Compensation of MIMO-OFDM Radio Signal Distortion in Radio over Fiber-Distributed Antenna System using Optical TDM

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♦ Abstract

Radio on Fiber-Distributed Antenna System (RoF-DAS) with optical Time Division Multiplexing (TDM) is known to improve coverage and wireless performance. This system uses switcher to demultiplex TDM signal for Multiple Input Multiple Output (MIMO) and switches are required to synchronize completely. If synchronization mismatch happens, it cause critically signal degradation. We proposes asynchronous optical TDM. In this proposal, synchronization mismatch is compensated by estimating the amount of drifting and cancel it out at the Remote Antenna Unit (RAU). The bit error ratio (BER) performance is evaluated by using computer simulation.

♦ Introduction

Key Technology

1. Radio on Fiber (RoF)
2. Distributed Antenna System (DAS)
3. Optical TDM

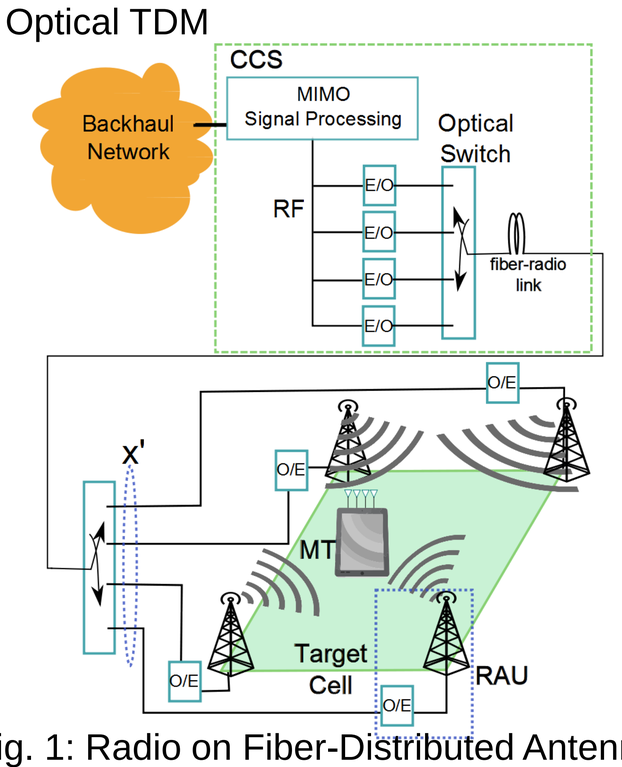

Fig. 1: Radio on Fiber-Distributed Antenna System with optical TDM

Merit

- High Coverage
- Low Spatial Correlation
- Reduction of transmission power

Configuration of This System

a. Optical pulse source emits periodic pulse train
b. RF signal modulates the optical pulse intensity
c. Employ optical delay lines and the optical signals are combined
d. O/E conversion is performed and signal is demultiplexed
e. RF signal are re-generated from TDM signal with band pass filters (BPFs)

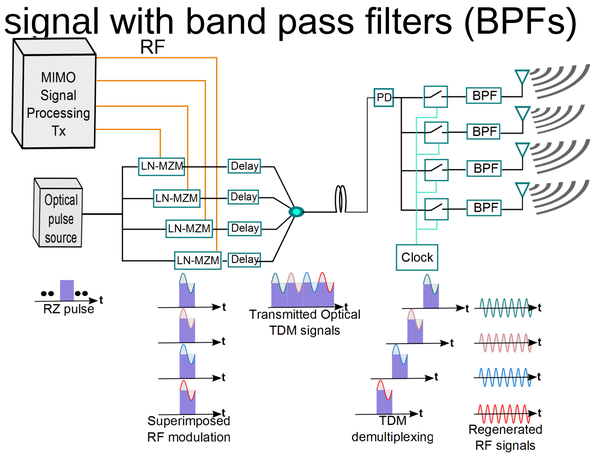

Fig. 2: Configuration of RoF-DAS using optical TDM

♦ Problem & Channel Model

Problem

The switch is required accurate behavior. If not, each signals are mixed (High correlation). High correlation causes wireless performance degradation. In order to avoid the decrease of the performance, we propose the compensation methods of synchronization mismatch

Channel Model

- **Ideal MIMO**

$$\boldsymbol{y} = \mathbf{H}_{air}\boldsymbol{x} + \boldsymbol{n}$$

- **With synchronization mismatch**

Transmitted signal is shown by this equation

$$\boldsymbol{x}' = \begin{bmatrix} x_1(1-\tau) & x_2\tau \\ x_2(1-\tau) & x_3\tau \\ x_3(1-\tau) & x_4\tau \\ x_1\tau & x_4(1-\tau) \end{bmatrix} = \begin{bmatrix} 1-\tau & \tau & 0 & 0 \\ 0 & 1-\tau & \tau & 0 \\ 0 & 0 & 1-\tau & \tau \\ \tau & 0 & 0 & 1-\tau \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \boldsymbol{T}\boldsymbol{x}$$

$$\boldsymbol{y}' = \boldsymbol{H}_{air}\boldsymbol{T}\boldsymbol{x} + \boldsymbol{n}$$

τ:Amount of mismatch $(0 \le \tau \le 1)$

- **Channel Capacity with synchronization mismatch**

Shannon-Hartley theorem

$$C = \log_2 \det\left(\boldsymbol{I} + \frac{\gamma_0}{n_t}(\boldsymbol{H}_{air}\boldsymbol{T})^H(\boldsymbol{H}_{air}\boldsymbol{T})\right)$$

γ_0 : ratio between transmission power and noise power

n_t : number of antenna at CCS

$\boldsymbol{I}$: identity matrix

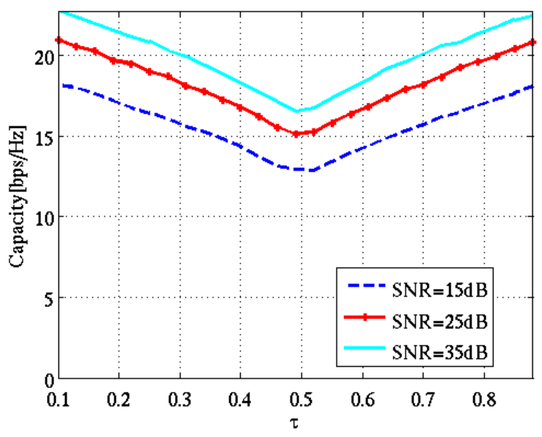

Fig. 3: Channel Capacity with τ

♦ Compensation Method

We implemented the delay matrix estimator at the RAU. In this proposal, we utilities pilot sequence $\boldsymbol{p}$

$$\mathbf{T}_{\text{est}} = \mathbf{T}\mathbf{p}\mathbf{p}^{\mathrm{T}} + \mathbf{n}_{\text{RoF}}\mathbf{p}^{\mathrm{T}}$$

Compensated transmission signal

$$\boldsymbol{x}'' = \boldsymbol{T}_{est}^{-1}\boldsymbol{x}$$

$$\boldsymbol{x}_{com} = \boldsymbol{T}\boldsymbol{T}_{est}^{-1}\boldsymbol{x}$$

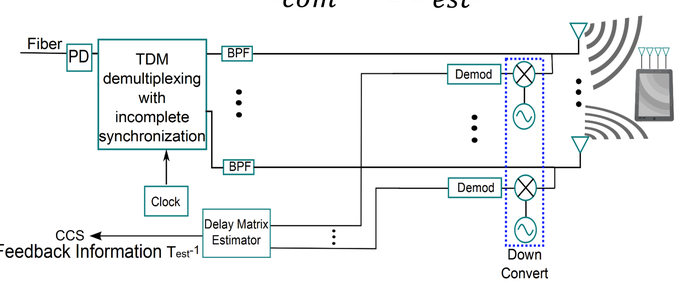

Fig. 4: Feedback Scheme

♦ Result

We suppose there is no propagation loss between RoF links.

TABLE I: SIMULATION PARAMETER

Modulation	16QAM
Number of RAUs	4
Number of MT's Antennas	4
Clock Delay	0.1~0.9
MIMO Detection	Zero-Forcing
Pilot Sequence	M-sequence
Noise	AWGN
Fading Channel (Air)	i.i.d, Flat Rayleigh Fading

In Fig. 5, the proposed methods can compensate synchronization mismatch over the range of all synchronization mismatch. However, as the tau approaches 0.5, BER of pure-ZF becomes lower. This is because correlation of channel matrix becomes higher as the tau approaches 0.5.
In Fig. 6, the proposed method give the good BER compared to pure-ZF among three modulation levels. For a BER of 10^-3, we obtain an additional gain of about 8.5dB for the proposed estimation algorithm in 16QAM.

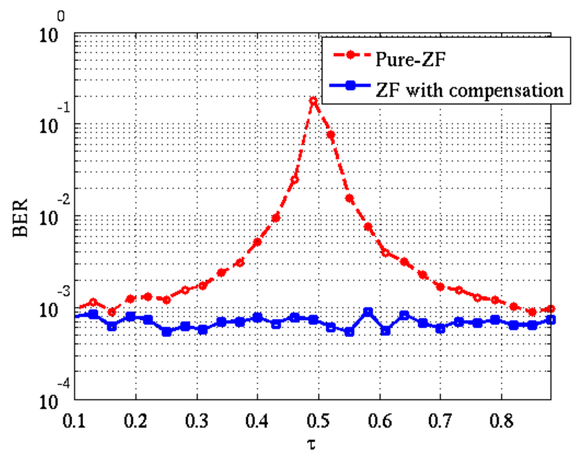

Fig. 5: BER vs synchronization mismatch (SNR = 35dB)

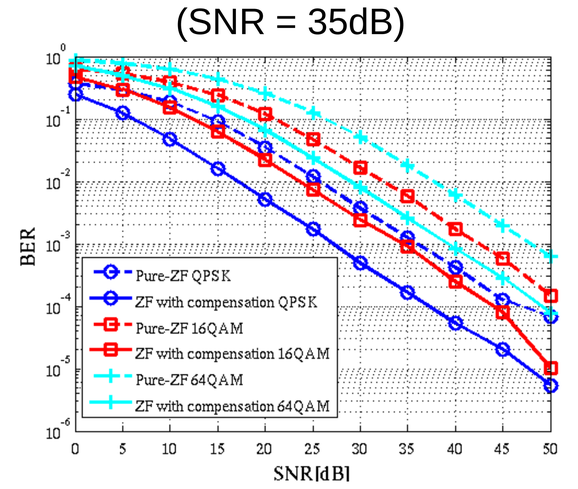

Fig. 6: BER vs SNR (τ = 0.4)

♦ Conclusion

- To avoid critical degradation due to the incomplete synchronization, a new compensation scheme is proposed.
- This scheme can estimate amount of synchronization mismatch and also gives an improvement in BER performance.