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

Submission Title : Summary of NG-SUN FSK PHY proposed by A2UICT in TG4ad

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Re : TG4ad Next Generation SUN PHYs

Abstract : This contribution summarizes the NG-SUN FSK PHY proposals presented by A2UICT to date in TG4ad.

Purpose: Discussion

Introduction

- **A2UICT proposed the NG-SUN FSK PHY based on P-FSK modulation and multiple retransmission spreading scheme.**
  - Proposal of P-FSK modulation scheme for NG-SUN PHY(Doc. # 052)
  - Initial Proposal of P-FSK based NG-SUN PHY for TG4ad (Doc. # 053)
  - Proposal of NG-SUN FSK PHY for IEEE 802.15.4ad ((Doc. # 139)
  - Proposal of a spreading method for implementing NG-SUN FSK PHY(Doc. # 239)
  - Multiple Retransmission Spreading Scheme for NG-SUN FSK PHY (Doc. # 300)
- **This contribution summarizes the NG-SUN FSK PHY proposals presented by A2UICT to date in TG4ad.**
  - Target Applications
  - Operating Frequency and Channel Plan
  - P-FSK Modulation and PHY Frame Structure
  - FEC, Data Whitening, and Multiple Retransmission Spreading Scheme
  - Link Budget Calculation and Performance Simulation
  - etc. ...

Target Applications

- **SUN is widely used to deploy large-scale outdoor IoT networks in various industries.**
  - Early SUN focused on wireless metering services for utilities such as electricity, water, and gas.
  - Recently, SUN has been expanded to various IoT applications in smart grids, smart cities, smart homes, and smart factories.
  - However, SUN still faces the challenge of improving performance to overcome the harsh wireless communication environment.
- **The target applications of the proposed NG-SUN PHY are various industrial IoT monitoring services that require seamless network provision in harsh wireless communication environments.**
- Provides seamless connectivity even in environments where securing sufficient wireless link budget is difficult due to high metal (shielding) characteristics such as onboard ships, container yards, and shipyards, and etc.
- Aims to perfectly implement emerging industrial IoT monitoring applications in smart buildings, smart cities, smart factories. and, etc.

Considerations for NG-SUN PHY

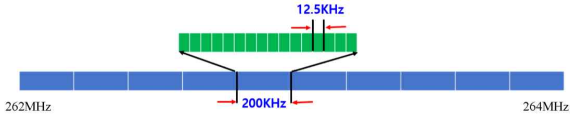
- **NG-SUN Channel :** harsh, high path loss environment
  - TX power : by local regulation(10, 20, 23dBm in Korea)
  - RX power: < -120dBm
  - SNR @ RX antenna: ~ less than 0dB
- **Reliability:** How to recover the information bit from the weak signal?
  - Narrowband PHY to lower the noise level
  - Modified FSK modulation for improved performance
  - Channel coding gain
  - Spreading gain
  - Antenna gain and etc.
- **Energy efficiency (low-power consumption) at battery-powered devices is also main consideration**
  - Modified FSK modulation for low power consumption

Proposal of Operating Frequency

- **Locally available sub-1GHz frequency bands in the world, e.g.,**
  - 902 MHz ~ 928 MHz(North and South America)
  - 863 MHz ~ 870 MHz(Europe)
  - 915 ~ 918 MHz(Japan)
  - 779 ~ 787 MHz(Chana)
  - 917~923.5 MHz(Korea)
  - Other available frequency bands
- **Additionally, we propose the following two frequency bands as new operating frequency bands for NG-SUN in Korea.**
  - 262 MHz ~ 264 MHz
  - 940.1 ~ 944.3 MHz

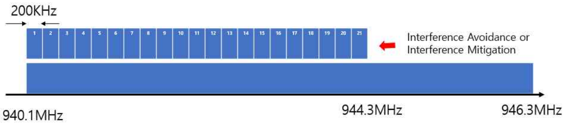
262 MHz ~ 264 MHz

- **Center Frequency:**
  - 262.00625 MHz + [12.5KHz x (N-1)], $1 \leq N \leq 160$,
    N=integer of channel number
- **Effective Radiated Power :** ≤ 100mW
- **Occupied Frequency Bandwidth :** ≤ 200KHz
- **Interference Avoidance**
  - Frequency Hopping or
  - LBT(Listen Before Transmission)



940.1 MHz ~ 944.3 MHz

- **Center Frequency**
  - 940.2 MHz + [(0.2 MHz x (N-1)], 1 ≤ N ≤ 20, N=integer of channel number
- **Radiated power including absolute antenna gain :** ≤ 200mW
  - The sum of transmission times is less than 5% of 1 minute
- **Occupied Frequency Bandwidth :** ≤ 200KHz
  - If device use frequency sweep , within 940.1~944.3 MHz
- **Must use interference avoidance or mitigation technique**
  - Frequency Hopping or
  - LBT(Listen Before Transmission)



Channel Plan

- **Number of channels per frequency band**

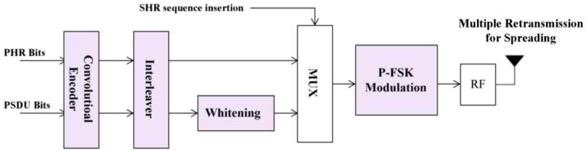
Number of Channels					
Frequency Band	Channel Spacing				
	12.5KHz	25KHz	50KHz	100KHz	200KHz
262 ~ 264 MHz 1)	160	80	40	20	10
940.1 ~ 944.3 MHz 2)	21	21	21	21	21

1) 12.5KHz Channel Spacing, Maximum occupid frequency bandwidth ≤ 200KHz

2) 200KHz Channel Spacing, Maximum occupid frequency bandwidth ≤ 200KHz

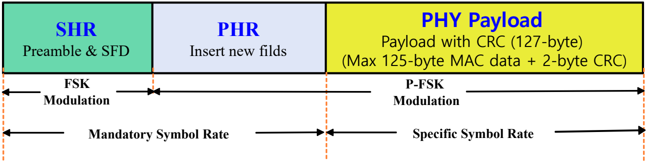
Proposal of NG-SUN FSK PHY Architecture

- **The key proposals in the NG-SUN FSK PHY are the P-FSK modulation scheme and multiple retransmission spreading scheme.**
  - **Propose Position based FSK(P-FSK) Modulation Scheme**
    - ☞ Reduces the SNR per bit required to achieve the target BER compared to 2FSK
    - ☞ No increase in implementation complexity
  - **Propose the Multiple Retransmission Spreading Scheme**
    - ☞ Huge performance improvement including the SNR gain and diversity gain
    - ☞ Enhance the performance over multipath channel



Proposal of PPDU Format for NG-SUN FSK PHY

- **Complies with the SUN FSK PPDU format of IEEE Std 802.15.4-2024**
  - FSK and P-FSK modulation in PPDU
    - **SHR:** modulated by FSK
    - **PHR and PSDU:** modulated by P-FSK
    - **SHR & PHR**: transmitted at mandatory symbol rate
    - **PSDU**: transmitted at symbol rate specified in PHR
  - Insert new fields in PHR(P-FSK modulation, Spreading Factor, Symbol Rate, ...)



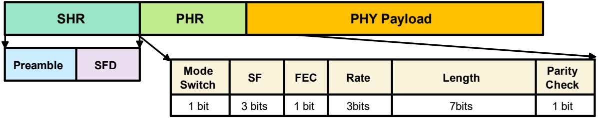
SHR Field for NG-SUN FSK PHY

- **Long preamble and SFD sequence are necessary due to harsh and high path loss channel environment**
  - **Preamble**
    - Complies with IEEE802 15.4-2024 FSK SUN standard
      - ☞ Multiple 8-bit sequence “10101010”
    - Enough octets for packet detection and synchronization
      - ☞ (Default length of the preamble field : 8 Octets)
  - **SFD**
    - Complies with IEEE802 15.4-2024 FSK SUN standard
      - ☞ At least 64-bit sequence(4-repetition of short sequence with length 16)
      - ☞ SFD detector can use full SFD sequence or part of SFD sequence according to its capability and channel condition

	SFD value for coded format (b0–b15)	SFD value for uncoded format (b0–b15)
phySunFskSfd = 0	0110 1111 0100 1110	1001 0000 0100 1110
phySunFskSfd = 1	0110 0011 0010 1101	0111 1010 0000 1110

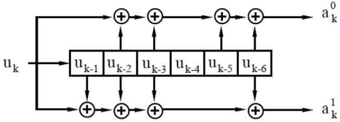
PHR Field for NG-SUN FSK PHY

- **Propose new PHR sequence for NG-SUN FSK PHY**
  - Mode Switch 0 : FSK SUN, 1: NG-FSK PHY
  - SF(3bits) : Spreading Factor1(0dB), 2(3dB), 4(6dB), 8(9dB), 16(12dB), 32(15dB)
  - FEC(1bit) : 0: FEC off, 1:FEC on
  - Rate(3bits) : Symbol Rate 6.15KHz, 12.5,KHz, 25KHz, 50KHz, 100KHz
  - Length(7bits) : max. PSDU 127-octet
  - Parity Check(1bit) : Simply detect PHR error to stop demodulation process



Forward Error Correction(FEC)

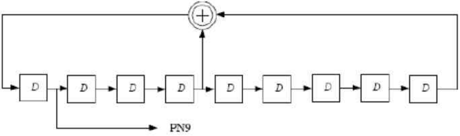
- **Long burst errors are more likely than random bit error**
  - Error correction capability is required for reliable operation in dramatically changing environments
- **Propose to use the same FEC of LECIM FSK PHY of IEEE Std. 802.15.4-2024**
  - Employ rate 1/2 convolutional coding with constraint length K = 7
  - $\oplus$ denotes modulo-2 addition.



LECIM FSK PHY convolutional encoder

Data Whitening

- Long runs of 1s and 0s in data (payload) may degrade the performance of bit timing recovery and tracking in FSK system
- Propose to use the same data whitening in SUN FSK PHY of IEEE Std. 802.15.4-2024
  - Exclusive OR of the PHY Payload field with the PN9 sequence.



< Schematic of the PN9 sequence generator >

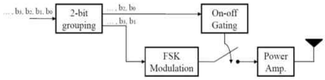
roposal of P-FSK Modulation Scheme

- **The P-FSK was developed to reduce the transmission power of FSK systems by designing a four-dimensional orthogonal signal**
  - Higher-dimension orthogonal signals for modulation can reduce the SNR per bit required to achieve a target probability of a bit error.
  - One may use the frequency-domain to obtain the high-level FSK to increase the number of dimensions.
    - ☞ Higher-level FSK occupies wider signal bandwidth.
    - ☞ High-level FSK system entails much complex receiver architecture to discriminate those increased number of frequencies.

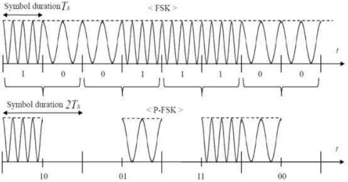
- **P-FSK generates 4-dimension orthogonal signals while keeping the same bit rate and signal bandwidth.**
  - Combines 2-level FSK : 2-dimension orthogonal signals (freq. domain) and 2-ary PPM : 2-dimension orthogonal signals (time domain)
  - Reduce the SNR per bit required to achieve a target BER

Basic Concept of P-FSK

- **Two bits are grouped together to be fed into the FSK modulator and on-off gating device to finally yield a P-FSK modulated waveform**
  - The on-off gating device is the only required hardware added to the conventional FSK transmitter
    - ☞ Its implementation overhead is negligible.
  - 4-dimension orthogonal signaling
    - ☞ 4 waveforms that indicate “00”,”01”,”10”, “11

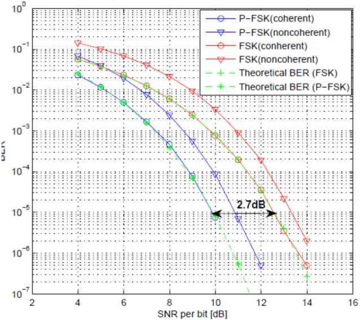


b_1: conveyed by the conventional FSK-modulated signal
b_0: modulated by the position.



Performance Comparison of FSK and P-FSK

- **BER performance of P-FSK : – 2.7dB gain @ BER 10^{-5} compared with FSK**
  - Coherent receiver : performance enhancement
  - Non-coherent receiver : low power consumption



- **Non-coherent receiver for P-FSK**
  - same as the conventional FSK
  - computational overhead is negligible

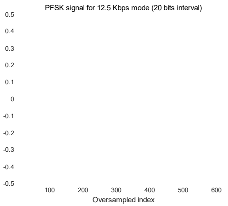
- Theoretical BER comparison

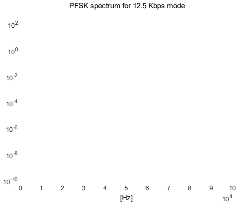
$$P_b^{\mathrm{FSK}} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$$

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

Spectrum of P-FSKSpectrum of P-FSK

- **Potential problem with position selection mechanism**
  - Sideband regrowth
    - ➢ Need additional filter to solve the problems
    - ➢ Additional complexity in the transmitter would be unavoidable
  - Average vs. peak signal power
    - ➢ Extension of coverage
- **Pulse shaping may be required to meet strict spectral emission masks.**





Proposal of Spreading Scheme

- **A simple spreading scheme in the form of repeating duplicated symbols was proposed to achieve high sensitivity in the initial proposal.**
  - NG-SUN channel: RF link with high path loss (>120dB)
  - Require better signal reception in harsh environments
- **A simple spreading scheme in the form of repeating duplicated symbols**
  - A => repetition of "A$\bar{A}$" where A is a symbol

    e.g.) 0 => repetition of "01" , 1 => repetition of "10"

    e.g.) 01 => repetition of "0110", "11" => repetition of "1100"
  - Repetition of "A$\bar{A}$": useful for FSK based system
    - ☞ Repetition rate depends on spreading factor(SF)

      SF 1(0 dB), 2(3dB), 4(6dB), 8(9dB),16(12dB), 32(15dB)
    - ☞ Can be selected according to channel condition

Proposal of New Spreading Scheme

- **The simple spreading scheme can only obtain SNR gain according to the spreading factor, but not diversity gain.**
  - Achieve SNR gain only according to the spreading factor
    - ☞ 3 dB gain @ SF=2, 12 dB gain @ SF=16
  - Only SNR gain can be obtained, no diversity gain can be obtained.
    - ☞ Degraded performance under multipath channel conditions
- **The simple spreading scheme causes extended packet transmission time due to repetition of duplicated symbols**
  - doubled transmission time @ SF=2, 16 times @SF=16
  - This could not be applicable due to limited chance of transmission
- **Proposed multiple retransmission spreading scheme**
  - SNR gain, Diversity gain should be achieved simultaneously
  - Easily applicable to the limited chance of transmission according to the regional regulations

Multiple Retransmission Spreading Scheme

- **When the transmitter receives an ACK from the receiver, it transmits the packet.**
  - Maximum # of re-transmission : defined by SF
  - Transmitter set the retrial counter @ new PHR
- **Receiver combines the received packets up to current packet before decoding**
  - When successful decoding is performed, the receiver send back ACK to the Transmitter
  - If the receiver does not combine the received but decoding failed packet, it is performing just STOP-and-WAIT ARQ operation
- **Retransmission of the packets by the transmitter can be applicable to the limited chance of transmission situation by the regional regulations**
  - Time interval between the retransmission of the packets can guarantee the independence of the multipath channels (Time diversity effect can be achieved)
- **According to the receiver operation (combining or not of the decoding failed packets)**
  - Combining applied : SNR and combining diversity gain can be obtained
  - Combining not applied : selection diversity gain can be obtained

Symbol Rate & Data Rate

- **Symbol Rate : 6.25KHz, 12.5KHz, 25KHz, 50KKHz, 100KHz**
  - The symbol rate depends on modulation index and channel spacing
    Modulation index : 0.5
    Channel Spacing : 12.5KHz, 25KHz, 50KHz, 100KHz, 200KHz
- **The data rate depends on the coding rate and spreading factor**
  - Convolution code rate ½
  - Spreading Factor(SF): 1(0dB), 2(3dB), 4(6dB), 8(9dB), 16(12dB), 32(15dB)

Data Rate with ½ code rate & Spreading					
Channel Spacing	12.5KHz	25KHz	50KHz	100KHz	200KHz
Modulation Index	0.5	0.5	0.5	0.5	0.5
Symbol Rate / SF	6.25KHz	12.5KHz	25KHz	50KHz	100KHz
1	3.125Kbps	6.25Kbps	12.5Kbps	25Kbps	50Kbps
2	1.5625Kbpsps	3.125Kbps	6.25Kbps	12.5Kbps	25Kbps
4		1.5625Kbps	3.125Kbps	6.25Kbps	12.5Kbps
8			1.5625Kbps	3.125Kbps	6.25Kbps
16				1.5625Kbps	3.125Kbps
32					1.5625Kbps

Performance Simulation

- **Simulation Environment for P-FSK PHY**
  - Channel model : COST207 GSM in urban area / IEEE802.22 in rural area
  - Data rate : 12.5 Kbps/50 Kbps
  - 1/2, K=7 convolution code
  - Hard decision Viterbi decoding
  - Interleaver-Deinterleaver
  - Total data : 200Kbits(25,000 bytes)
  - 1,000 packets of 25 byte(200 bits)/packet
  - # of multiple transmission : 1 / 4 / 16
- **Performance Simulation Results**
  - Uncoded/Coded BER vs. Eb/No
  - PER vs. Eb/No

COST 207/IEEE 802.22 channel models

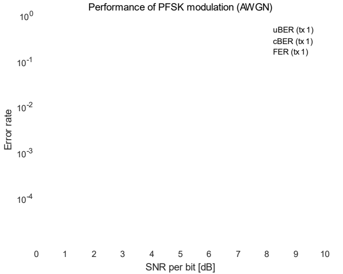
- **# of paths : 6 for each model**
  - Max. delay of IEEE802 model is larger than COST207
  - Each path contributes to performance degradation due to ISI if any kinds of counter measures are not used
    - ☞Performance degradation would be getting worse with increasing transmission rate
    - ☞IEEE802 channel will be more serious than COST207 channel
- **Quasi-static Rayleigh channel**
  - Due to small value of Doppler spread
    - ☞The coefficient of each multipath remains constant over a packet transmission
    - ☞Re-generation of channel coefficients per each packet transmission

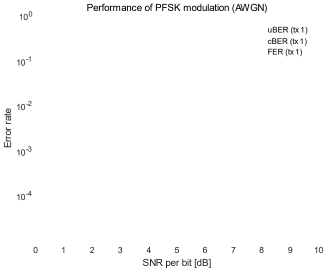
Expectation of the Performance

- **Error rate performance:**
  - For low rate transmission : Performance would be similar to that of single path fading channel
  - For higher rate transmission : Error floor would be added to the single path fading performance due to Inter-Symbol Interference (ISI)
- **Approach to enhance the performance**
  - Need to achieve some form of diversity gain
  - NG-SUN FSK PHY tries to incorporate spreading to get enhanced sensitivity performance
  - If we implement the spreading in the form of multiple transmission of a packet and receiver tries to combine the demodulated symbol, we can get time diversity gain over the SNR gain

BER/PER Simulation Results(1)

- **Performance of P-FSK modulation over AWGN @ 12.5Kbps**
  - 1% PER @ Eb/N0 of 4.4 dB
- **Performance of P-FSK modulation over AWGN @ 50Kbps**
  - 1% PER @ Eb/N0 of 4.5 dB

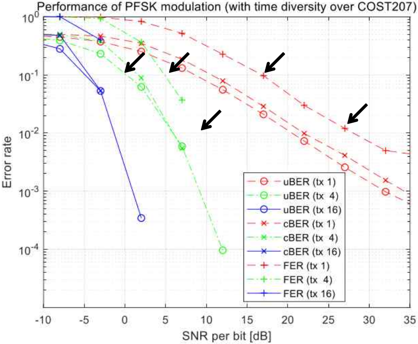




BER/PER Simulation Results(2)

□ Performance of P-FSK modulation over COST207@12.5Kbps

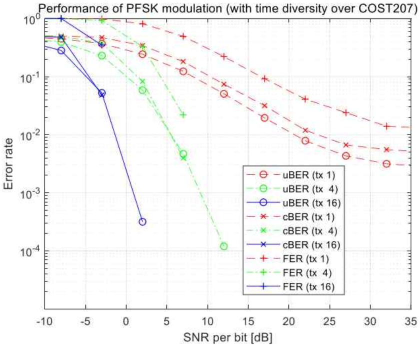
- **1%/10% PER @**
  - Eb/No of 28/17 dB for single transmission
  - Eb/No of 9/5 dB for 4 times retransmission
    - ☞ 9/12 dB gain (6 dB SNR gain + 13/6 dB diversity gain)
  - Eb/No of 2/0 dB for 16 times retransmission
    - ☞ 26/17 dB gain (12 dB SNR gain + 14/5 dB diversity gain)



IBER/PER Simulation Results(3)

☐ Performance of P-FSK modulation over COST207@50Kbps

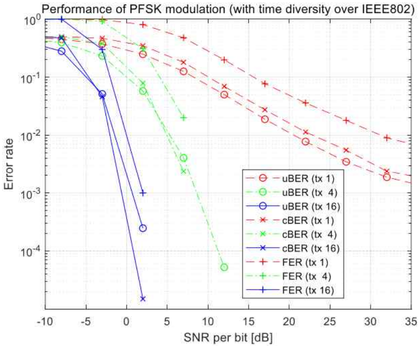
- **1%/10% PER @**
  - Eb/No of ??/17 dB for single transmission
  - Eb/No of 9/4.5 dB for 4 times transmission
    - ☞ ??/12.5 dB gain (6 dB SNR gain + ??/6.5 dB diversity gain)
  - Eb/No of 1/-1 dB for 16 times transmission
    - ☞ ??/18 dB gain (12 dB SNR gain + ??/6 dB diversity gain)



BER Simulation Results(4)

□ **Performance of P-FSK modulation over IEEE802@12.5Kbps**

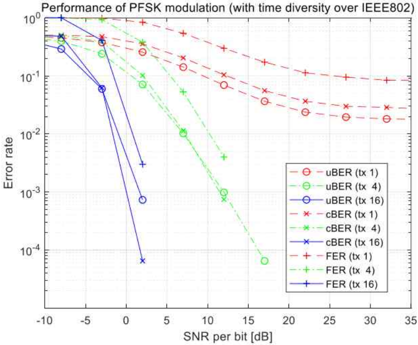
- **1%/10% PER @**
  - Eb/No of 31/15 dB for single transmission
  - Eb/No of 8/4.5 dB for 4 times transmission
    - ☞ 23/10.5 dB gain (6 dB SNR gain + 17/4.5 dB diversity gain)
  - Eb/No of 0/-2 dB for 16 times transmission
    - ☞ 31/17 dB gain (12 dB SNR gain + 19/5 dB diversity gain)



BER Simulation Results(5)

□ Performance of P-FSK modulation over IEEE802@50Kbps

- **1%/10% PER @**
  - Eb/No of ??/25 dB for single transmission
  - Eb/No of 10/5 dB for 4 times transmission
    - ☞ ??/20 dB gain (6 dB SNR gain + ??/14 dB diversity gain)
  - Eb/No of 0.5/-2 dB for 16 times transmission
    - ☞ ??/27 dB gain (12 dB SNR gain + ??/15 dB diversity gain)

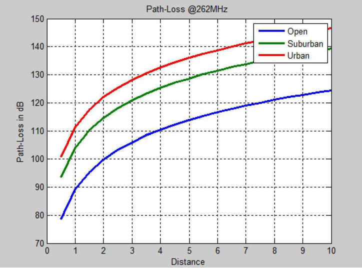


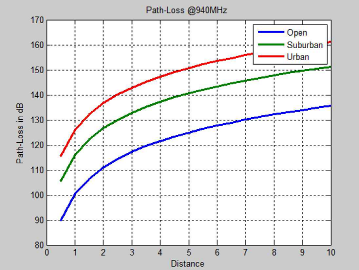
Summary of Simulation Results

- With single transmission for a packet, the error rate performance follows the single path fading and error floor as expected.
- With multiple retransmissions and receiver combining (noncoherent) of the demodulated symbols, the error rate performances show huge improvement including the SNR gain and diversity gain
  - ☞ 1% of PER can be achieved even at higher transmission rates
- Therefore, we propose the multiple retransmission spreading scheme to improve the performance of NG-SUN PHY in multipath channels.

Pass Loss Model for NG-SUN

- **Okumura-Hata Model(Large City Urban, Sub-urban, Open)**
  - Large City Urban Pass Loss at 4Km for 262MHz ≈ 133dB
  - Suburban Pass Loss at 4Km for 262MHz ≈ 125dB
  - Large City Urban Pass Loss at 4Km for 940MHz ≈ 147dB
  - Suburban Pass Loss at 4Km for 940MHz ≈ 137dB





Pass Loss Calculation(Large Urban@262MHz)

- **Path Loss@4Km : -133dB**
- **RX Power@4Km : -111dBm**

Channel Model Parameter	Value	Remarks
Frequency(MHz)	260	Valid Range 150-1500 MHz
Distance between transmitter and receiver(Km)	4	Valid Range 1-20 km
Antenna height of the transmitter (m)	30	Valid Range 30-200 m
Antenna height of the receiverd(m)	2	Valid Range 1-10 m
Path Loss Calculation		
TX Power(dBm)	20	Subject to Tx Power Regulations
TX Antenna Gain(dBi)	6	Subject to Tx Power Regulations
Path Loss(dB)	-133	Must reference the right path loss from the Hata-Okumura
Shadowing Margin(dB)	-12	To buffer against variable shadowing loss
Penetration Loss(dB)	0	For underground vaults, etc
RX Antenna Gain(dBi)	6	Same as TX Antenna Gain
Interface at receiver point(dB)	2	Rise over Thermal Interference
RX Power at receiving point(dBm)	-111	Compare against Rx sensitivity

Link Budget(Large Urban@262MHz)

- **Minimum Eb/No for P-FSK:**
  - Coherent receiver: 10dB @ BER 10^{-5}
  - Non-coherent receiver: 11dB @ BER 10^{-5}
- **Processing Gain: Spreading Gain + Channel Coding Gain**
  - Channel coding gain: SDD 5dB, HDD 3dB
  - Spreading Gain: SF1(0 dB), SF2(3 dB) , SF3(6 dB) , SF4(9 dB) , SF5(12dB)

Parameter	Unit	Value	
Symbol Rate[Rb]	KHz	6.25	100
Bandwidth[BW]	KHz	12.5	200
Rx power at receiver point[P_r]	dBm	-111	-111
Receiver AWGN noise[N=-174+10log(BW)]	dBm	-133	-121
RF noise figure of endpoint[N_f]	dB	7	7
Average noise power[P_n = M + N_f]	dBm	-126	-118
Minimum E_b/N_o[S]	dB	10	10
Implementation Loss[I]	dB	3	3
Processing Gain[PG]	dB	5	8
Link Margin(LM=P_r - P_n – S – I + PG)	dB	7	2
Proposed Minimum RX sensitivity level(P_{min})	dBm	-118	-113

ass Loss Calculation(Large Urban@940MHz)

- **Path Loss@2Km : -137dB**
- **RX Power@2Km : -115dBm**

Channel Model Parameter	Value	oyes
Frequency(MHz)	940	Valid Range 150-1500 MHz
Distance between transmitter and receiver(Km)	2.0	Valid Range 1-20 km
Antenna height of the transmitter (m)	30	Valid Range 30-200 m
Antenna height of the receiverd(m)	2	Valid Range 1-10 m
Path Loss Calculation		
TX Power(dBm)	20	Subject to Tx Power Regulations
TX Antenna Gain(dBi)	6	Subject to Tx Power Regulations
Path Loss(dB)	-137	Must reference the right path loss from the Hata-Okumura
Shadowing Margin(dB)w	-12	To buffer against variable shadowing loss
Penetration Loss(dB)	0	For underground vaults, etc
RX Antenna Gain(dBi)	6	Same as TX Antenna Gain
Interface at receiver point(dB)	2	Rise over Thermal Interference
RX Power at receiver point(dBm)	-115	Compare against Rx sensitivity

Link Budget(Large Urban@940MHz)

- **Minimum Eb/No for P-FSK:**
  - Coherent receiver: 10dB @ BER 10^{-5}
  - Non-coherent receiver: 11dB @ BER 10^{-5}
- **Processing Gain: Spreading Gain + Channel Coding Gain**
  - Channel coding gain: SDD 5dB, HDD 3dB
  - Spreading Gain: SF1(0 dB), SF2(3 dB) , SF3(6 dB) , SF4(9 dB) , SF5(12dB)

Parameter	Unit	Value	
Symbol Rate[Rb]	KHz	6.25	100
Bandwidth[BW]	KHz	12.5	200
Rx power at receiver point[P_r]	dBm	-115	-115
Receiver AWGN noise[N=-174+10log(BW)]	dBm	-133	-121
RF noise figure of endpoint[N_f]	dB	7	7
Average noise power[P_n = M + N_f]	dBm	-126	-118
Minimum E_b/N_o[S]	dB	10	10
Implementation Loss[I]	dB	3	3
Processing Gain[PG]	dB	5	14
Link Margin(LM=P_r - P_n – S – I + PG)	dB	3	1
Proposed Minimum RX sensitivity level(P_{min})	dBm	-118	-119

Coexistence

- **Low Duty Cycle**
  - Small and infrequent messages
  - NB PHY with large number of available channels per band and low duty cycling property enable to coexist with other services in the same band
- **Frequency Hopping**
  - Dwell Time Limit : 400 ms max
    - US 902-928 MHz(FCC Part 15.247)
    - KR 920-923MHz (Korea)
  - **Hopping with Fragmentation**
    - Fragmentation is needed to overcome the limited PSDU transmission time to satisfy the dwell time for frequency hopping at extremely low data rates.
    - Require Fragmentation for P-FSK PSDU

Key Aspects of PHY Proposal

Parameter		Proposed NG-SUN PHY
Operating Frequency Band		Sub-1GHz(Global), 262~264MHz & 940.1~944.3MHz(Korea)
Channel Spacing		12.5KHz, 25KHz, 50KHz, 100KHz, 200KHz
TX Power		As allowed by regulatory regimes(Korea :10mW, 100mW, 200mW)
Modulation		Filtered P-FSK
Symbol Rate		6.25KHz,12.5KHz, 25KHz, 50KHz, 100KHz
Spreading		Spreading Factor : 1, 2, 4, 8, 16, 32
FEC		Convolutional code Stringent Length K=7
Data Whitening		XOR(PSDU,PN9 sequence)
PHY Frame Structure	SHR	Multiple 8-bit sequence of Preamble At least 64-bit sequence of SFD(4 repetation of 16bits sequence)
	PHR	Mode SW(1), SF,(3) FEC(1), Rate(3), Length(7), Parity Check(1)
	PSDU	Max. 127-byte(Max. 125-bytes MAC data + 2-bytes CRC)
	CRC	16-bit ITU CRC
Co-existence feature		LBT or Frequency Hopping with Fragmentation

Introduction

Thanks for Listening !
Q&A