Considerations on the Non-Synchronized Ranging Channels

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Venue:
Re: IEEE 80216m-09/0020, “Call for Contributions on Project 802.16m Amendment Working Document (AWD) Content”
“Comments on AWD 15.3.9 UL-CTRL”

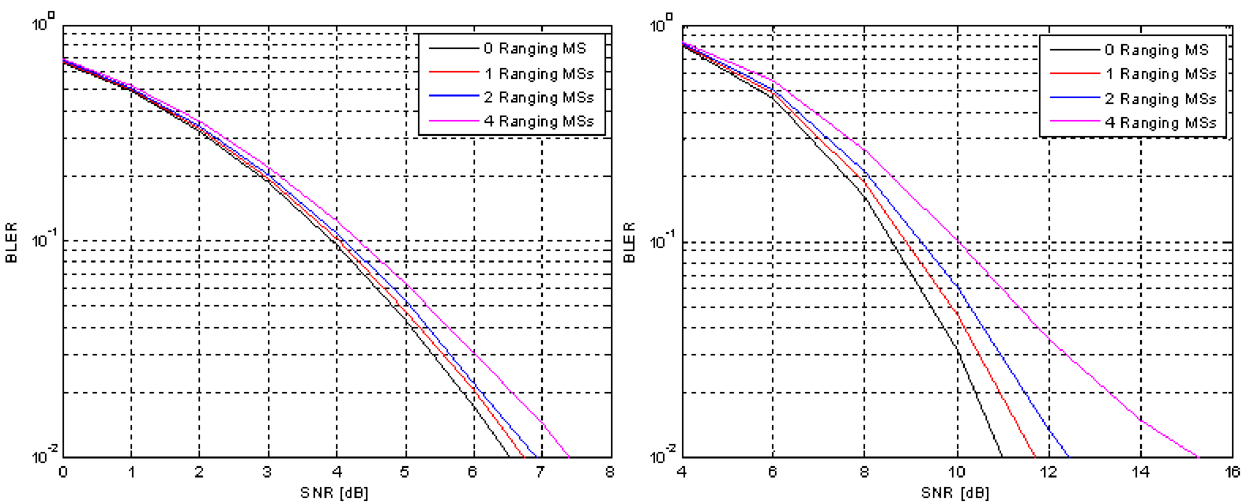
Purpose: To be discussed and adopted by TGm for the IEEE 802.16m AWD.

Introduction

- **In this contribution, we need to determine the ranging formats and corresponding parameters for supporting various coverage, e.g., ranging subcarrier spacing, occupied bandwidth, lengths of RCP, RP, GT, etc.**
- **In addition, it is also essential to support enough reuse factors/opportunities using the ranging formats and their configurations in order not to restrict the system deployment.**
- **To Determine Required Basic Ranging Parameters and Formats**
  - Provide the simulation results in various scenarios, i.e.,
    - ✓ Ranging subcarrier spacing: Different and Same with data subcarrier spacing
    - ✓ Resource size: 1 Subband vs. 2 Subbands
    - ✓ Link budget analysis for coverage comparison in data and ranging channels
  - Ranging performance comparison in several ranging structures
    - ✓ Miss detection performance with 0.1% False alarm rate comparing with 16e ranging channels
    - ✓ Required SNR for ranging channels comparable to that of data channels
    - ✓ 16m ranging overhead comparison with 16e ranging and LTE RACH
  - Reuse factors in terms of ranging opportunities
    - ✓ Supportable ranging codes: Ranging BW & Subcarrrier spacing
    - ✓ Increased opportunities for providing enough reuse factors (compared with LTE)

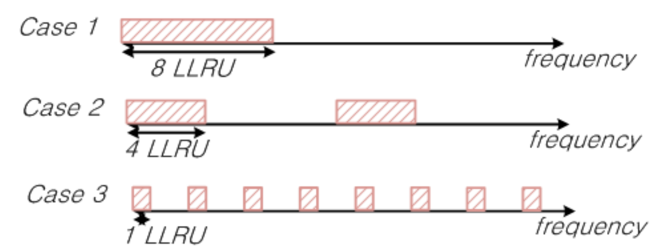
Localized Allocation for Ranging Channels

- In the SDD [1], the physical resource of ranging channel for non-synchronized AMS is consecutive Nr_{sc} ranging subcarriers ($BW_{RCH\text{-}NS}$ Hz corresponding to continuous Nr_{ru} CRUs) and Nr_{sym} OFDMA symbols ($T_{RCH\text{-}NS}$ sec).
- Problems of distributed allocation [2-4]
  - Data performance degradation
    - ✓ Due to large delay of ranging channel, inter-subcarrier interference is occurred.
  - Ranging performance degradation
    - ✓ The correlation properties are worse if the equal-space allocation in subcarrier level is not allowed.



(a) QPSK (b) 16-QAM

< Data performance degradation [2] >



Resource Allocation	Length of code	Performance degradation for 1% P_m and 0.1% $R_{FA\text{-}64}$ $[E_p/N_0]$
Case 1	701	-
Case 2	701	0.7 dB
Case 3	701	1.2 dB

< Ranging performance degradation [4] >

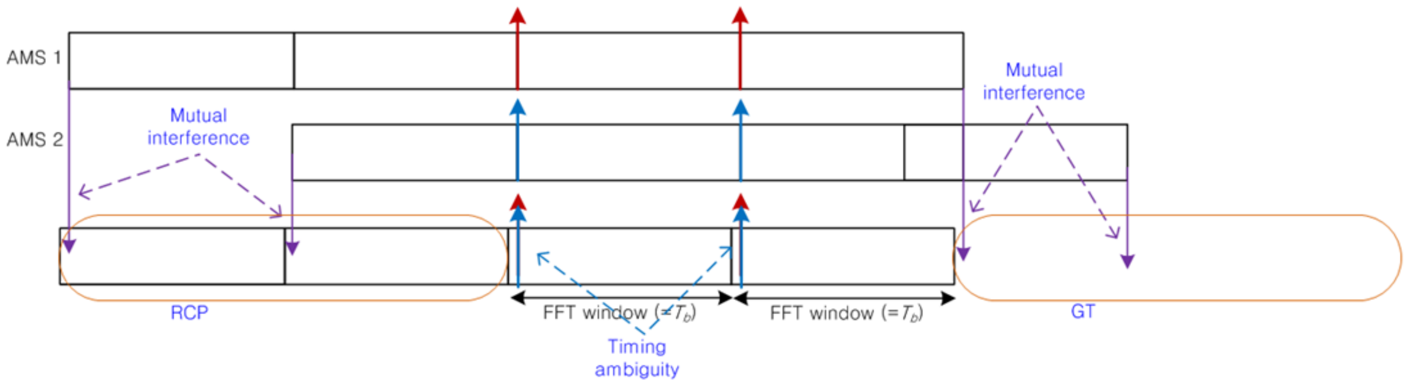
Subcarrier Spacing

❑ Data subcarrier spacing

A shortage of available ranging codes occurs.

Simple repetition of T_b can not support a longer propagation delay than T_b.

✓ The larger delay than T_b causes timing ambiguity



Using the time-domain detector, we need to clarify and find solutions

- How to distinguish the timing ambiguity without performance degradation?
- How to remove the mutual interference?
- It has **very high complexity** because it is shall be calculated for all possible delay. For example, if considering the 100km cell radius for 20MHz, 15200 times correlation per code are necessary!!

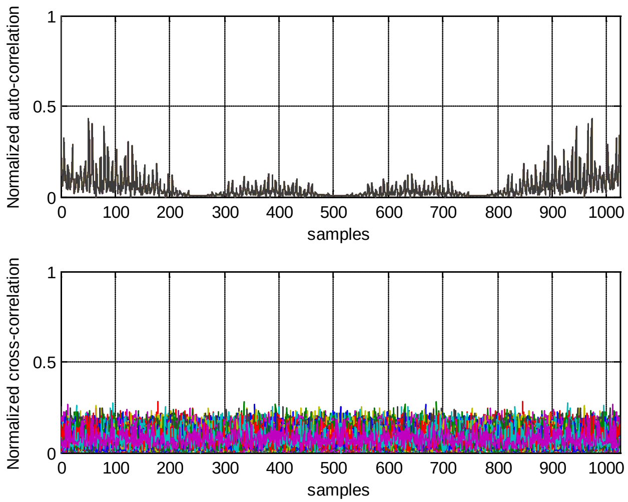
❑ Smaller ranging subcarrier spacing ($\triangle f_{RA}=\triangle f/2.5$)

The better performance up to 350km/h has been already provided in [5].

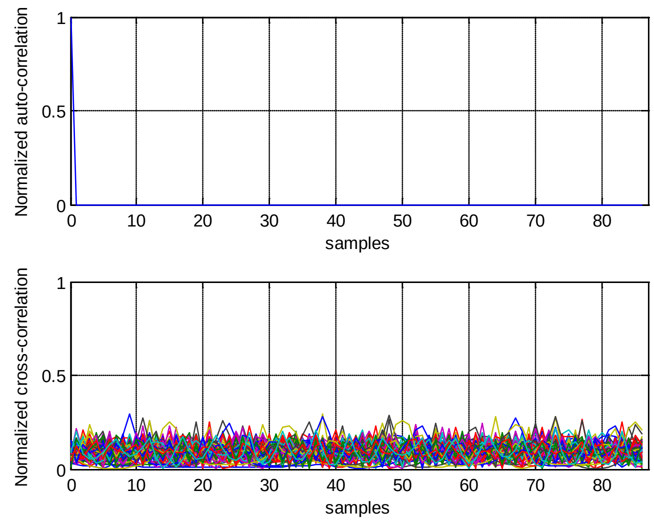
Simply implemented at AMS & ABS, e.g., by oversampling at AMS or overlap-and-add method without large FFT at ABS.

Ranging Preamble Codes (1/2)

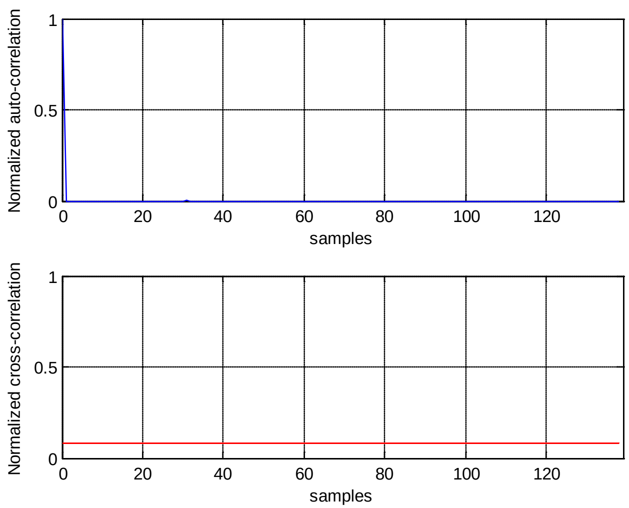
❑ Good Auto- and Cross-correlation Properties



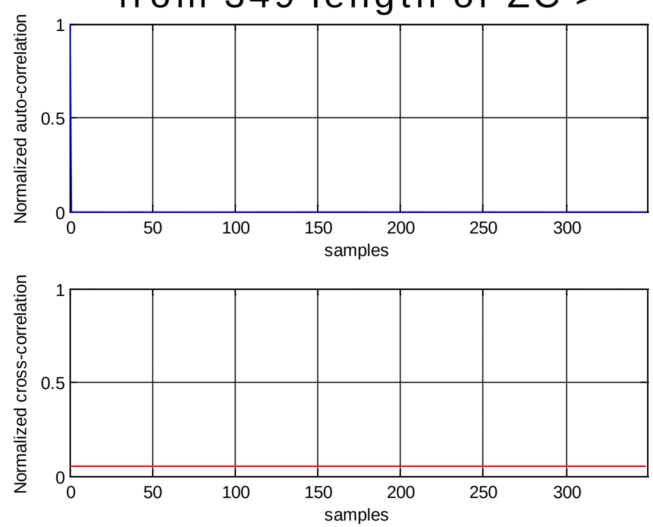
<16e PUSC (144 length)>



<Truncated 87 length of ZC from 349 length of ZC >



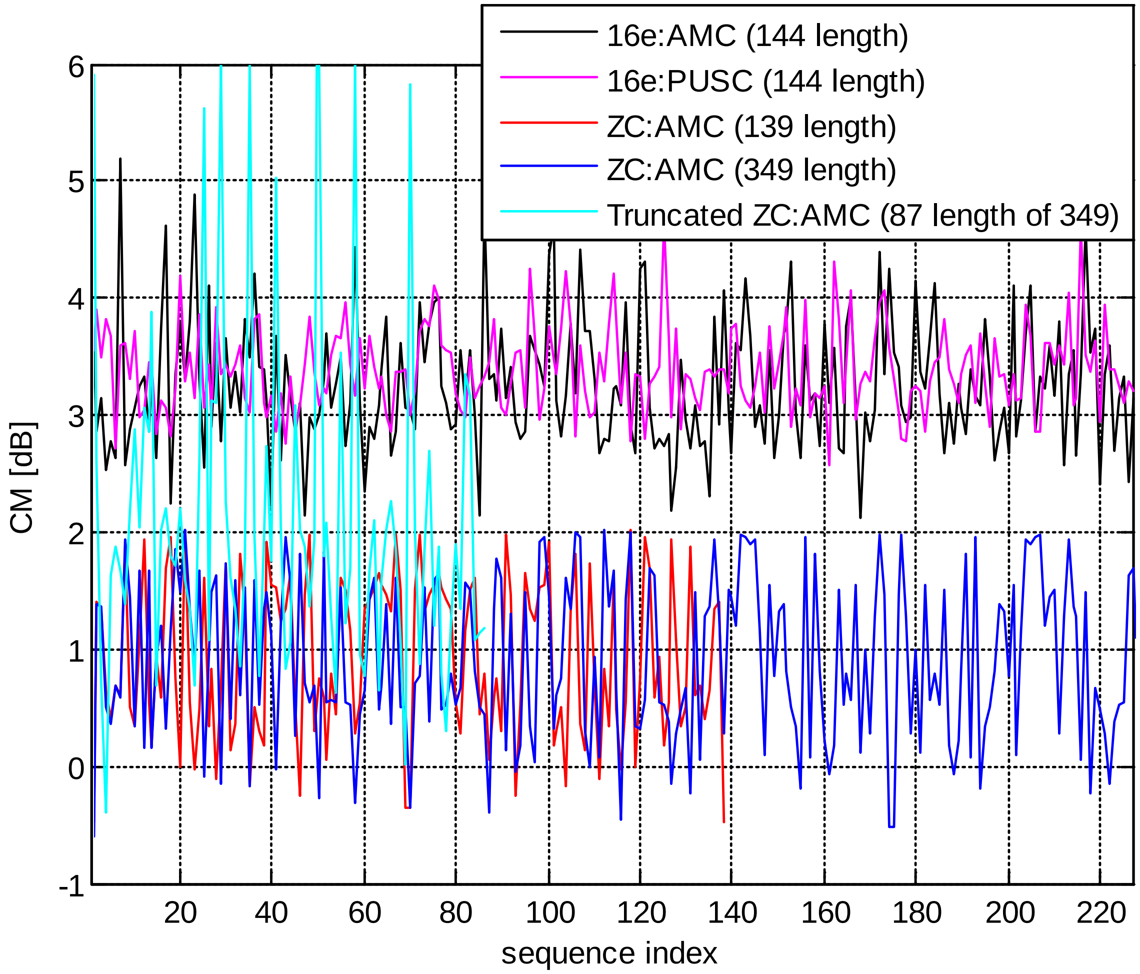
< 139 length of ZC>



< 349 length of ZC>

Ranging Preamble Codes (2/2)

- Low CM Properties for Ranging Preamble Codes



Proposed Ranging Formats and Parameters [6-8]

<table>
<tr><th rowspan="2">Format No.</th><th rowspan="2">Format</th><th rowspan="2">T_{RP}</th><th rowspan="2">Δf_{RP}</th><th rowspan="2">Duplex mode (2)</th><th colspan="2">Within subframe for data CP=1/8 $\cdot T_b$</th><th colspan="2">Within type-1 subframe for data CP=1/16 $\cdot T_b$</th><th colspan="2">Within type-2 subframe for data CP=1/16 $\cdot T_b$</th></tr>
<tr><th>T_{RCP}</th><th>$C_{\max}$</th><th>T_{RCP}</th><th>$C_{\max}$</th><th>T_{RCP}</th><th>$C_{\max}$</th></tr>
<tr><td rowspan="2">0</td><td rowspan="2">RCP+ RP+ RCP+ RP</td><td rowspan="3">228.5714 µs (4096× T_{st})</td><td rowspan="5">△f/2.5</td><td>FDD</td><td>57.1429 µs (1280× T_{st})(1)</td><td>6.852 km</td><td>43.8393 µs (982× T_{st})</td><td>5.708 km</td><td>76.2054 µs (1707× T_{st})</td><td>10.560 km</td></tr>
<tr><td rowspan="2">TDD</td><td rowspan="2">75.7143 µs (1696× T_{st})(1)</td><td rowspan="2">9.636 km</td><td rowspan="2">54.8214 µs (1227× T_{st})</td><td rowspan="2">7.354 km</td><td rowspan="2">87.1429 µs (1952× T_{st})</td><td rowspan="2">12.206 km</td></tr>
<tr><td>1</td><td>RCP+ RP</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">RCP+ RP+ RP</td><td rowspan="2">228.5714 µs (5120× T_{st})</td><td>FDD</td><td>11.4286 µs (256× T_{st})</td><td>22.270 km(3)</td><td>5.7143 µs (128× T_{st})</td><td>17.988 km</td><td>5.7143 µs (128× T_{st})</td><td>32.549 km</td></tr>
<tr><td>TDD</td><td>113.5714 µs (2544× T_{st})</td><td>15.311 km</td><td>82.1429 µs (1840× T_{st})</td><td>11.456 km</td><td>130.7143 µs (2928× T_{st})</td><td>18.737 km</td></tr>
<tr><td>3</td><td>RCP+ RP</td><td>731.4286 µs (6144× T_{st})</td><td>△f/8</td><td>Both</td><td>678.57143 µs (15200× T_{st})</td><td>70.237 / 95.934 km</td><td>672.85714 µs (15072× T_{st})</td><td>55.676 / 95.934 km</td><td>672.85714 µs (15072× T_{st})</td><td>99.340 / 95.934 km</td></tr>
</table>

(1) : The number of samples with sampling time for 20 MHz.
(2) : It is assumed that the TTG is 105.714 µs and 82.853 µs for T_g=1/8T_b and T_g=1/16T_b, respectively.
The maximum SSRTG is 50 µs for TDD mode.
(3) : It is assumed that first RP is used as RCP for Format 2 in FDD mode.

Comparisons of Ranging Formats: Bandwidths

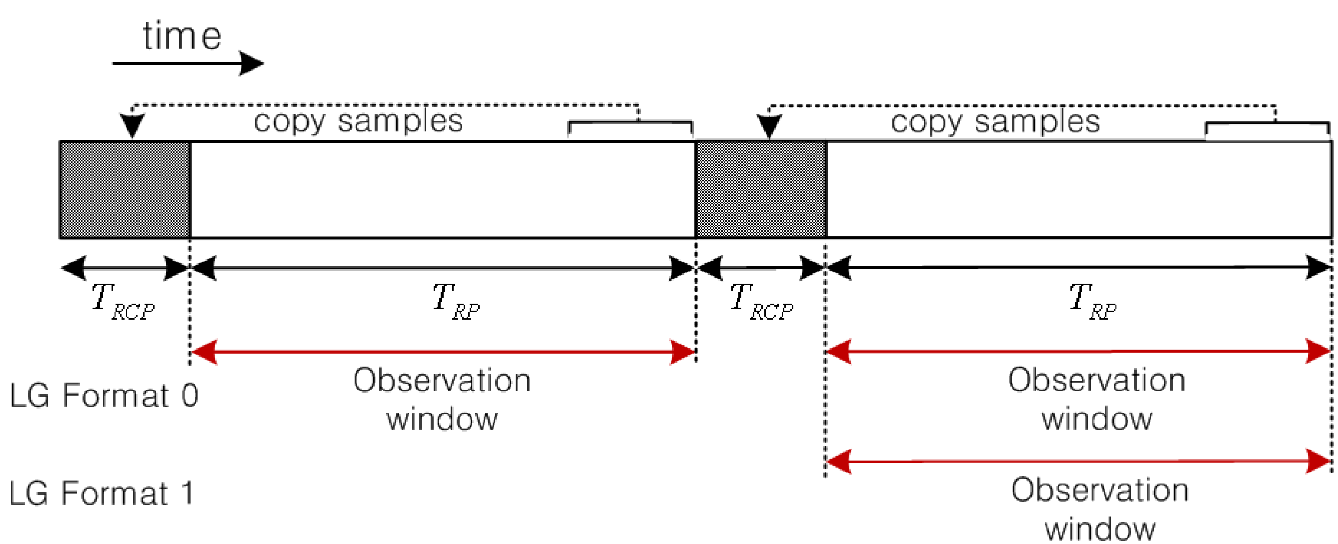
- **For different ranging subcarrier spacing : $\triangle f_{RA}=\triangle f/2.5$**

  Using the default ranging structure in the SDD (Structure 1 in the AWD), there exists a couple of its usage, i.e.,

  - ✓ Format 0: A single ranging opportunity with RP repetition
  - ✓ Format 1: 2 ranging opportunities in the TDM manner without RP repetition
    - Not necessary to consider GT between 2 ranging channels

  The length of ranging codes in 2 different ranging BWs

  - ✓ 349 length of ZC codes for 2 subbands
  - ✓ 173 length of ZC codes for 1 subband



Comparisons of Ranging Formats: different subcarrier spacing with data

- **Comparisons between $\triangle f_{RA}=\triangle f/2.5$ and $\triangle f_{RA}=\triangle f/2$**

  $\triangle f/2.5$ can be provide the increased detection energy and lower cross-correlation properties.

  The length of ranging codes in same ranging BWs (1 subband)

  - ✓ 173 length of ZC codes for $\triangle f_{RA}=\triangle f/2.5$
  - ✓ 139 length of ZC codes for $\triangle f_{RA}=\triangle f/2$

Comparisons of Ranging Formats: same subcarrier spacing with data

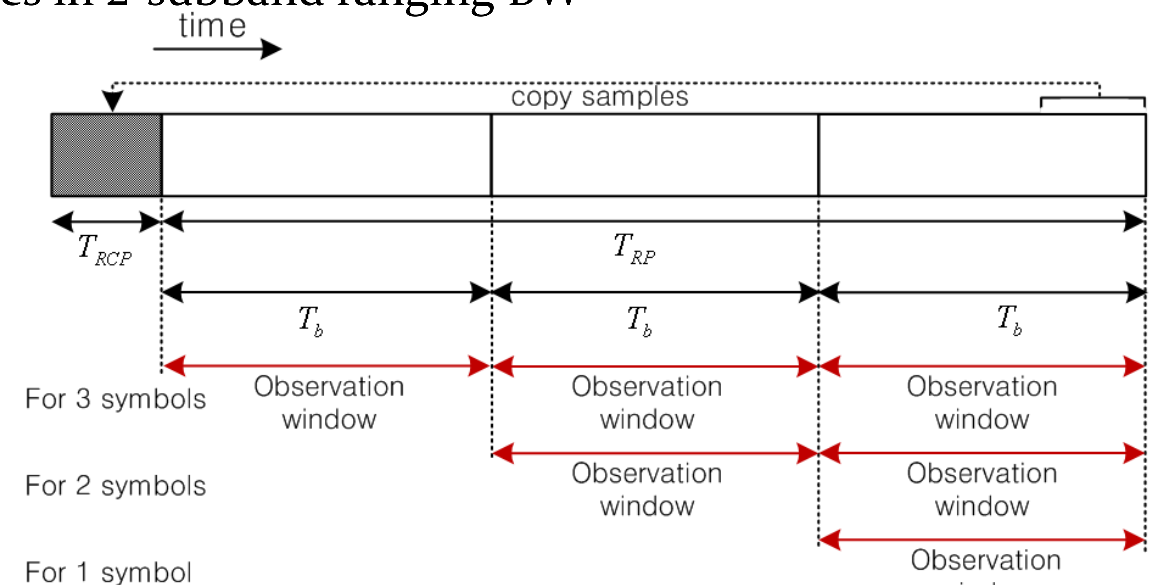
- **For same ranging subcarrier spacing with data : $\triangle f_{RA}=\triangle f$**

  Using the structure 2 or its modification, the ranging formats using the data subcarrier spacing can be considered with different repetition factors, i.e.,

  ✓ 1-, 2- or 3-symbol duration for ranging observation window

  The length of ranging codes in 2-subband ranging BW

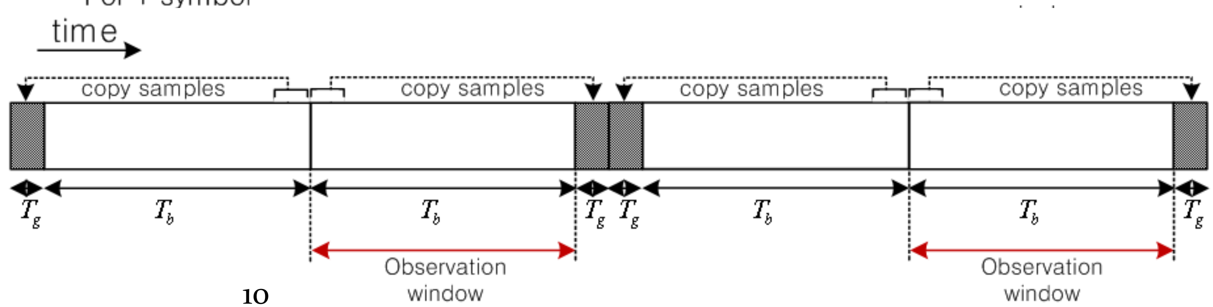
  ✓ 139 length of ZC codes



- **16e ranging channel**

  2/4 symbol-structure

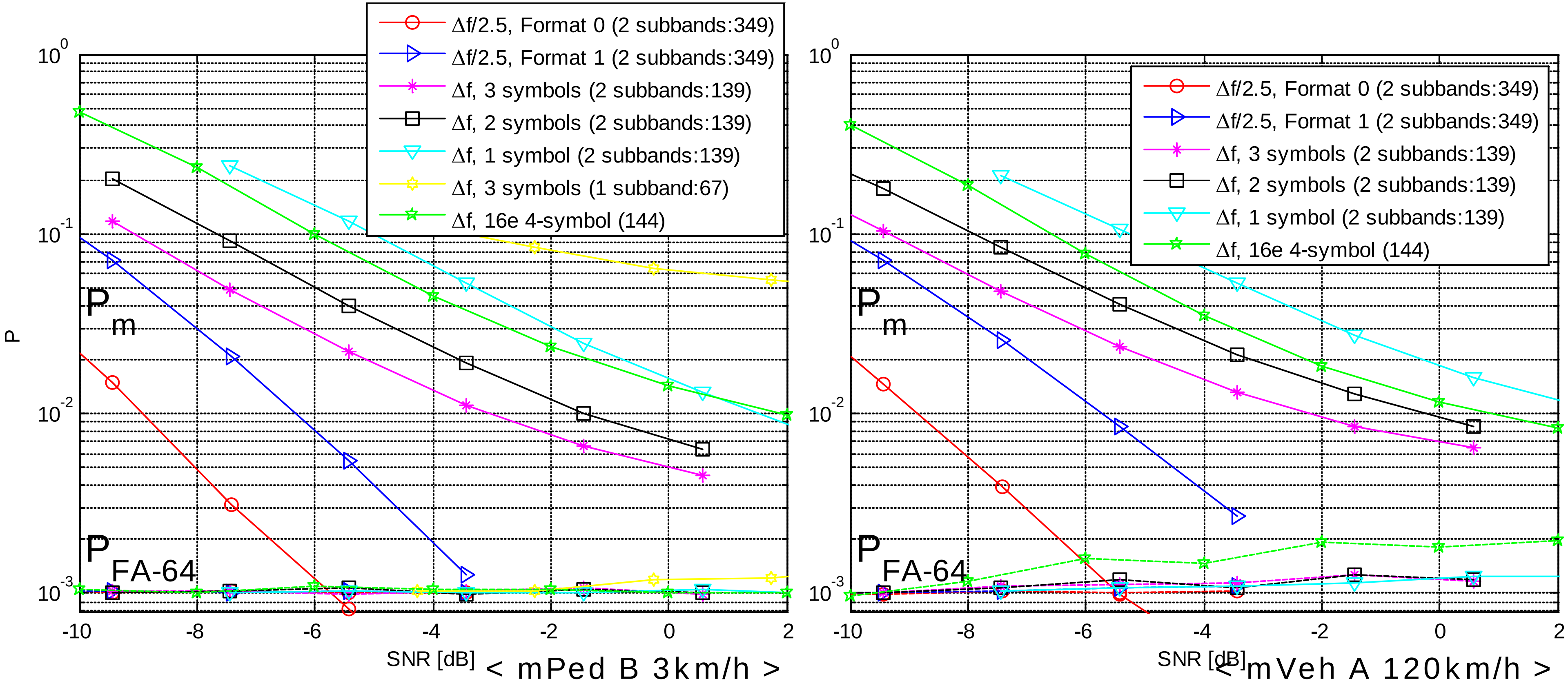
  144 length of 16e codes



Simulation Environments

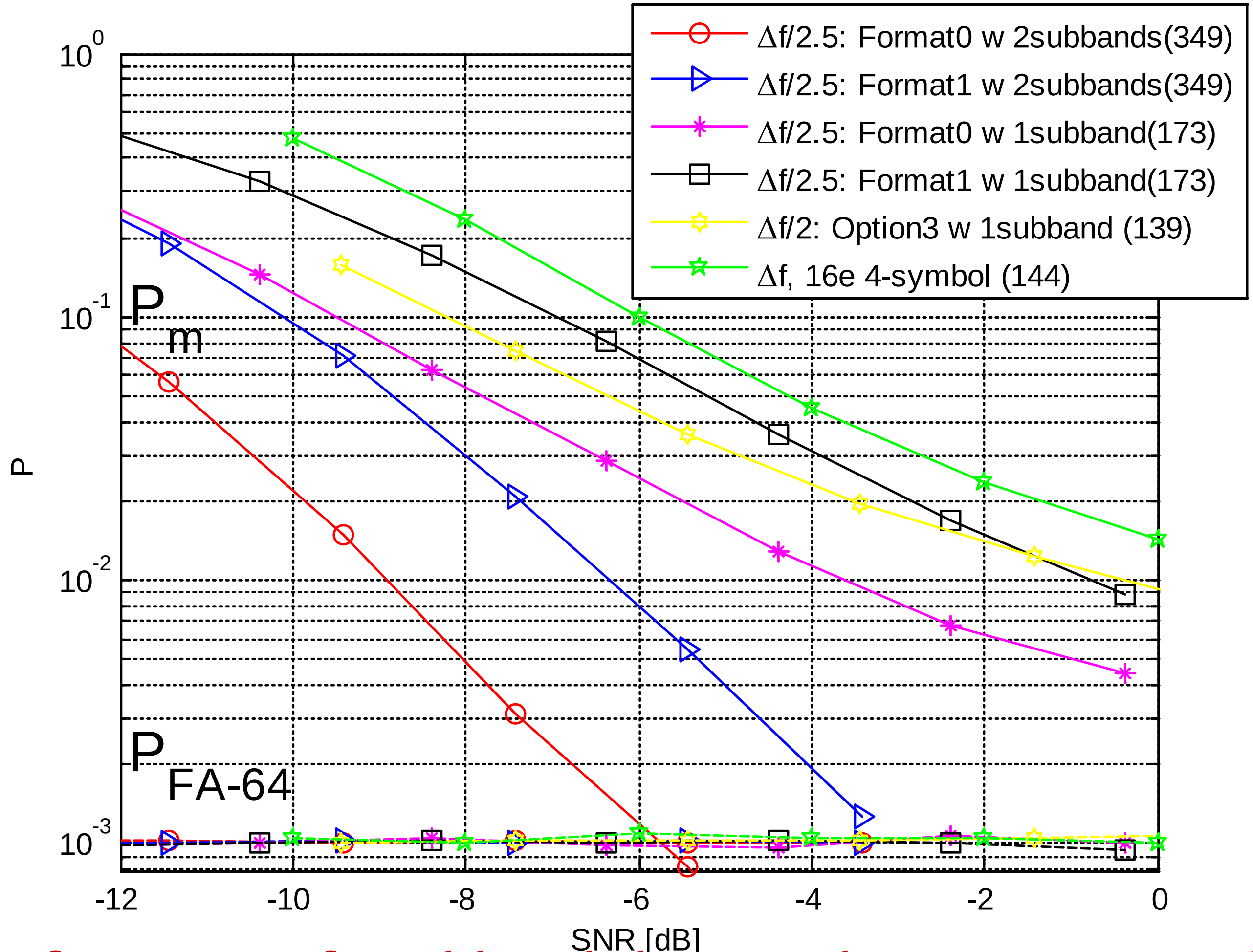
	Parameters	Assumptions
System	Carrier Frequency (f_c)	2.5 GHz
	Total Bandwidth (BW)	5 MHz
	Number of Points in FFT (N_{FFT})	512
	Sampling Frequency (F_s)	5.6 MHz
	Subcarrier Spacing (Δf)	10.9375 kHz
	OFDMA Symbol Duration without Cyclic Prefix ($T_b = 1/\Delta f$)	91.43 μs
	Cyclic Prefix Length (faction of T_b)	1/8
	OFDMA Symbol Duration with Cyclic Prefix (T_s)	102.86 μs for CP=1/8
	Residual Frequency Offset	Random < 218.75 Hz (< 2% of Δf)
Channel	Multi-antenna Transmission Format	1 Tx
	Receiver Structure	2 Rx
	Fading Channel Model	Modified Pedestrian B 3km or Modified Vehicular A 120 km/h
Ranging	Ranging Resource	2 subbands or 1 subband
	Ranging Subcarrier Spacing	$\Delta f 2.5$ or Δf or $\Delta f / 2$ (4.3750 or 10.9375 or 5.46875 kHz)
	Ranging Detector	Frequency domain energy detector
	Number of Ranging Codes per Channel	64 (w/o cyclic shift)
	Number of Ranging Channel per Sector	1
	Codes Set per Sector	Random within all codes
	Code Selection per AMS	Random within code set of sector
	Round Trip Delay	Random within 5km RTD
	Target Miss-Detection Probability	1 %
	Target Overall False Alarm Rate	0.1 %

Ranging Subcarrier Spacing (2 subbands)



- **The performance of △*f*/2.5 subcarrier spacing has 5~6 dB gain compare with that of data subcarrier spacing.**
  - △*f*/2.5 subcarrier spacing can obtain higher time diversity gain in high mobility environment.
- **If only one symbol is used for detection with data subcarrier spacing, it has worse performance than 16e 4-symbol structure.**
- **Data subcarrier spacing with 1 subband has significant performance degradation.**

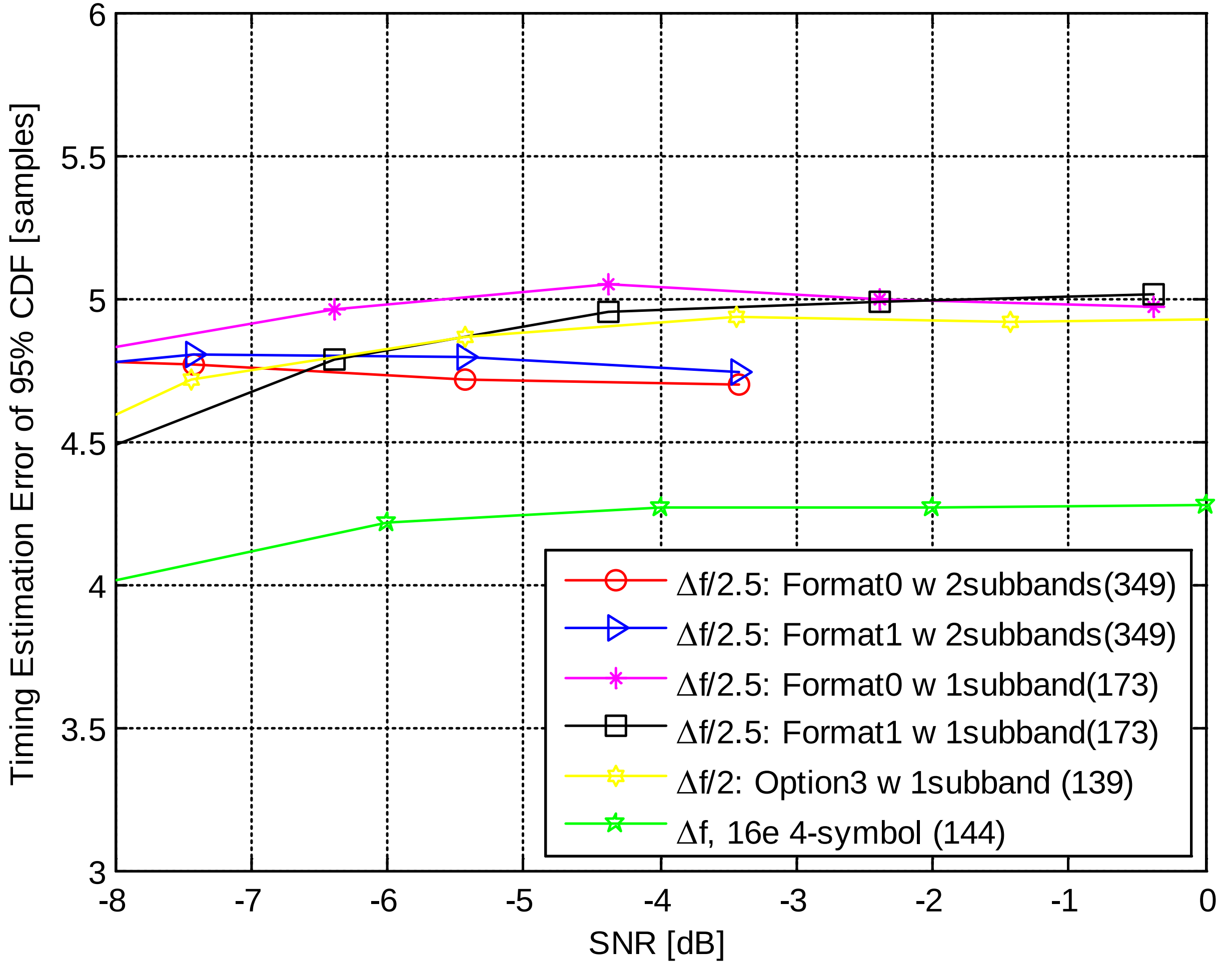
Ranging Bandwidth ($\triangle f_{RA}=\triangle f/2.5$ or $\triangle f/2$)



☞ **The performance of 2 subbands has 5~6 dB gain compared with that of 1 subband.**

☞ **Under the same overhead, the performance of $\triangle f/2.5$ subcarrier spacing outperforms that of $\triangle f/2$ subcarrier spacing.**

Timing Estimation Error



☞ **In the 1- or 2-subband ranging bandwidth, the timing error less than 5 samples (0.89 μs) in 95% is quite enough - Comparable with the 16e timing performance, i.e., 4.27 samples (0.76 μs).**

Data Coverage vs. Ranging Coverage

❑ Consider 12.2 kbps VoIP

- Total VoIP packet size : 44 bytes for active ☞ 352 bits
- CTC coding rate 101/256, 71/256, 48/256, 31/256 ☞ 893, 1270, 1878, 2907 bits
- QPSK modulation ☞ 447, 635, 939, 1435 subcarriers
- Required PRUs ☞ 5, 7, 10, 15 PRUs
- Required CINR (20%) ☞ -2.5, -3.5, -4.5, -6.0 dB

< The Receiver Sensitivity [dBm] >

Coding rate		101/256 CTC	71/256 CTC	48/256 CTC	31/256 CTC
Used PRUs in Freq.	1	-118.56	-119.56	-120.56	-122.06
	2	-115.56	**-116.55**	**-117.55**	-119.05
	3	-113.79	-114.79	**-115.79**	**-117.29**
	4	-112.54	-113.54	-114.54	**-116.04**
Ranging	△*f*/2.5	**-115.64 (1 subband)/-117.93 (2 subbands)**			
	△*f*/2	**-112.44 (1 subband)**			
	△*f*	**-107.43 (1 symbol/2 subbands)** **-110.43 (2 symbols/2 subbands)** **-112.03 (3 symbols/2 subbands)**			

Thermal noise : -174 dBm/Hz, Noise figure: 5 dB, -2dB margin for ranging from target SNR 0.1% $P_{FA\text{-}64}$ and 1% P_m (pp. 12~13)

☞ To support data and ranging coverage balancing, 2 subbands for ranging BW should be supported.

Number of codes: Opportunities

- **Ranging opportunities are directly coupled with the reuse factor:**
  - △*f*/2.5 subcarrier spacing (vs. △*f* subcarrier spacing)
    - Approx. 2.5 times increased cross-correlation
  - 2 subbands (vs. 1 subband)
    - Approx. 2 times increased reuse factors
- **Sufficient reuse factor is needed for at least 1-tier support:**
  - Exploiting time-domain opportunity in a subframe is beneficial to increase the reuse factors.

< The reuse factor in 5km cell radius >

Subcarrier spacing	Ranging bandwidth	# of root seq.	# of used root seq. per cell for 64 opp.	Reuse factor	
				Single Format	Including Format 1
△*f* /2.5	2 subbands	348	16	**21.75**	**43.50**
	1 subband	172	16	10.69	**21.38**
△*f*	2 subbands	138	64	2.14	4.28
	1 subband	66	64	1.02	2.03
LTE	6 RBs	838	16	**52.38**	

Support 1 tier

Support 2 tiers

Not support even 1 tier!

Occupied Resource: Overhead

- **16m for 10 MHz**
  - FDD : 48 PRUs by 8 subframe
  - 4:4 TDD : 48 PRUs by 4 subframe
- **LTE for 10 MHz**
  - FDD : 50 RBs by 10 subframe
  - UD configuration 1 TDD (D S U U D D S U U D) : 50 RBs by 4 subframe

Subcarrier spacing	Ranging channel	Duplex mode	No. of ranging channels per super-frame (20 ms)				
			1 ch.	2 ch.	4 ch.	8 ch.	16 ch.
16m	**2 subbands × 6 symbols**	**FDD**	**0.5208**	**1.0417**	**2.0833**	**4.1667**	**8.3333**
		TDD	**1.0417**	**2.0833**	**4.1667**	**8.3333**	**16.6667**
	1 subband × 6 symbols	**FDD**	**0.2604**	**0.5208**	**1.0417**	**2.0833**	**4.1667**
		TDD	**0.5208**	**1.0417**	**2.0833**	**4.1667**	**8.3333**
LTE	**6 RBs × 14 symbols**	**FDD**	**0.6000**	**1.2000**	**2.4000**	**4.8000**	**9.6000**
		TDD	**1.5000**	**3.0000**	**6.0000**	**12.0000**	**24.0000**
	6 RBs × 28 symbols	FDD	1.2000	2.4000	4.8000	9.6000	19.2000
		TDD	3.0000	6.0000	12.0000	24.0000	48.0000

☞ **2-subband ranging bandwidth can provide lower overhead than that of LTE.**

Conclusion

- **From the Simulation and Analysis Results,**

  Ranging performance

  - ✓ $\triangle f$/2.5 subcarrier spacing has 5~6 dB gain compare with $\triangle f$ subcarrier spacing
  - ✓ 2 subbands bandwidth has 5~6 dB gain compare with 1 subband bandwidth
  - ✓ We can assume $\triangle f$ subcarrier spacing with 1 subband may have 10~12 dB performance degradation.

  Power balancing with data channel

  - ✓ To support comparable coverage with data channel, the ranging channel shall operate lower SNR, properly.

  Number of code and reuse factor

  - ✓ The ranging codes basically provides good CM and correlation properties.
  - ✓ The reuse factor of codes shall be supported to cover at least 1 tier in the 5km cell coverage.
  - ✓ It is desirable that the reuse factor of codes with frequency reuse could be close to the number of cell ID.

- **Proposed AWD Text**

  Adopt the proposed AWD text in C802.16m-09/1092 or its latest version.

Reference

[1] IEEE 802.16m-08/003r8, "IEEE 802.16m System Description Document," April 2009.

[2] IEEE C802.16m-08/448r1, "Initial/Handover Ranging for IEEE 802.16m System," May 2008.

[3] IEEE C802.16m-08/853r2, "Ranging Channel Structure for the 802.16m SDD," July 2008.

[4] IEEE C802.16m-08/978, "Ranging Channel Structure for Non-Synchronized MSs," September 2008.

[5] IEEE C802.16m-UL_PHY_Ctrl-08/066, "Ranging Channel Structure for Non-Synchronized MSs," November 2008.

[6] IEEE C802.16m-09/0335r1, "Proposed Text of Ranging Section for the IEEE 802.16m Amendment," January 2009.

[7] IEEE C802.16m-09/0696, "Proposed Text for the Draft P802.16m Amendment on the PHY Structure for Ranging channel," March 2009.

[8] IEEE C802.16m-09/1902, "Proposed AWD Text on the Ranging Structures for Non-synchronized AMSs," April 2009.