

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

Submission Title: ETRI FSK PHY Proposal for TG4m

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Re: Call for proposals

Abstract: This contribution presents a final proposal for the TG4m

Purpose: Final proposal to 802.15m

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- TVWS WPAN considerations
- Dual PHY for TVWS WPAN
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- Location capability for FSK PHY
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Requirements Overview

- Key requirements for TVWS WPAN (Doc. 11-684-11)
 - Operations in TVWS frequency bands under regulatory constraints
 - Data rate of typically 40Kbps to 2Mbps & optionally 10Mbps
 - Optimal & power efficient device command & control applications
 - Operating range of at least 1Km
 - At least 1000 direct neighboring devices
 - Multi-band capability
 - Coexistence with primary users (TV broadcasting)

TVWS WPAN Considerations (1)

- Rural areas
 - Easy to find available TVWS channels
 - Usually not crowded: free from interference
 - Max. 100mW TX power for Mode I/II devices
 - 1km service coverage is easily met
- Metropolitan areas
 - Difficult to find TVWS channels due to rebroadcast TV signals
 - Reduced TX power in adjacent channel: Max. 40mW TX power for Mode I/II devices
 - Usually crowded: several services in one TVWS channel
 - Reliability enhancing features are desirable (optionally required)

TVWS WPAN Considerations (2)

- Interoperability requirement
 - TVWS channel availability is not guaranteed, especially in metropolitan areas
 - Seamless WPAN services should be maintained regardless of TVWS channel status
 - Transition to 900MHz band may be required
 - IEEE 802.15.4g SUN standard is well established in 900MHz band
- There should be at least one operation mode to provide connectivity between TVWS WPAN and SUN

Dual PHY for TVWS WPAN

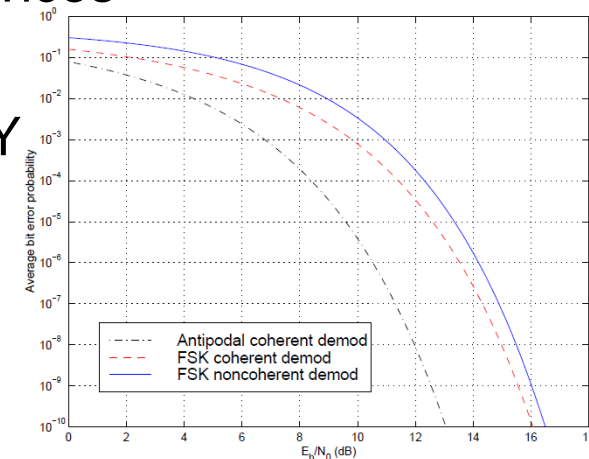
- PHY Data rate in TG4m
 - Typically 40Kbps~2Mbps, optionally ~10Mbps
- Various applications in TGD(doc.11-0684-10)
 - Single PHY cannot cover all the applications
 - FSK PHY: Low data rate & low complexity PHY
 - OFDM PHY: High data rate & high reliability PHY

Application	Candidate PHY
Smart Utility Networks	FSK
Infrastructure Monitoring Networks	FSK
Intelligent Transportation System	OFDM
Surveillance Control & Monitoring Networks	OFDM

Narrowband FSK PHY

Motivation for NB FSK PHY

- Benefits
 - No need of high-linearity power amplifier (PA)
 - Non-coherent receiver: low-power consumption
 - No need to track the phase of the carrier
 - Performance difference between coherent receiver and non-coherent receiver: roughly 1dB
 - Suitable for battery-powered Mode I devices
 - Simple, cheap and proven technology
 - SUN & LECIM standards take FSK PHY



* Wong & Lok: *Theory of Digital Communications*, Chapter 2. Modulation & Demodulation, p221

FSK PHY for TVWS WPAN (1)

- Propose to adopt mandatory TG4g FSK PHY
 - Data rate: 50Kbps
 - Channel BW: 200KHz
 - Modulation: 2 Filtered FSK
 - No whitening
 - No FEC & Interleaving
 - No mode switch

FSK PHY for TVWS WPAN (2)

- Link Budget for FSK PHY
 - Path loss: Modified Hata model is considered (Doc.11-684-11)
 - Required Eb/No: 13dB@ 10^{-5} for FSK
 - Reliability enhancing features are required

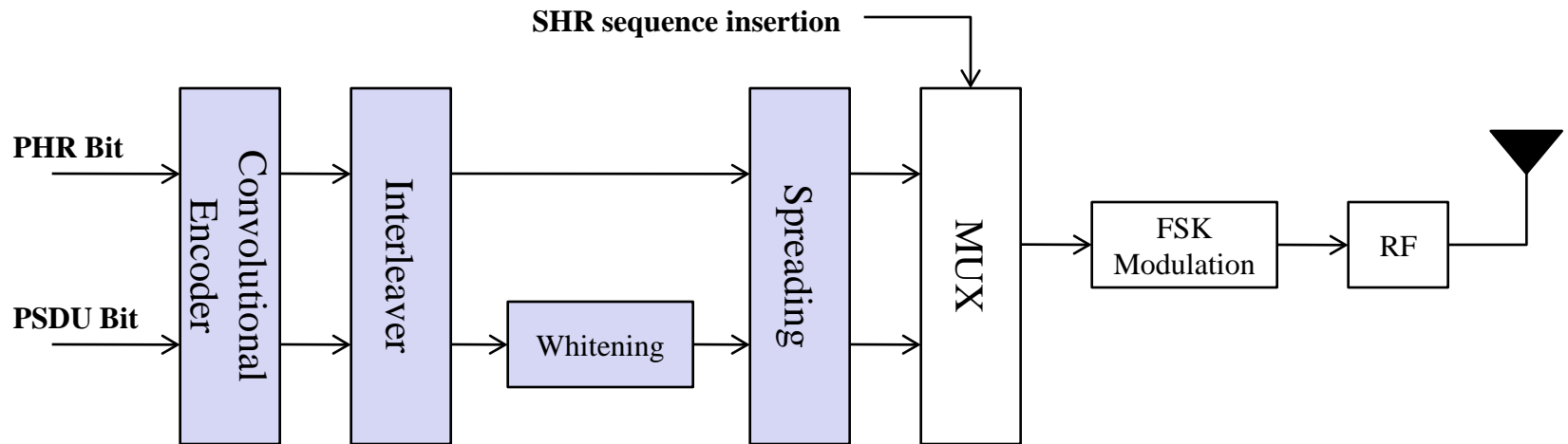
Link Budget for TG4m TVWS WPAN FSK PHY 50Kbps		
Parameters	Unit	Value
1) Bandwidth [BW]	MHz	0.2
2) Average TX Power [Pt]	dBm	5.6
3) TX antenna gain [Gt]	dBi	0.0
4) Center frequency [fc]	Hz	6.9500E+08
5) Path loss at 1km (Modified Hata model)	dB	112.0
6) RX antenna gain [Gr]	dBi	0.0
7) RX power [Pr=Pt+Gt+Gr-L1-L2]	dBm	-106.4
8) Receiver AWGN noise floor [N=-174+10log(BW)]	dBm	-121.0
9) RF noise figure [Nf]	dB	10.0
10) Average noise power [Pn=N+Nf]	dBm	-111.0

FSK PHY for TVWS WPAN (3)

- Propose to include reliability enhancing features
 - Parity bit in PHY header (mandatory)
 - Whitening (optional)
 - FEC & Interleaving (optional)
 - Spreading (optional)
 - Longer SFD sequence (optional)

FSK PHY for TVWS WPAN (4)

- PHY data flow



Function block that can be selected based on regional regulations and deployment environments

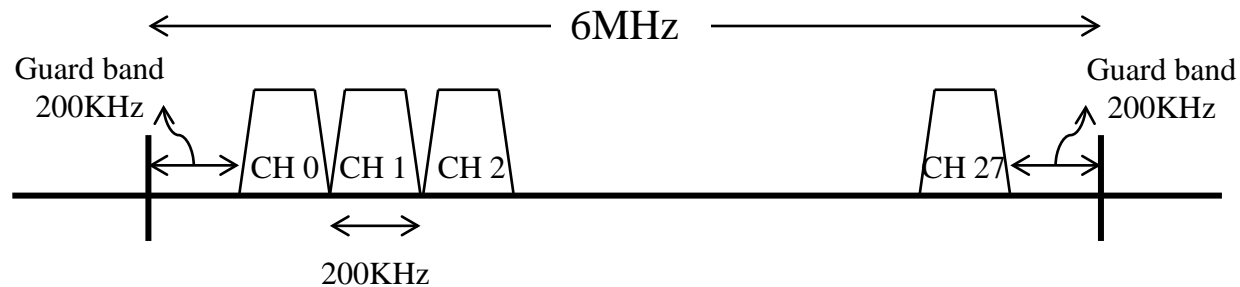
FSK PHY for TVWS WPAN (5)

- Modulation & channel parameters
 - Mode #1: mandatory 50Kbps (same as TG4g)
 - Mode #2: 100Kbps
 - 100Kbps is more attractive than 150Kbps when considering implementation
 - Mode #3: 200Kbps (same as TG4g)

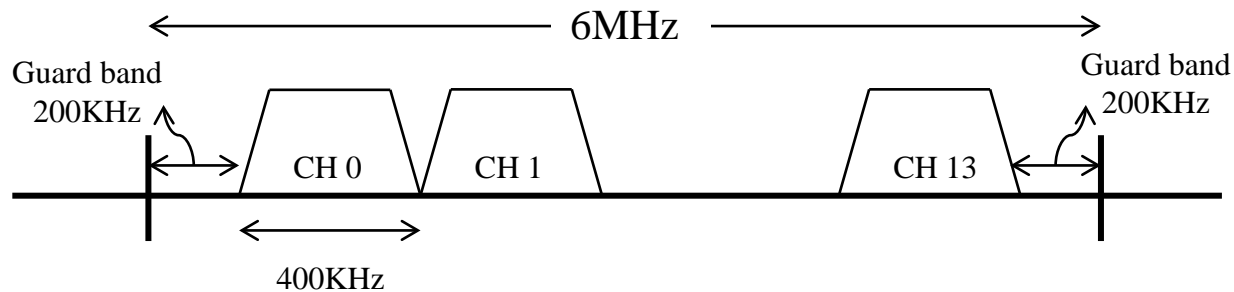
	Operating Mode #1	Operating Mode #2	Operating Mode #3
Data rate (Kb/s)	50	100	200
Modulation	Filtered 2FSK	Filtered 2FSK	Filtered 2FSK
Modulation Index	1	0.5	0.5
Channel Spacing (KHz)	200	400	400

FSK PHY for TVWS WPAN (6)

- Channel Plan for 6MHz bandwidth
 - 50Kbps mode: 28 channels

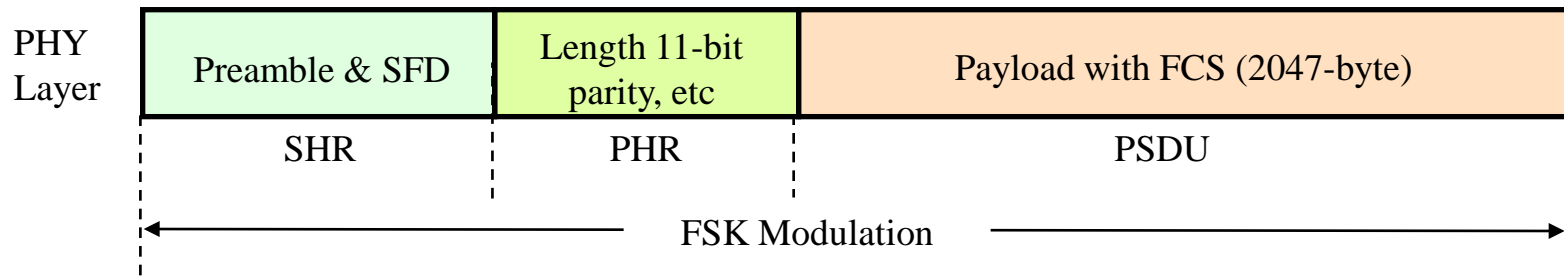


- 100Kbps & 200Kbps mode: 14 channels



FSK PHY for TVWS WPAN (7)

- PHY packet format



- Preamble

- multiples of “01010101” as specified in 15.4g
- Length: 4-100 octet

- SFD

- Basically, same as 15.4g
- Optionally, a longer SFD sequence is required for higher reliability (doc. 12-0048-00 & 12-0094-00)

FSK PHY for TVWS WPAN (8)

- PHY header (PHR)
 - Frame length: 11bit → max. 2047-octet PSDU
 - Bit string index [3:15]: same as TG4g SUN
 - Bit string index [2]: Ranging packet indication for ranging counter
 - Bit string index [1]: Parity bit
 - Simply detect PHR error to stop demodulation process
 - Bit string index [0]: Reserved bit
 - Consider interoperability between TG4m & SUN/LECIM

Bit string index	0	1	2	3	4	5-15
Bit mapping	0/1	Parity	RNG	FCS	DW	L10-L0
Field name	Reserved	Parity	Ranging packet	FCS type	Data whitening	Frame Length

FSK PHY for TVWS WPAN (9)

- The parameters configuring the use of FEC & interleaving and spreading are listed in PHY PIB attributes
 - phyTVWSFSKFECEnabled: on/off
 - phyTVWSFSKInterleavingEnabled: on/off
 - phyTVWSFSKSpreadingEnabled: on/off
 - phyTVWSFSKSpreadingFactor: 2-bit (0,1,2,4)
 - phyTVWSFSKSFDLength: 0 (2-byte SFD), 1 (longer SFD)

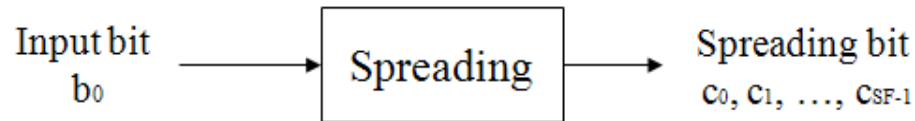
FSK PHY for TVWS WPAN (10)

- FEC & Interleaving
 - Propose to use the same FEC & Interleaving in LECIM FSK (as in doc.12-089-06)

FSK PHY for TVWS WPAN (11)

- Spreading

- Propose to use the same spreading scheme in LECIM (as in doc.12-089-06)



Spreading factor (SF)	Input bit (b_0) = 0	Input bit (b_0) = 1
1	$(c_0) = 0$	$(c_0) = 1$
2	$(c_0, c_1) = 01$	$(c_0, c_1) = 10$
4	$(c_0, \dots, c_3) = 0101$	$(c_0, \dots, c_3) = 1010$
8	$(c_0, \dots, c_7) = 0101\ 0101$	$(c_0, \dots, c_7) = 1010\ 1010$

- Repetition of “01” or “10” is useful for FSK system
- Spreading factor can be selected according to channel condition

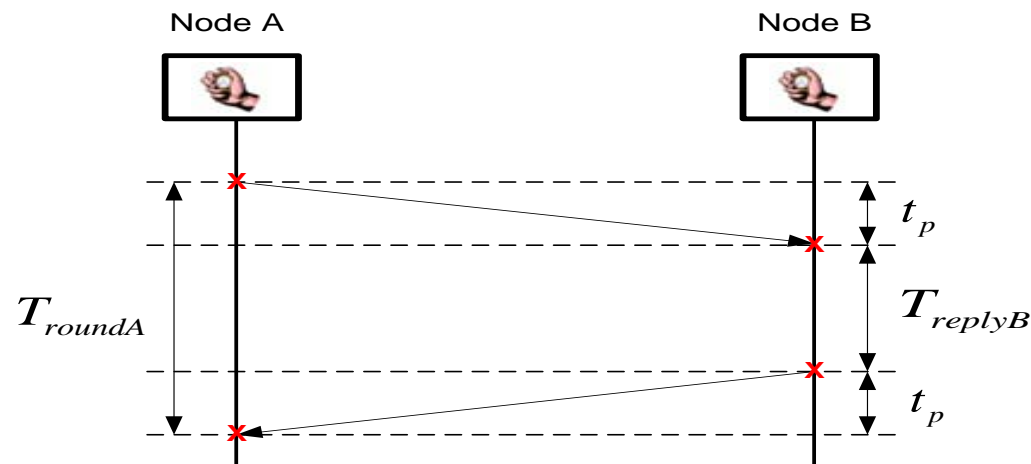
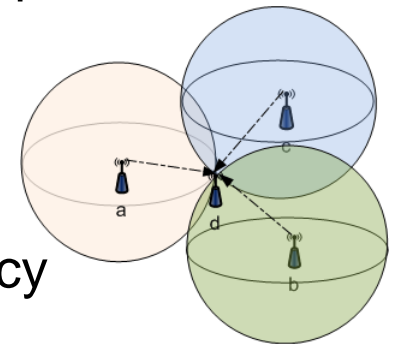
Location Capability for FSK PHY

RF Localization for TG4m

- Doc.12-167-00 (RF localization in TVWS) initiated RF localization issue
 - Motivation
 - GPS is not 100% available such as indoors, urban canyons and GPS jamming
 - Battery-powered Mode I device may not equip with GPS receiver
- Propose optional RF localization for TG4m

RF Localization

- Positioning
 - At least 3 references with known positions are required to retrieve a 2D-Position from 3 ranging (distance) measurements
- Ranging methods
 - TWR (Two Way Ranging) is desirable for accuracy

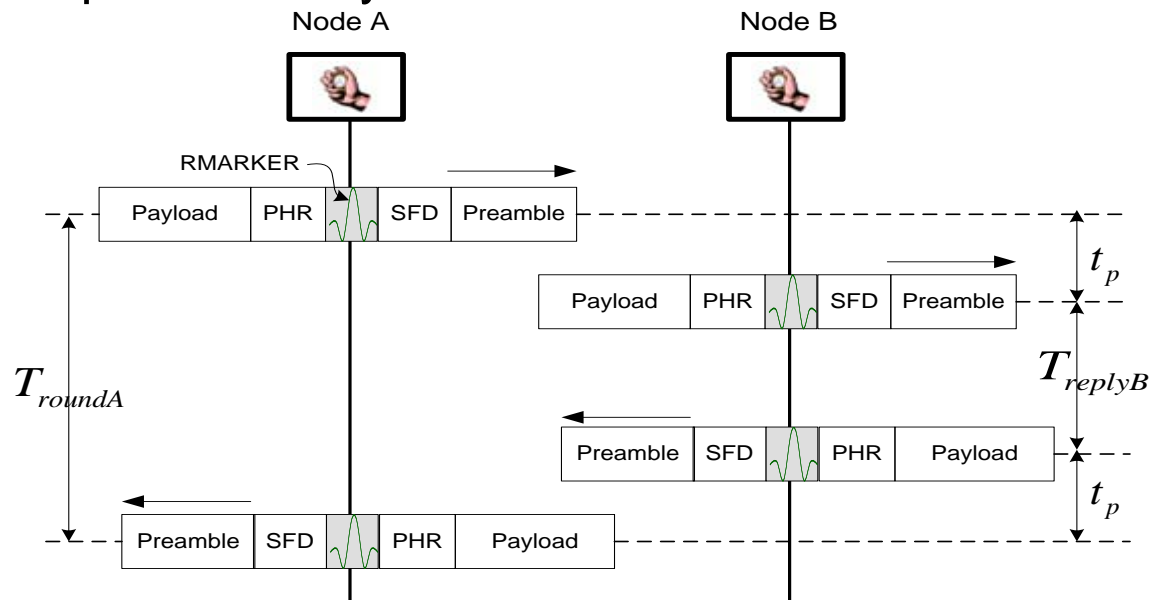


Time of Flight (ToF) :

$$t_p = \frac{T_{roundA} - T_{replyB}}{2}$$

Positioning Concept in 15.4a

- ToF estimation based on Two Way Ranging (TWR)
 - Ranging counters in Node A & Node B
 - Timestamps for precise instant that RMARKER are transmitted and received
 - Operation only when RNG bit in PHR is set

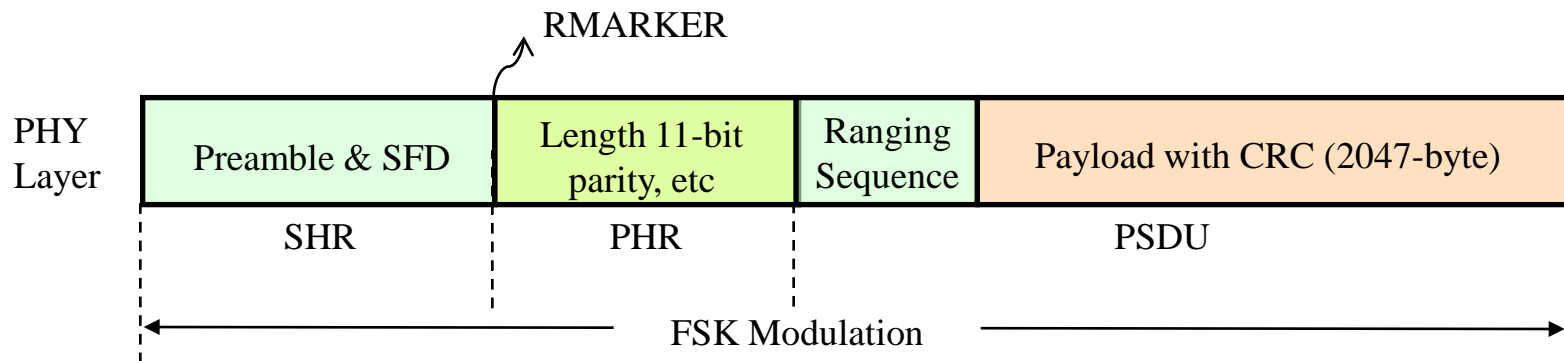


Positioning for FSK PHY

- NB FSK PHY
 - Used for low rate & low cost applications
 - May require location capability even though its accuracy is generally worse than OFDM PHY
- ToA estimation in FSK PHY
 - It is difficult to retrieve ToA from correlation which are commonly used in UWB or OFDM
 - It is desirable to extract FSK symbol transition timing

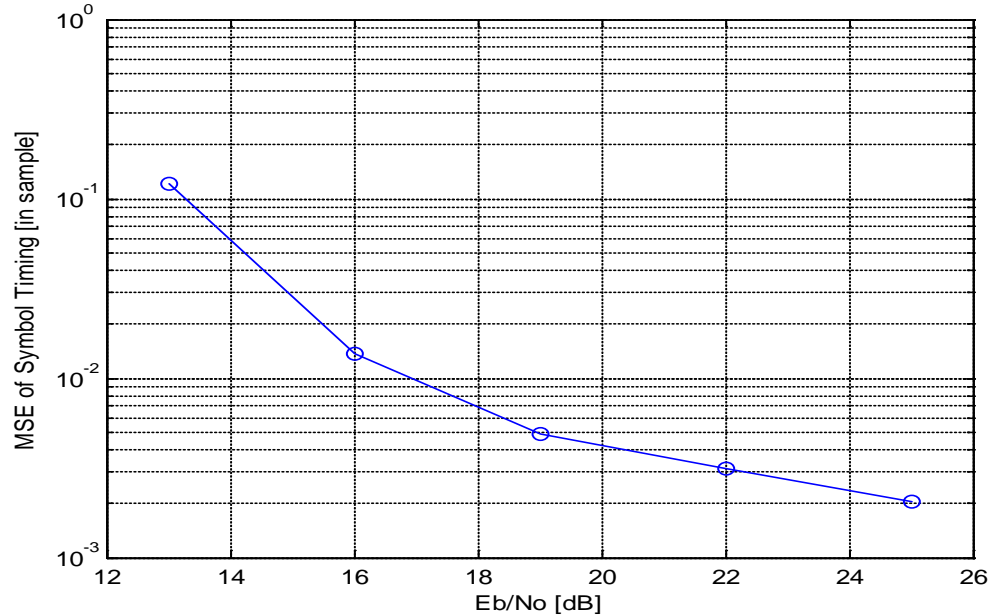
ToA Estimation in FSK PHY

- Ranging sequence
 - Select best sequence for retrieving symbol transition timing
 - Repetition of “01” pattern would be good
- Ranging sequence insertion
 - If RNG bit in PHR is “1”, insert ranging sequence right after PHR
- RMARKER for ranging counter operation
 - First PHR symbol transition



ToA Estimation Accuracy

- Simulation environments
 - Data rate: 200KHz
 - Ranging sequence: 8 repetition of “01”
 - Operation clock: 16 x 200KHz



Considerations for TG4m Ranging

- Ranging mechanism
 - Well established in 15.4a IR-UWB standard as discussed in Doc. 12-0247-02
 - e.g., PHY/MAC supporting features
 - Propose to use the 15.4a ranging mechanism
- Performance degradation factors
 - ToA estimation errors
 - Clock drifts
 - SDS-TWR may resolve this problem, but network traffic will increase due to increased message exchange
 - Additionally, enhanced ranging protocol may be required

Summary

- FSK PHY for TG4m TVWS WPAN
 - Adopt basically TG4g MR-FSK PHY
 - Include reliability enhancing features
 - Parity in PHR, Whitening, FEC & Interleaver, Spreading

- Location capability for FSK PHY (Optional)
 - Adopt basically 15.4a ranging mechanism
 - Insert ranging sequence for FSK symbol transition estimation
 - RNG (ranging indication bit) in PHR
 - RMARKER for ranging counter operation
 - First PHR symbol transition