of the nodes involved are tied together in the wired form. Those of the wireless form in [6]-[9] used a closed-loop 1-bit feedback control scheme. Green energy scheme can be utilized to a fully wireless implementation of CB. This can be achieved by using the miniature solar panel for each node as against only battery power that will deplete after a short time as the case may be.

Universal software radio peripherals (USRPs) are software defined radio (SDR) designed devices that carry out analog-to-digital and digital-to-analog conversion with the help of the radio frequency (RF) front end on one side and field programmable gate array (FPGA) on the other for preprocessing. As such, the much needed hardware parts are now mostly software defined, thereby reducing electronic noise, thermal noise, and physical space.

The stability of USRP hardware systems has to do with its frequency as it is expected that the same value of frequency should be produced by the system at all time or a given period of time. The reason for the frequency instability is due to noise (thermal, environment, resonator, electronic, and external white noise) which affects the LO. The performance of USRP received signals is affected by the LO phase noise resulting in phase offsets and frequency drifts in the CB nodes[10]. Nonlinear estimators/smoothers should be employed to mitigate these LO instabilities by linearizing the frequency drift in order to obtain a near zero phase offset of the received signal. Process and measurement noise parameters of the LO need to be experimentally obtained and used with appropriate filters (extended Kalman filter (EKF) in this article) in order to eliminate the frequency drift.

This article considers the frequency stability (short-term) measure of the phase noise in the frequency domain of a single NI USRP-2920 device. These short-term fluctuations have a much larger effect on the received signals when the USRP are being used as sensor nodes in CB which rely on extreme processing to extract additional

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