Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Proposed Text of Ranging Section for the IEEE 802.16m Amendment**
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Source(s)	HyunWoo Lee, Jin Sam Kwak, Young-Hyoun Kwon, Sungho Moon **LG Electronics** — Voice: +82-31-450-7902 E-mail: camille@lge.com, samji@lge.com
Re:	IEEE 802.16m-08/053r1, "Call for Comments and Contributions on Project 802.16m Amendment Working Document" Based on the sections of SDD : 11.9 UL PHY control structure, especially mapping
Abstract	This contribution proposes the text of ranging channel section to be included in the IEEE 802.16m amendment.
Purpose	To be discussed and adopted by TGm for the IEEE 802.16m Amendment
Notice	
Release	
Patent Policy	

Proposed Text for Ranging Channels in the IEEE 802.16m Amendment

HyunWoo Lee, Jin Sam Kwak, Young-Hyoun Kwon and Sungho Moon
LG Electronics

1. Introduction

This contribution proposes the text of ranging channel section to be included in the IEEE 802.16m amendment. The proposed text is developed so that it can be readily combined with IEEE P802.16 Rev2/D8 [1], it is compliant to the 802.16m SRD [2] and the 802.16m SDD [3], and it follows the style and format guidelines in [4].

2. Modifications to the SDD text

The text proposed in this contribution is based on subclauses 11.9.2.4 in the IEEE 802.16m SDD [3]. The modifications to the SDD text are summarized below:

- **Updated the section of ranging channel structure:**

  Subclause 11.9.2.4.1.2 of the 802.16m SDD [3] explains the components of the ranging channel and the default ranging physical structure. In this contribution, the high-level description in the current SDD as the stage 2 document style is modified to be adopted in the stage-3 amendment text.

- **Added the details of ranging channel structures:**

  The ranging channel formats and its exact values are proposed. The details of the design criteria and rationales are addressed in the Section 3.

- **Left the section of ranging preamble as TBD:**

  The type of ranging preamble is proposed as a Zadoff-Chu sequence. However, the details of the sequence are TBD.

- **Left the section of ranging channel configurations including subclause 8.4.7.4 in [1] as TBD:**

  The ranging channel configurations (ranging opportunity and/or time/frequency allocation) are TBD.

- **Added the similar text for ranging transmitted signal generation as shown in subclause 8.4.2 in [1]**

  The transmitted signal for ranging channel is defined as shown in subclause 8.4.2 in [1] since the ranging channel uses different subcarrier spacing and the length of cyclic prefix with the data channel.

- **Left the section of ranging channel for synchronized AMSs as TBD:**

  Since there has been no agreement/discussion on the details of the ranging channel for synchronized AMS in the current SDD, the ranging channel for synchronized AMSs is TBD.

3. Ranging channel structure for IEEE 802.16m

According to the 802.16m SRD [2], the cell coverage shall be optimized up to 5 km cell radius and have graceful degradation up to 30 km cell radius. Also, the system should be functional up to 100 km cell radius. Therefore, some kinds of ranging channel formats shall be considered to support the various coverage requirements.

1. **Default ranging channel structure for about 5 km cell radius**

As described in the SDD [3], Figure 1 shows the default ranging channel structure spanning one subframe and consisting of ranging cyclic prefix (RCP) and ranging preamble (RP)[1]. To support the comparable coverage between data and ranging channel, the totally required length of RP shall be longer than 4-OFDMA data symbol duration [5]. This implies that the default ranging channel structure with repeated RP is used as a single opportunity. In the cases where UL power limited situation is not serious as hot spot/relay operations or the increased ranging opportunities are necessary for supporting the large amount of ranging channels such as the multi-carrier supports, a single RP can be separately used for different non-synchronized AMSs in order to increase the ranging opportunities [3]. To avoid the mutual interference between two different ranging configurations, the baseline structure and the length of each part should be the same [6].
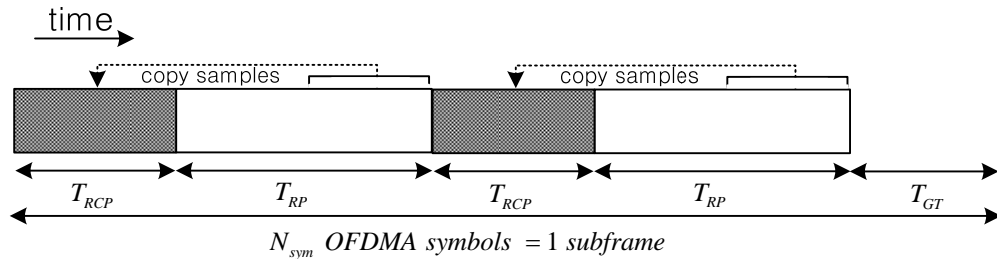

Figure 1. Default ranging structure for non-synchronized MSs [2].

The design criteria for the lengths of RCP and PR within a subframe are as follows:

(a) The length of RCP, T_{RCP}, shall be longer than maximum RTD of 5 km cell radius (33.356410 µs) plus maximum delay spread (11.428571 µs or 5.714286 µs) to support simply frequency domain detector.

(b) The length of GT, T_{GT}, shall be longer than maximum RTD of 5 km cell radius (33.356410 µs) to prevent inter-symbol interference to the next OFDMA symbols.

(c) The length of RP, T_{RP}, shall be at least longer than maximum RTD of 5 km cell radius (33.356410 µs) to estimate timing offset.

(d) The length of RP should be longer than maximum RTD of 30 km cell radius (200.138457 µs) to support the simple coverage extension based on the same preamble without resource waste for the simple implementation with low complexity. The details are explained in the Section 3.2.

(e) To support comparable coverage between data and ranging channel, the required total length of repeated RP can be calculated as shown in [5]. The power balancing between data and ranging channel is given by

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[1] The guard time is not necessary to be specified in the amendment text.

$$\frac{E_p}{N_0} \cdot \frac{1}{T_p} = \frac{E_b}{N_0} \cdot R$$

where T_p is the preamble duration, R is data rate. Since the SNR for data channel is a function of the transmission data rate, we therefore need to establish a reasonable minimum data rate for data channel. As a simple example, it is assumed that target E_p / E_b is 16.0~16.5 dB roughly (e.g., $E_p / N_0 = 19.5$ dB, $E_b / N_0 = 3$ dB [5]) and the minimum data rate is 96 kbps. Then, the required preamble length becomes longer than 414.6950~465.2954 µs. It should be noted that, in order to maintain the coverage balance between data and ranging channels, the required length of RP increases as the minimum data rate decreases.

(f) The size of DFT or FFT, in which the ranging sampling rate is readily adjustable from data sampling rate, should be multiples of 2, 3 or 5 for easy implementation. Note that it can be implemented by time-domain oversampling instead of frequency-domain oversampling such as large size of DFT or FFT, e.g., overlap-save method or overlap-add method [7].

Based on the above design criteria, Table 1 shows THREE options for default ranging channel within a subframe in the frame structure with $T_g = 1/8 \cdot T_b$.

Table 1. The possible lengths for default ranging structure (FS with $T_g = 1/8 \cdot T_b$)

	T_{RP}	Δf_{RP}	T_{RCP}	T_{GT}	C_{max}
Option 1	182.857143 µs ($4096 \times T_{rtu}$)	5.46875 kHz	87.58929 µs ($1962 \times T_{rtu}$)	76.16071 µs ($1706 \times T_{rtu}$)	11.4162 km
Option 2	228.571429 µs ($5120 \times T_{rtu}$)	4.375 kHz	57.14286 µs ($1280 \times T_{rtu}$)	45.71429 µs ($1024 \times T_{rtu}$)	6.8524 km
Option 3	274.285714 µs ($6144 \times T_{rtu}$)	3.64583333334 kHz	26.65179 µs ($597 \times T_{rtu}$)	15.22321 µs ($341 \times T_{rtu}$)	2.2819 km

where T_{rtu} denotes a reference time unit defined as $T_{rtu} = 1/(10937.5 \times 2048)$ seconds. Δf_{RP} is the ranging subcarrier spacing and C_{max} is the maximum supportable cell radius without inter-symbol interference.

In the viewpoint of (1-c), the option 1 can not obtain the required preamble energy in worst situation. In other words, if the option 1 is used, the ranging coverage will be shorter than data coverage. In addition, from (1-d), the maximum coverage and timing offset estimation of the option 1 are limited to 27.4096 km cell radius because the length of RP is shorter than RTD of 30 km cell radius (200.138457 µs). Therefore, the option 2 is the most preferable for the length of RP in the default ranging channel structure. This is also quite in line with the coverage extension up to 30 km cell radius with a single preamble ONLY as described in the next sub-section.

2. Extended ranging channel structure for about 30 km cell radius

To support larger cell radius than default ranging channel structure, e.g. about 30 km cell radius in the 802.16m SRD, the different ranging configuration should be considered.

The design criteria for the lengths of RCP and PR within a subframe are as follows:

(a) The length of RCP shall be longer than maximum RTD of about 30 km cell radius (200.138457 μs) plus maximum delay spread (11.428571 μs or 5.714286 μs) to support simply frequency domain detector. When the repeated RP is used, the first RP can be used as a part of RCP. In other words, the length of 'RCP+RP' can be interpreted as an extended RCP by replacing the length of the RCP with the data CP such as 11.428571 μs or 5.714286 μs .

(b) The length of GT is as long as possible to support the maximum RTD of about 30 km cell radius (200.138457 μs) to prevent inter-symbol interference to the next OFDMA symbols.

(c) The length of RP shall be longer than maximum RTD of about 30 km cell radius (200.138457 μs) to estimate timing offset.

(d) It is desirable to have the same length of RP in the default ranging structure in the extended ranging channels for the simple implementation with low complexity.

Based on the above design criteria, Table 2 shows THREE options of the ranging channel within a subframe for supporting up to 30 km cell radius in the frame structure with $T_g = 1/8 \cdot T_b$.

Table 2. The possible lengths for coverage-extended ranging structure (FS with $T_g = 1/8 \cdot T_b$)

	T_{RP}	Δf_{RP}	T_{RCP}	T_{GT}	C_{max}
Option 1	182.857143 μs $(4096 \times T_{rtu})$	5.46875 kHz	11.42857 μs $(256 \times T_{rtu})$	240.000000 μs $(5376 \times T_{rtu})$	27.4096 km
Option 2	228.571429 μs $(5120 \times T_{rtu})$	4.375 kHz	11.42857 μs $(256 \times T_{rtu})$	148.5714 μs $(3328 \times T_{rtu})$	22.2703 km
Option 3	274.285714 μs $(6144 \times T_{rtu})$	3.64583333334 kHz	11.42857 μs $(256 \times T_{rtu})$	57.14286 μs $(1280 \times T_{rtu})$	8.5655 km

In order to maintain the consistency of the ranging preamble design in the coverage extension with the default ranging structure, the preamble length should be longer than the maximum RTD (200.138457 μs) for timing offset estimation and coverage support of up to 30 km cell radius. In other words, the Option 2 can support a single preamble design for the coverage extension up to 30 km cell radius within a subframe. In Table 2, C_{max} means the ranging coverage without the inter-symbol interference in the next subframe. Even though Option 1 provides longer coverage than that of Option 2 in the viewpoint of

the inter-symbol interference, the Option 1 can not support 30 km cell radius with the allowance of graceful degradation in the 802.16m SRD due to the failure of the timing estimation. Therefore, it is desirable to adopt the Option 2 for the coverage extension up to 30 km cell radius with the slight performance degradation due to the interference in the worst case scenario.

3. **Ranging channel structure for 100 km cell radius support**

To support 100 km cell radius with simple frequency domain detector and timing estimation, the length of RCP and RP shall be longer than 100 km RTD (667.12819 µs). This implies that the ranging channel should be spanned multiple concatenated subframes [3].

Since the length of RP for a support of 100 km cell radius is longer than the required RP length in the criterion (1-e), even though a single long RP may provide the performance degradation in the high speed AMSs, the RP repetition is not necessary in order to avoid the increase of ranging overhead.

The criteria for exact length of each part are follow:

(a) The length of RCP should be same than maximum RTD of 100 km cell radius (667.128190 µs) plus maximum delay spread (11.428571 µs or 5.714286 µs) to support simply frequency domain detector. The longer length of RCP than that is not needed even if it is not fit with length of subframes.

(b) The length of RP shall be longer than maximum RTD of 100 km cell radius (667.128190 µs) to estimate timing offset.

(c) (f) The size of DFT or FFT, in which the ranging sampling rate is readily adjustable from data sampling rate, should be multiples of 2, 3 or 5 for easy implementation. Note that it can be implemented by time-domain oversampling instead of frequency-domain oversampling such as large size of DFT or FFT, e.g., overlap-save method or overlap-add method [7].

Based on the above design criteria, Table 3 shows TWO options of the ranging channel supporting 100km cell radius in case of $T_g = 1/8 \cdot T_b$.

Table 3. The possible lengths for extremely coverage-extended ranging structure (FS with $T_g = 1/8 \cdot T_b$)

	T_{RP}	Δf_{RP}	T_{RCP}	within 3 subframes		within 4 subframes	
				T_{GT}	C_{max}	T_{GT}	C_{max}
Option 1	714.285714 µs ($16000 \times T_{rtu}$)	1.4 kHz	678.57143 µs ($15200 \times T_{rtu}$)	458.5714 µs ($10272 \times T_{rtu}$)	68.73813 km	1075.7143 µs ($24096 \times T_{rtu}$)	100 km

Option 2	731.428571 µs ($16384 \times T_{rtu}$)	1.3671875 kHz	678.57143 µs ($15200 \times T_{rtu}$)	441.4286 µs ($9888 \times T_{rtu}$)	66.16848 km	1058.5714 µs ($23712 \times T_{rtu}$)	100 km

As shown in Table 3, the T_{GT} and its coverage C_{max} without ISI are coupled with the overhead of the ranging channels. In accordance with the 802.16m SRD, i.e., the 802.16m system should be functional up to 100 km cell radius, it is desirable to adopt the 3-subframe ranging structure with a relaxation of the ISI restriction. Note that since the AMS do not need to know the length of GT, in which there is no transmitted signal from AMS, the GT assignment can be handled as an implementation issue.

In summary, the Table 4 shows the all configurations for ranging channels supporting from 5 to 100 km cell radius in accordance with the 802.16m SRD. In Table 4, the lengths of T_{RCP} and C_{max} for data $T_g = 1/16 \cdot T_b$ are obtained by the same design methods for data $T_g = 1/8 \cdot T_b$. Note that the coverage C_{max} in format 3 for data $T_g = 1/16 \cdot T_b$ is based on the assumption that all adjacent subframes are the same subframe types.

Table 4. Ranging channel formats supporting up to 100 km cell radius

Format No.	Ranging channel format	T_{RP}	Δf_{RP}	Within subframe for data CP=$1/8 \cdot T_b$		Within type-1 subframe for data CP=$1/16 \cdot T_b$		Within type-2 subframe for data CP=$1/16 \cdot T_b$	
				T_{RCP}	C_{max}	T_{RCP}	C_{max}	T_{RCP}	C_{max}
0	RCP+RP+ RCP+RP	228.571429 µs ($4096 \times T_{rtu}$)	4.375 kHz	57.14286 µs ($1280 \times T_{rtu}$)	6.852 km	43.79464 µs ($981 \times T_{rtu}$)	5.708 km	76.16071 µs ($1706 \times T_{rtu}$)	10.560 km
1	RCP+RP								
2	RCP+RP+ RP	228.571429 µs ($5120 \times T_{rtu}$)	4.375 kHz	11.42857 µs ($256 \times T_{rtu}$)	22.270 km	5.71429 µs ($128 \times T_{rtu}$)	17.988 Km	5.71429 µs ($128 \times T_{rtu}$)	32.549 km
3	RCP+RP	731.428571 µs ($6144 \times T_{rtu}$)	1.3671875 kHz	678.57143 µs ($15200 \times T_{rtu}$)	66.168 / 100 km	672.85714 µs ($15072 \times T_{rtu}$)	51.607 / 100 km	672.85714 µs ($15072 \times T_{rtu}$)	95.291 / 100 km

4. References

[1] IEEE P802.16Rev2/D8, "DRAFT Standard for Local and metropolitan area networks / Part 16: Air Interface for Broadband Wireless Access Systems," December 2008.

[2] IEEE 802.16m-07/002r7, "IEEE 802.16m System Requirements," December 2008.

[3] IEEE 802.16m-08/003r6, "IEEE 802.16m System Description Document," December 2008.

[4] IEEE 802.16m-08/043, "Style guide for writing the IEEE 802.16m," September 2008.

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

[6] IEEE C80216m-UL_PHY-Ctrl-08/066, "Ranging Channel Structure for Non-Synchronized MSs," November 2008.

[7] John G. Proakis and Dimitris G. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications," Prentice Hall, third edition, 1996.

Text proposal for inclusion in the 802.16m amendment

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4. Abbreviations and acronyms

Insert the following at section 4:

RCP   ranging cyclic prefix
RP   ranging preamble

15. Advanced Air Interface

15.3. Physical layer

Insert a new section 15.3.x:

15.3.x.   Ranging channel

15.3.x.1.   Ranging channel for non-synchronized AMSs

The ranging channel for non-synchronized AMSs is used for initial access and handover.

15.3.x.1.1.   Ranging channel structure

A physical ranging channel for non-synchronized mobile stations is composed of the ranging preamble (RP) with its length T_{RP} and the ranging cyclic prefix (RCP) with its length T_{RCP}, which depends on the ranging subcarrier spacing $\triangle f_{RP}$, within a localized bandwidth corresponding to the consecutive [8]×P_{sc} data subcarriers, where P_{sc} is defined 15.3.6.1. Figure (x+1) illustrates the default ranging channel structure in a time domain.

[Note: Ref. 15.3.6.1 : Physical and logical resource unit for uplink physical structure, which will be described in the amendment for the UL PHY structure]
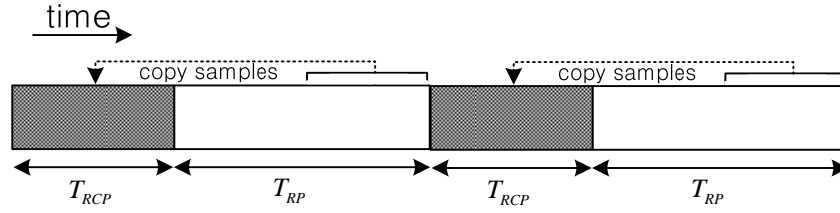
Figure (x+1) – Default ranging channel format

The default ranging channel format called Format 0 is used as a single ranging opportunity by a non-synchronized AMS. Based on the default ranging channel structure, there are several ranging channel formats. Table (x+1) shows the ranging channel formats and the parameter values. In Table (x+1), the size of various fields in the time domain is expressed by using the reference time unit $T_{rtu}=1/(10937.5\times2048)$ seconds.

Table (x+1) – Ranging channel formats and parameters

Format No.	Ranging Channel Format	T_{RCP}	T_{RP}	$\triangle f_{RP}$
0	RCP+RP+RCP+RP	$T_g+k\times T_{rtu}$ (a)	$5120\times T_{rtu}$	4.375 kHz
1	RCP+RP			
2	RCP+RP+RP	T_g	$2\times5120\times T_{rtu}$ (b)	
3	RCP+RP	$T_g+14944\times T_{rtu}$	$16384\times T_{rtu}$	1.3671875 kHz

(a): The RCP for Formats 0 and 1 depends on OFDMA parameters and subframe types as follows:

$$k = \left\lceil \left\{ \left[N_{sym}\cdot T_s - 2\cdot\left(T_{RP}+T_g\right)\right]/3\right\}/T_{rtu} \right\rceil \cdot T_{rtu}$$ (x+1)

where N_{sym} is the number of OFDMA symbols in a subframe as defined 15.3.6.1, T_s and T_g are defined in 15.3.2.1.

(b): The length of RP for Format 2 denotes the total length of repeated ranging preamble.

[Note: Ref. 15.3.6.1 : Physical and logical resource unit for uplink physical structure , which will be described in the amendment for the UL PHY structure]

In the Format 1, the single RCP and RP is a part of the default ranging channel structure, which is used as a ranging opportunity by a non-synchronized AMS; Format 2 consists of the RCP and repeated RPs without the second RCP in Format 0; The Formats 0, 1, and 2 occupy a single subframe; Format 3 denotes the single RCP and RP over multiple consecutive subframes.

For the ranging opportunity of the non-synchronized AMS, each user randomly chooses one of ranging preamble sequence from the available ranging sequence set in a cell defined in 15.3.x.1.2. When the ranging channel structure is Format 1, each user additionally chooses one of a couple of time opportunities within a subframe. When the ranging channel format is configured as Format 0, 2, 3, or Format 1 in the first time opportunity, the transmission start time of the ranging channel is aligned with the UL subframe start time at the AMS. For the Format 1 in the second time opportunity, the transmission of the ranging channel starts $T_{RCP}+T_{RP}$ after the transmission time of the corresponding UL subframe.

[TBD]

9

15.3.x.1.2. Ranging preambles

The ranging preambles are classified into initial ranging preambles and handover ranging preambles. The initial ranging preambles shall be used for initial network entry and association. Handover ranging preambles shall be used for ranging against a Target BS during handover.

The ranging preambles are generated from Zadoff-Chu sequences with cyclic shift, generated from one or several root Zadoff-Chu sequences.

The pth ranging preamble sequence $x_p(n)$ is defined by

$$x_p(n) = e^{-j\frac{\pi p n(n+1)}{N_{RP}}}, \quad 0 \le n \le N_{RP} - 1 \tag{x+2}$$

where N_{RP} is the length of ranging preamble sequence. From p^{th} ranging preamble sequence, r^{th} ranging preamble sequence are defined by cyclic shift according to

$$x_{p,r}(n) = x_p\left[(n + N_{CS}) \bmod N_{RP}\right] \tag{x+3}$$

where N_{CS} is the unit of cyclic shift.

[TBD]

15.3.x.1.3. Ranging channel configurations

[TBD]

15.3.x.1.4. Transmitted signal for ranging channel

Equation (x+4) specifies the transmitted signal voltage to the antenna, as a function of time, during ranging channel format.

$$s(t) = \begin{cases} \text{Re}\left\{e^{j2\pi f_C t}\zeta(t)\cdot\beta_{RA}\displaystyle\sum_{k=\psi}^{\psi+N_{RP}-1} x_{p,r}(k-\psi)\cdot e^{j2\pi k \Delta f_{RP}(t-T_{RCP})}\right\}, \\ \qquad\qquad\qquad 0 \le t < T_{RCP} + T_{RP} \ \ for\ all\ formats \\ \text{Re}\left\{e^{j2\pi f_C t}\zeta(t)\cdot\beta_{RA}\displaystyle\sum_{k=\psi}^{\psi+N_{RP}-1} x_{p,r}(k-\psi)\cdot e^{j2\pi k \Delta f_{RP}(t-T_{RP}-2\cdot T_{RCP})}\right\}, \\ \qquad\qquad T_{RCP} + T_{RP} \le t < 2\cdot(T_{RCP} + T_{RP}) \ \ for\ format\ 2 \end{cases} \tag{x+4}$$

where

$\quad t \qquad$ is the elapsed time since the beginning of the subject ranging channel,

$\quad \beta_{RA} \qquad$ is a amplitude scaling factor,

ψ is a parameter related to physical frequency position in terms of ranging subcarrier spacing and is defined by

$$\psi = -\left[(N_{used}-1)/2 - k_0 \cdot P_{sc}\right] \cdot K + \varphi$$

k_0 is a logical ranging channel parameter in the frequency domain as units of N_l, where N_l is the number of the adjacent PRUs within a subband as defined 15.3.6.2.1.

[Note: Ref. 15.3.6.2.1 : Subband partitioning for uplink physical structure, which will be described in the amendment for the UL PHY structure]

P_{sc} is the number of the consecutive subcarriers within a PRU in frequency domain as defined 15.3.6.1.

[Note: Ref. 15.3.6.1 : Physical and logical resource unit for uplink physical structure, which will be described in the amendment for the UL PHY structure]

K is a scaling factor representing subcarrier frequency spacing ratio between the RP and uplink data transmission and is defined by $K = \triangle f / \triangle f_{RP}$

φ is a fixed offset determining the frequency-domain location of the RP within the ranging physical resource blocks and is [TBD]

$\zeta(t)$ is a correction function to accommodate the interleaved DC subcarrier between PRUs

$$\zeta(t) = \begin{cases} 1 & , \psi < 0 \\ e^{j2\pi \cdot \Delta f \cdot t} & , o/w \end{cases}.$$

15.3.x.2.   Ranging channel structure for synchronized mobile stations

[TBD]

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