Influence of Phase Noise on the Frequency Division Multiplexing Channel Sounding

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Nov. 18, 2010

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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 point of views

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

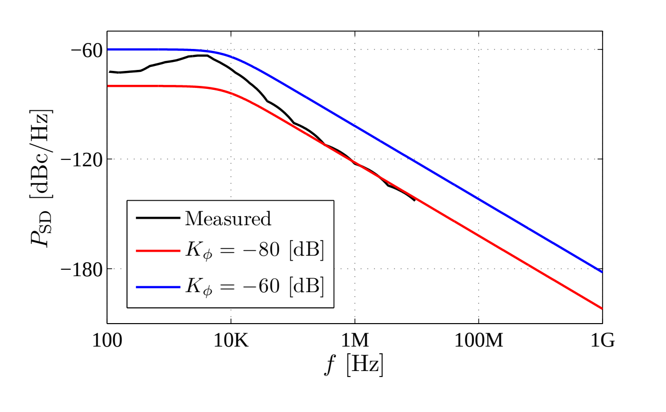
Phase Noise Spectrum

- The power spectrum $S(f)$ and autocorrelation $\rho(\tau)$ of the phase noise in a transceiver with the frequency synthesizer are modeled as

$$S(f) = K_{\phi} \frac{1 + (f/f_{\mathrm{z}})^2}{1 + (f/f_{\mathrm{p}})^2} \tag{1}$$

$$\rho(\tau) = \frac{K_{\phi} f_{\mathrm{p}}^2}{f_{\mathrm{z}}^2} \delta(\tau) + K_{\phi} \pi f_{\mathrm{p}} \left(1 - \frac{f_{\mathrm{p}}^2}{f_{\mathrm{z}}^2}\right) e^{-2\pi f_{\mathrm{p}} |\tau|} \tag{2}$$

Phase Noise Spectrum



- Parameters: $f_{\text{p}} = 8$ KHz, $f_{\text{z}} = \infty$ and two values of K_ϕ

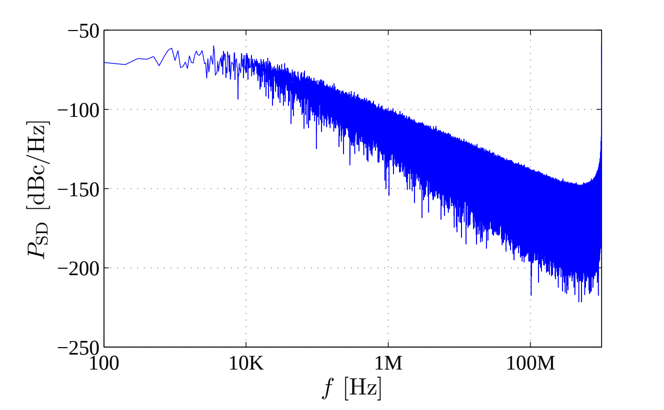
Autoregressive Modeling of the Phase Noise

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

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

- Here k indicates the sample index, T_s is the sampling period, vector $\mathbf{a} \in \mathbb{R}^M$ represents the autoregressive process coefficients with order M and $w(k) \sim \mathcal{N}(0, \sigma_w^2)$ is the zero-mean Gaussian process with variance σ_w^2

Synthesized Phase Noise Spectrum

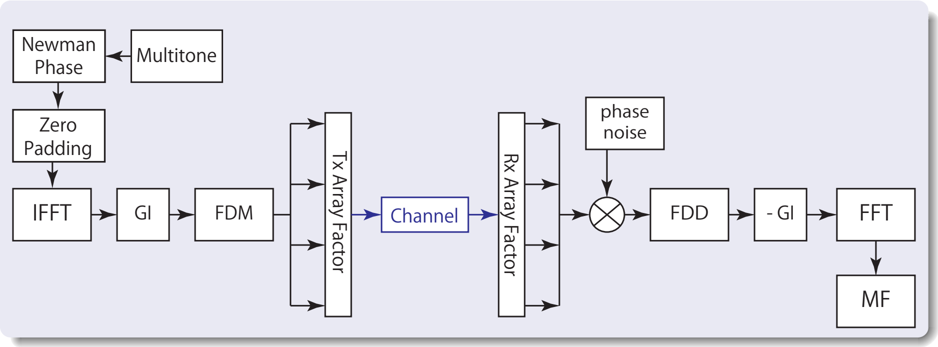


- Parameters: $T_s = (8 \times 10^8)^{-1}$ s, $f_p = 8$ KHz, $f_z = \infty$ and $K_\phi = -70$ dB

System Parameters

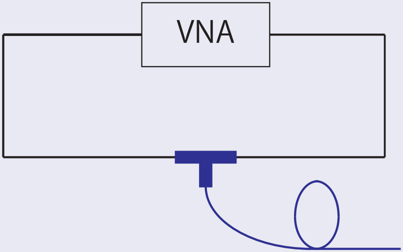
f_c	11.0 GHz
No. of channels (per unit)	4
No. of units	6
Sampling frequency	800 MHz
Multitone bandwidth	400 MHz
No. of tones	2048
Tone separation Δf	195.3 KHz
Symbol period	6.12 μs
FFT length	5.12 μs
Cyclic prefix period	1.0 μs
No. of FDM multiplexes	4
FDM offset shift δf	48.8 KHz
Frame format	6 symbol + preamble
Frame length	9 symbol length

Simulation Block Diagram

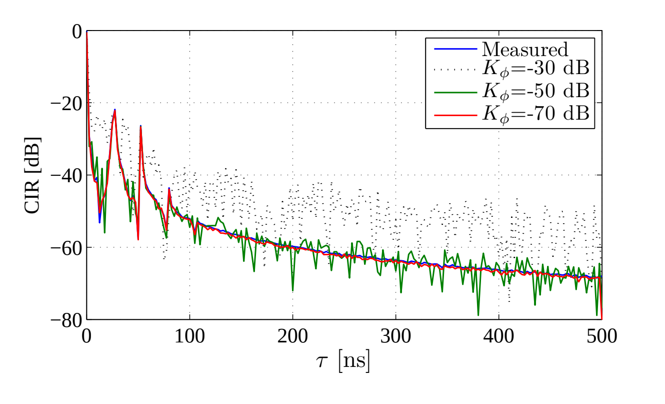


Emulated Channel

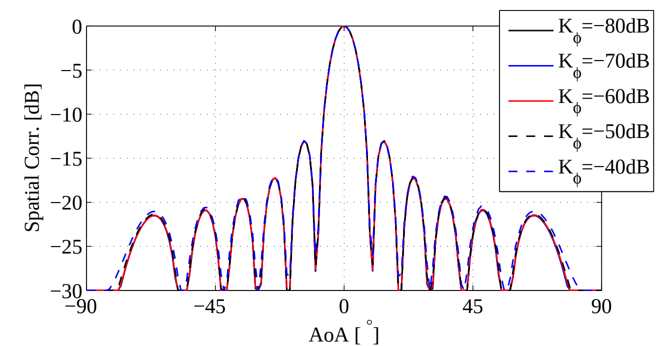
- In order to evaluate the performance of the system, an emulated impulse response was used as the propagation channel
- This was achieved by producing a stable delay spectrum using an open ended RF cable connected through a power splitter



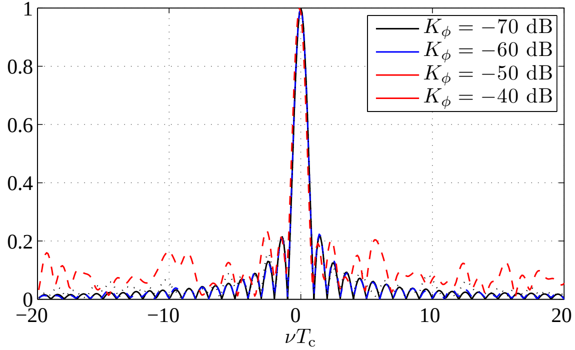
Channel Impulse Response



Angle Spectrum



Doppler Spectrum



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

This work was partly supported by "The research and development project for expansion of radio spectrum resources" of The Ministry of Internal Affairs and Communications, Japan

Thank You !