INTERFERENCE AND PHASE NOISE MITIGATION IN A DUAL-POLARIZED FASTER-THAN-NYQUIST TRANSMISSION

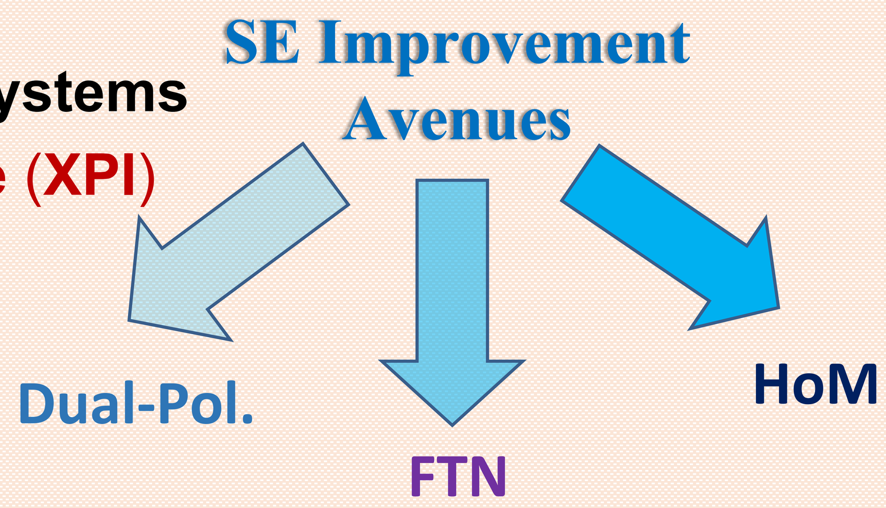
Mrinmoy Jana, Lutz Lampe, (UBC, Canada)
and Jeebak Mitra (Huawei Technologies, Canada)

Introduction

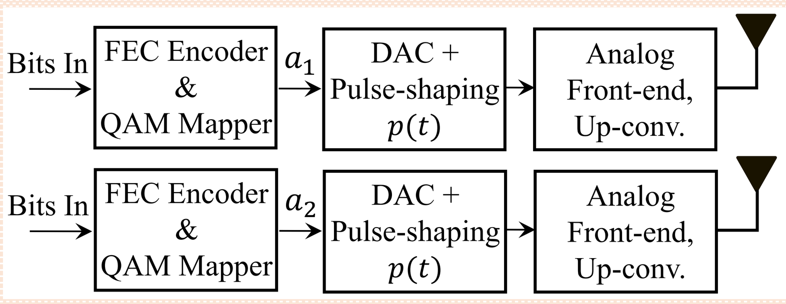
- Increasing cellular-traffic demands warrant spectral efficiency (SE) improvement for the existing microwave backhaul links.
- Three technologies considered here
  - Dual-polarization (DP)
  - Faster-than-Nyquist (FTN) Signaling
  - Higher-order modulation (HoM)

Challenges in DP-FTN-HoM Systems

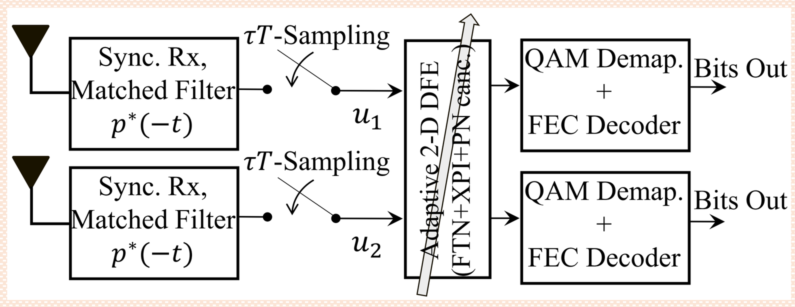
- Cross-polarization Interference (XPI)
- Inter-symbol interference (ISI)
  - FTN-induced ISI
  - Multipath ISI
- Phase noise (PN)



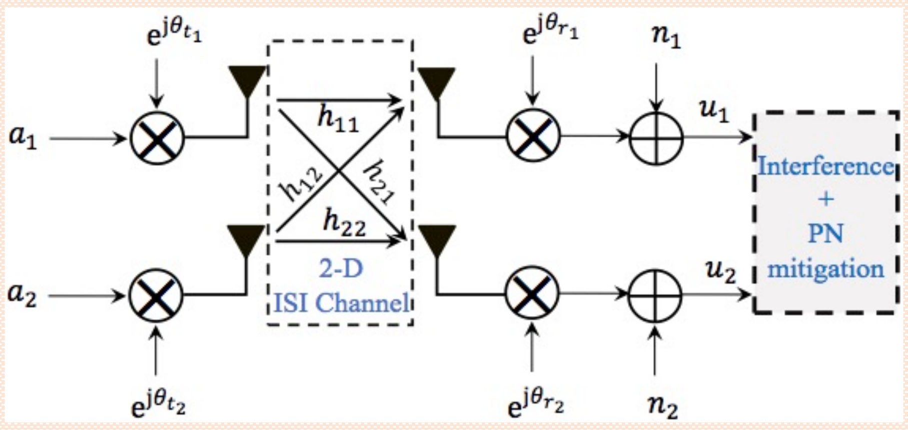
System Model



Transmitter



Receiver

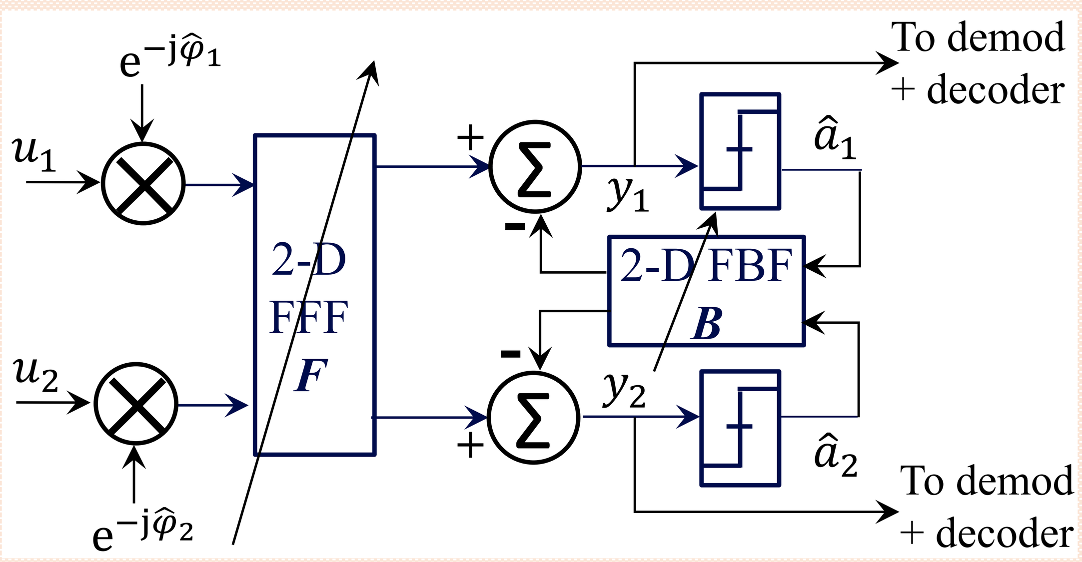


- τ – FTN acceleration factor
- β – RRC roll-off
- FEC – Forward-error correction
- h_{ij} – overall ISI channel taps
- θ_{t_i} – transmitter PN (Wiener process)
- θ_{r_i} – receiver PN (Wiener process)

Discrete-time baseband system model

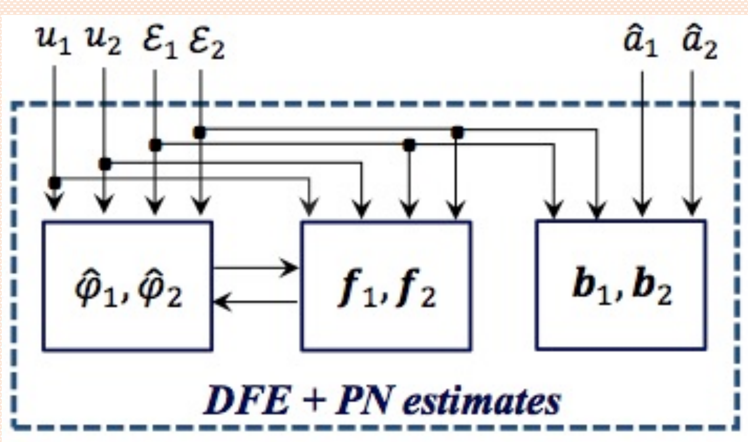
$$u_i[k] = e^{j\theta_{r_i}[k]} \sum_{j=1}^{2} \sum_l a_j[k-l]\, e^{j\theta_{t_j}[k-l]} h_{ij}[l] + n_i[k], \quad i,j = \{1,2\}.$$

Interference and PN Mitigation



- A new strategy to mitigate ISI, XPI and PN jointly.
- FTN-ISI, multipath ISI and XPI are modeled as a combined two-dimensional (2-D) ISI channel.
- 2-D decision feedback equalizer (DFE) coupled with PN tracking.

- Least-mean square (LMS) updation strategy to adaptively compute:
  - 2-D feedforward filter (FFF) tap weights
  - 2-D feedback filter (FBF) tap weights
  - PN estimates per pol. branch
- FFF adaptation and PN estimation are coupled together.



$$y_i[k] = \sum_{j=1}^{2} \left(\sum_{\nu=0}^{N_f-1} f_{ij}[\nu,k] u_j[k-\nu] e^{-j\hat{\varphi}_j[k-\nu]} - \sum_{\nu=0}^{N_f-1} b_{ij}[\mu,k] \hat{a}_j[k-k_0-\mu] \right) + n_i[k].$$

LMS adaptation:

$$\boldsymbol{f}_i[k+1] = \boldsymbol{f}_i[k] - \alpha \boldsymbol{P}[k] \boldsymbol{u}_g[k] \mathcal{E}_1^*[k],$$
$$\boldsymbol{b}_i[k+1] = \boldsymbol{b}_i[k] + \delta \boldsymbol{P}[k] \hat{\boldsymbol{a}}_g[k] \mathcal{E}_i^*[k],$$
$$\hat{\varphi}_i[k+1] = \hat{\varphi}_i[k] - \gamma \Upsilon_i[k], \qquad i,j = \{1,2\}.$$

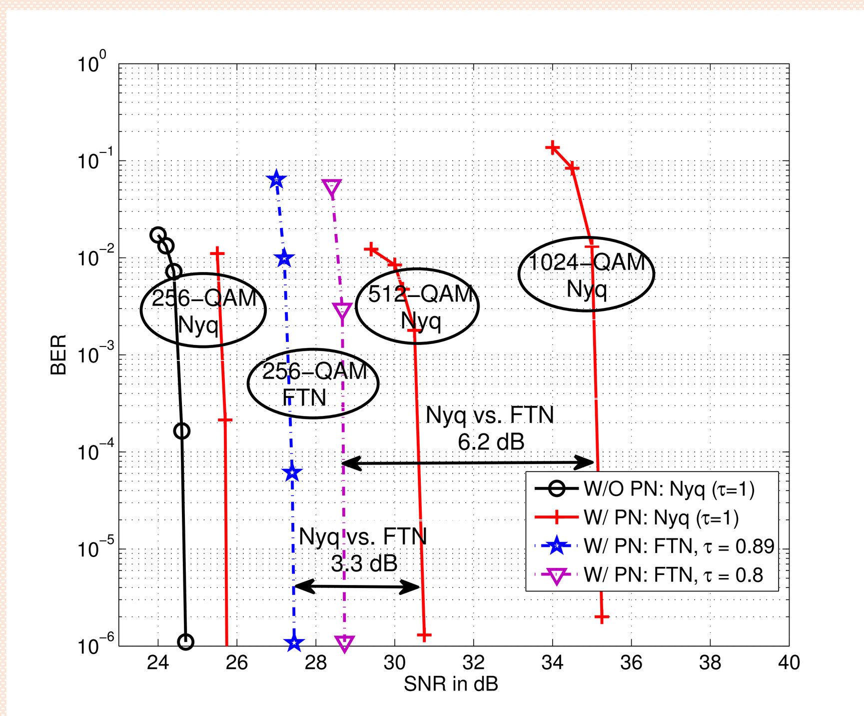
where

$$\boldsymbol{f}_i[k] = \left[\{f_{i1}^*[m,k]\}_{m=0}^{N_f-1}, \{f_{i2}^*[n,k]\}_{n=0}^{N_f-1}\right]^T,$$
$$\boldsymbol{b}_i[k] = \left[\{b_{i1}^*[m,k]\}_{m=1}^{N_b}, \{b_{i2}^*[n,k]\}_{n=1}^{N_b}\right]^T,$$
$$\boldsymbol{u}_g[k] = \left[\{u_1[k-m]\}_{m=0}^{N_f-1}, \{u_2[k-n]\}_{n=0}^{N_f-1}\right]^T,$$
$$\hat{\boldsymbol{a}}_g[k] = \left[\{\hat{a}_1[k-k_0-m]\}_{m=1}^{N_b}, \{\hat{a}_2[k-k_0-n]\}_{n=1}^{N_b}\right]^T,$$
$$\boldsymbol{P}[k] = \mathrm{diag}\left(e^{-j\hat{\varphi}_1[k]}, \ldots, e^{-j\hat{\varphi}_1[k]}, e^{-j\hat{\varphi}_2[k]}, \ldots, e^{-j\hat{\varphi}_2[k]}\right).$$

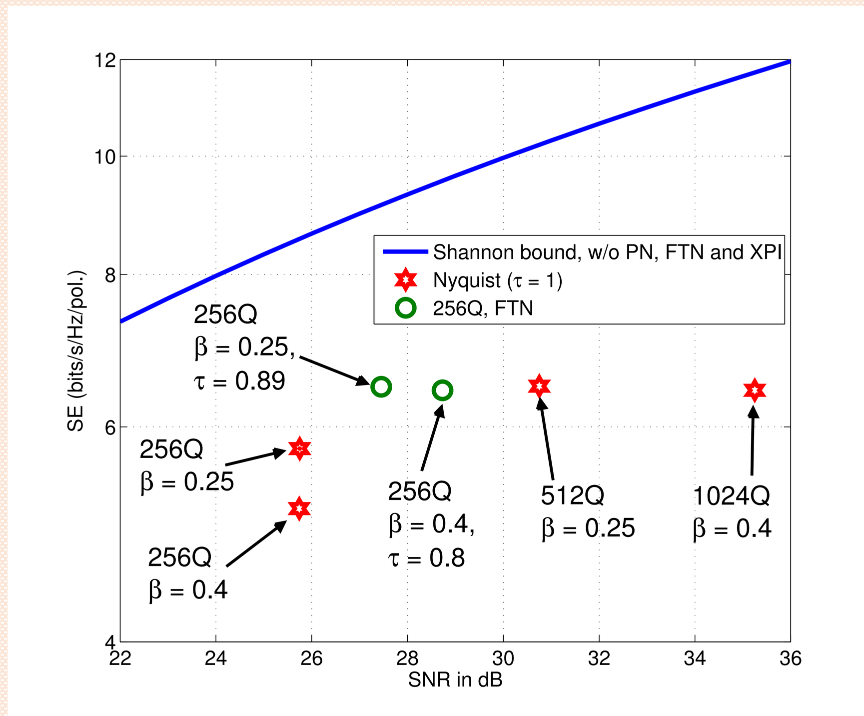
Simulation Results

- Coded bit-error rate (BER) and spectral efficiency (SE) are evaluated as a function of signal-to-noise ratio (SNR).
- DP-FTN systems show huge SE gains over higher-order DP-Nyquist systems in the presence of PN.

Modulation	FTN τ	RRC β	ISI Channel	Baudrate	PN	FEC
256-QAM 512-QAM 1024-QAM	0.8, 0.89, 1	0.25, 0.4	Rummler, XPI = 15 dB	$\frac{23}{\tau}$ Mbaud	Wiener process stdev = 0.13°	LDPC rate 0.8



BER vs SNR



SE vs SNR

256-QAM DP-FTN Gains over higher-order DP-Nyquist Systems	
512-QAM	1024-QAM
3.3 dB	6.2 dB

Conclusion

- To improve SE of the fixed wireless backhaul links, synchronous DP-FTN HoM systems have been investigated for the first time in this work.
- DP system suffers from XPI, FTN causes ISI, and HoM formats are vulnerable to PN.
- A joint XPIC and PN compensation scheme coupled with an adaptive LMS-DFE is proposed to mitigate interference and accomplish carrier phase tracking.
- FTN systems with the proposed method exhibit 3-6 dB SNR gain over Nyquist transmission that uses higher modulation orders to achieve the same data rate.
- For a given modulation order, DP-FTN offers 12-25% SE improvement over DP-Nyquist systems with a 1.7-3 dB SNR degradation.

Acknowledgements

This work was supported by Huawei Canada, and the Natural Sciences and Engineering Research Council of Canada (NSERC).