Influence of Phase Noise on the Frequency Division Multiplexing Channel Sounding

Mir Ghorashi    Minseok Kim    Jun-ichi Takada

Tokyo Institute of Technology

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Introduction

- A concern over the propagation channel estimation using measurement campaigns is the channel sounder phase noise.
- Phase noise, created in the transceiver oscillator due to the frequency fluctuations, may affect the precision of the propagation channel analysis.
- The influence of the phase noise on the OFDM signal and MIMO-OFDM systems has been explored from different points of view.

Motivation

- Analysis of the phase noise influence in a MIMO-OFDM software-radio based architecture for the channel sounding.
Phase Noise Models

- Phase noise is the frequency fluctuations of the local oscillators at the transmitter and the receiver.
- To improve the stability of the oscillators frequency synthesizer, circuitries based on the phase locked loop is employed. Thus the applied phase noise depends on the characteristics of the phase locked loop used in the transceiver.
- Phase noise is best modeled as the superposition of a long term phase drift and a zero mean uncorrelated Gaussian process.
- In this research we only take account the short term noise, since by employing the Rubidium (or Cesium) reference clock at the transmitter and receiver, common in the state-of-the-art channel soundings, the influence of the long term component is negligible.
The power spectrum $S(f)$ and autocorrelation $\rho(\tau)$ of the phase noise in a transceiver with the frequency synthesizer are modeled as

$$S(f) = K\phi \frac{1 + (f/f_z)^2}{1 + (f/f_p)^2}$$

$$\rho(\tau) = \frac{K\phi f_p^2}{f_z^2} \delta(\tau) + K\phi \pi f_p \left(1 - \frac{f_p^2}{f_z^2}\right)e^{-2\pi f_p |\tau|}$$
Phase Noise Spectrum

Parameters: $f_p = 8$ KHz, $f_z = \infty$ and two values of $K_\phi$
Autoregressive Modeling of the Phase Noise

- The short term phase noise component $\phi_{st}$ affecting each sample of the received signal is approximated by an autoregressive process which can be synthesized as

$$\phi_{st}(kT_s) = a^H[\phi_{st}((k - 1)T_s), \cdots, \phi_{st}((k - M)T_s)]^T + w(k) \quad (3)$$

- Here $k$ indicates the sample index, $T_s$ is the sampling period, vector $a \in \mathbb{R}^M$ represents the autoregressive process coefficients with order $M$ and $w(k) \sim \mathcal{N}(0, \sigma^2_w)$ is the zero-mean Gaussian process with variance $\sigma^2_w$. 
Parameters: $T_s = (8 \times 10^8)^{-1}$ s, $f_p = 8$ KHz, $f_z = \infty$ and $K_\phi = -70$ dB
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_c )</td>
<td>11.0 GHz</td>
</tr>
<tr>
<td>No. of channels (per unit)</td>
<td>4</td>
</tr>
<tr>
<td>No. of units</td>
<td>6</td>
</tr>
<tr>
<td>Sampling frequency</td>
<td>800 MHz</td>
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<tr>
<td>Multitone bandwidth</td>
<td>400 MHz</td>
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<tr>
<td>No. of tones</td>
<td>2048</td>
</tr>
<tr>
<td>Tone separation ( \Delta f )</td>
<td>195.3 KHz</td>
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<tr>
<td>Symbol period</td>
<td>6.12 ( \mu )s</td>
</tr>
<tr>
<td>FFT length</td>
<td>5.12 ( \mu )s</td>
</tr>
<tr>
<td>Cyclic prefix period</td>
<td>1.0 ( \mu )s</td>
</tr>
<tr>
<td>No. of FDM multiplexes</td>
<td>4</td>
</tr>
<tr>
<td>FDM offset shift ( \delta f )</td>
<td>48.8 KHz</td>
</tr>
<tr>
<td>Frame format</td>
<td>6 symbol + preamble</td>
</tr>
<tr>
<td>Frame length</td>
<td>9 symbol length</td>
</tr>
</tbody>
</table>
In order to evaluate the performance of the system, an emulated impulse response was used as the propagation channel.

This was achieved by producing a stable delay spectrum using an open ended RF cable connected through a power splitter.
Results

Channel Impulse Response

Measured

$K_\phi = -30 \text{ dB}$

$K_\phi = -50 \text{ dB}$

$K_\phi = -70 \text{ dB}$
Doppler Spectrum

\[ K_\phi = -70 \text{ dB} \]
\[ K_\phi = -60 \text{ dB} \]
\[ K_\phi = -50 \text{ dB} \]
\[ K_\phi = -40 \text{ dB} \]
Concluding Remarks

- The influence of the phase noise on the propagation channel analysis for an FDM based channel sounder investigated through simulations.
- Previous studies usually discussed the impact of the phase noise on the TDM scheme for the channel sounding.
- A measured channel was considered to simulate the delay spectrum of the channel.
- It is observed that with the FDM scheme the impact of the phase noise on the delay, angle and Doppler spectrum estimation is negligible.
- Measurements with the channel sounder confirms this result.
Acknowledgment

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Thank You!