Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Supporting document for ETRI NB PHY proposal]
Date Submitted: [21 July, 2011]
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Re: [802.15.TG4k]

Abstract: This contribution is prepared to support the ETRI NB PHY proposal

Purpose:

Outline

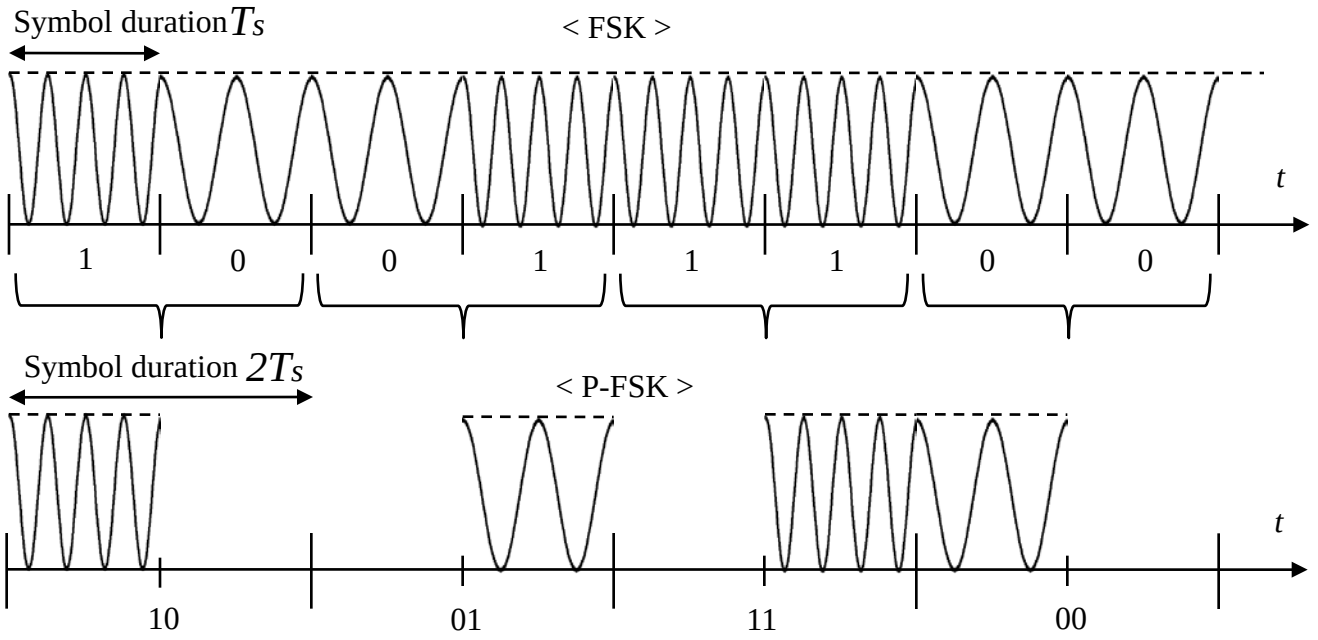
- The goal of this document is to help understanding of P-FSK modulation presented in ETRI narrowband PHY proposal for 802.15.4k LECIM networks
- This document includes
  - P-FSK concept
  - P-FSK Transmitter
  - P-FSK Receiver

P-FSK Concept

- Conventional FSK: relatively poor performance
- High-dimension orthogonal signals
  - Can reduce the SNR per bit required to achieve a target BER
  - 2-level FSK: 2-dimension orthogonal signals (freq. domain)
  - 2-ary PPM (Pulse position modulation): 2-dimension orthogonal signals (time domain)
  - Combination of 2-level FSK and 2-ary PPM
    - Position-based FSK (P-FSK)
    - Can construct 4-dimension orthogonal signals while keeping the same bit rate and signal bandwidth

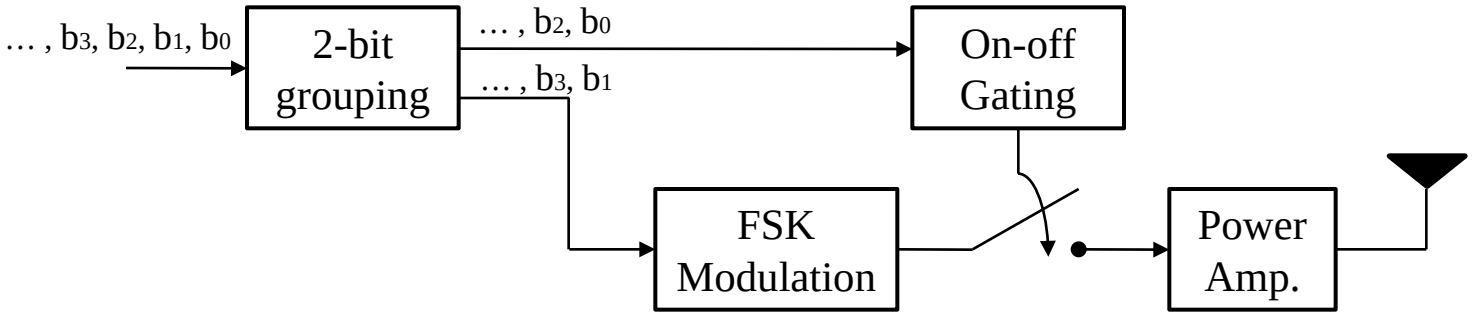
P-FSK Concept

- Position-based FSK (P-FSK)
  - Two bits are encoded by transmitting a FSK-modulated signal in one of two possible positions (time-shifts)



P-FSK Transmitter

- Example of P-FSK transmitter
  - Implementation overhead is negligible
    - Additional block: on-off gating block



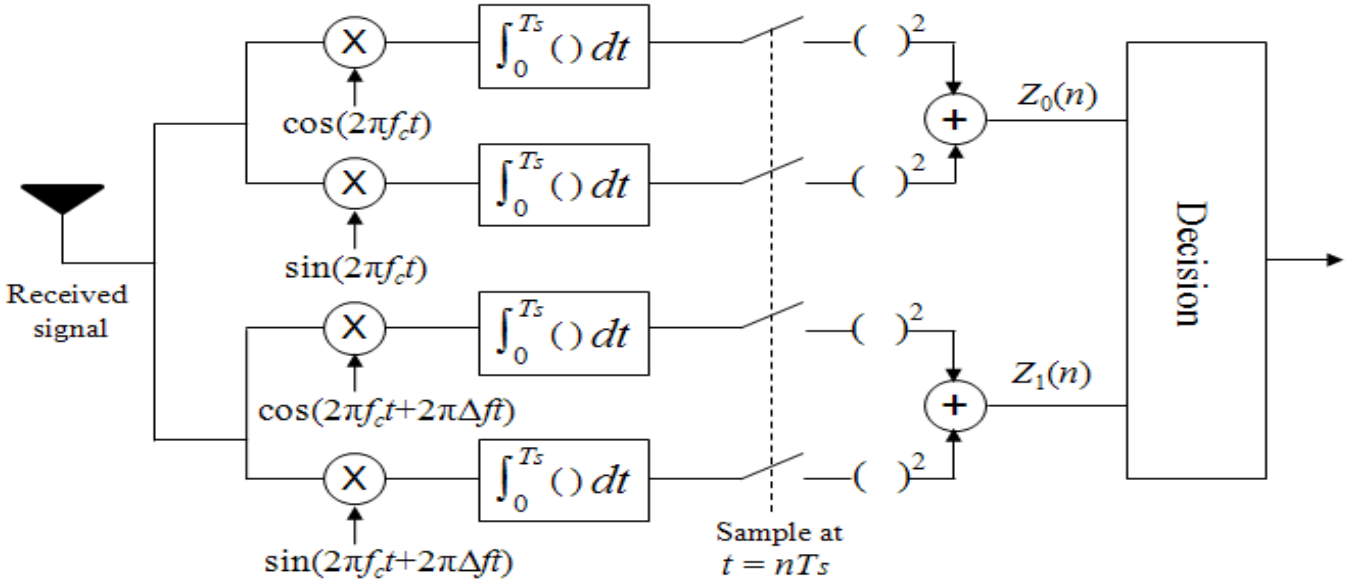
b_1: conveyed by the conventional FSK-modulated signal
b_0: modulated by the position.

P-FSK Receiver

- Coherent receiver
  - For 4-dimension orthogonal signals of the P-FSK scheme, the optimal coherent receiver selects the signal resulting in the largest cross-correlation between the received signal and each of 4 possible transmitted signals
  - Phase-locked loop is required to track the phase of the carrier

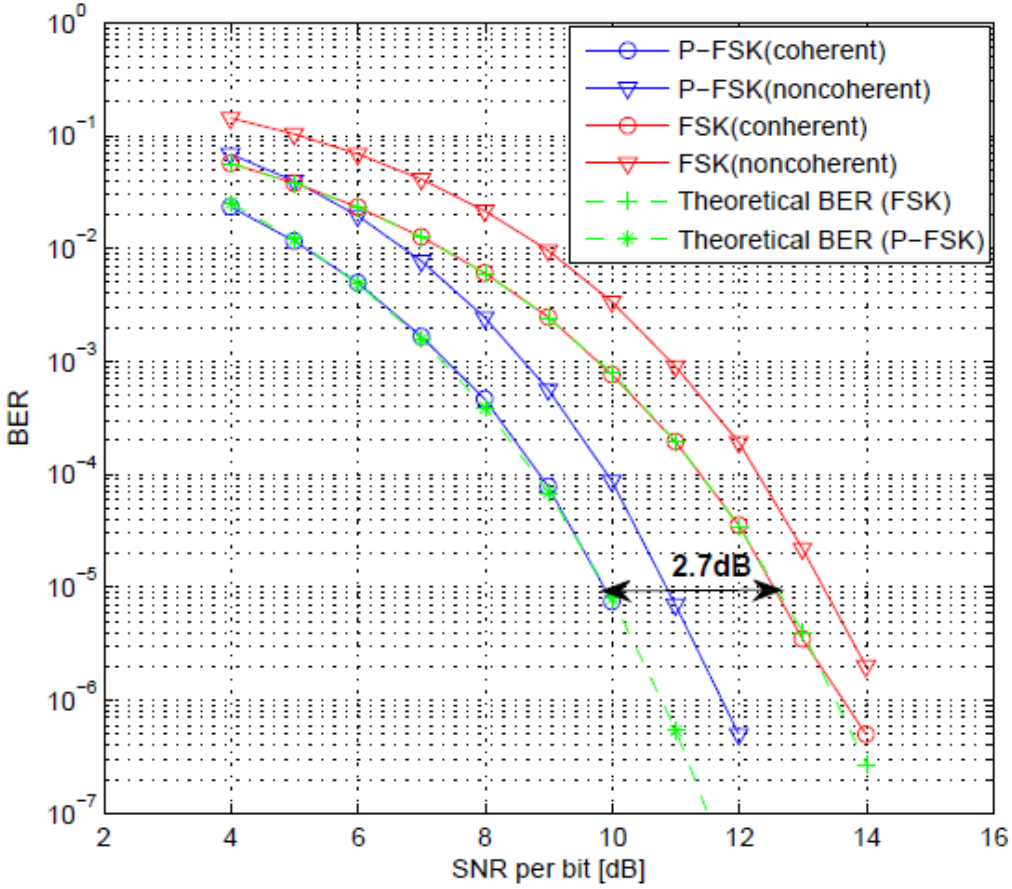
P-FSK Receiver

- Non-coherent receiver structure
  - Same as the conventional FSK non-coherent receiver
  - Position bit recovery
    - Collect the squared envelops during two time interval and compare the energy



P-FSK Performance

- BER performance of P-FSK: 2.7dB gain at BER 10^{-5}



- Theoretical BER comparison

$$P_b^{\mathrm{FSK}} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$$

$$P_b^{\mathrm{P-FSK}} \leq 2 \cdot Q\left(\sqrt{\frac{E_s}{N_0}}\right) = 2 \cdot Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

Conclusion

- Position-based FSK (P-FSK)
  - Combination of FSK and PPM
  - 4-dimension orthogonal signals
  - 2.7dB gain @ BER 10^{-5} compared with FSK
  - Implementation overhead is negligible