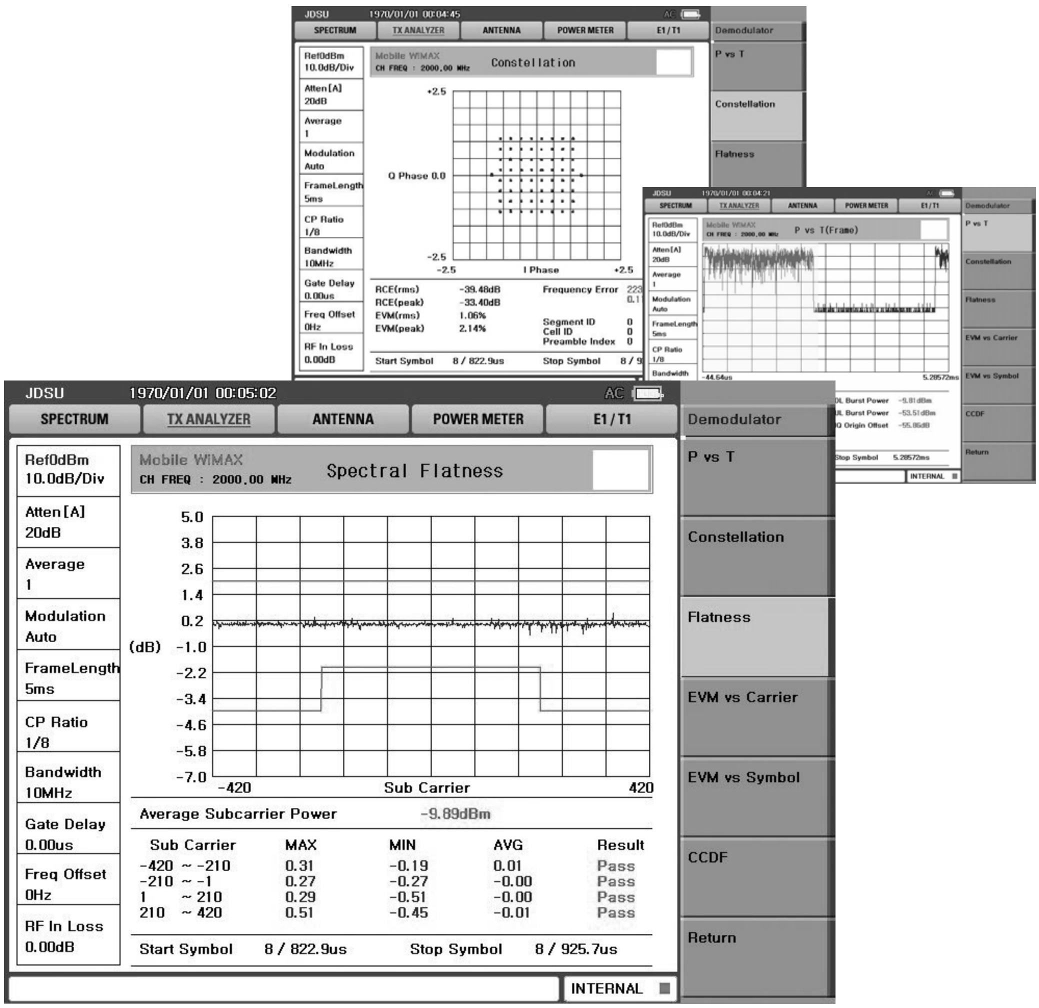
Application Note

JD7105A Base Station Analyzer

Mobile WiMAX PHY Layer Measurement



Understanding of Mobile WiMAX PHY

WiMAX is a broadband wireless access (BWA) technology based on the IEEE 802.16-2004 and IEEE-802.16-2005 standards. The physical layer of WiMAX was designed with much influence from Wi-Fi, especially IEEE-802.11a. Although many aspects of the two technologies are different due to the inherent differences in their purpose and application, some of their basic building blocks are very similar. The WiMAX Forum recently releases 802.16_Rev2 as a revision and consolidation of IEEE-802.16e-2004/2005 and IEEE-802.16f-2005.

The IEEE-802.16 suite of standards defines four physical (PHY) layers, any of which can be used with the media access control (MAC) layer to develop a broadband wireless system. Among the PHY layers, Wireless MAN OFDMA is a 2048-point FFT-based OFDMA PHY for point-to-multipoint operations at frequencies between 2 GHz and 11 GHz. In the IEEE 802.16e specifications this PHY layer has been modified to SOFDMA (scalable OFDMA), where the Fast Fourier Transform (FFT) size is variable and can take any one of the following values: 128, 512, 1024 and 2048. The variable FFT size allows for optimum operation and implementation of the system over a wide range of channel bandwidths and radio conditions. This PHY layer has been accepted by WiMAX for mobile and portable operations and is also referred to as mobile WiMAX.

GenComm

OFDM

OFDM is a transmission scheme which users can achieve high rate data transmission by utilizing multiple narrowband sub-carriers instead of single wideband carrier. In order to deliver high rate data with multiple narrow band carriers, OFDM algorithm converts high rate serial data streams into multiple parallel low rate data streams and loading low rate data streams on each sub-carrier. For example, if we need to send data with 10 Mbps throughput, OFDM scheme split the data stream with one hundred of sub-streams so that the each sub-stream deliver just 10 kbps data throughput.

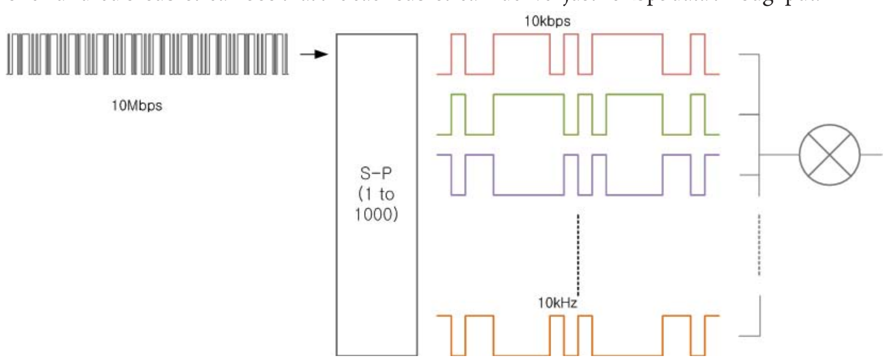


Figure 1-1 S-P conversion scheme

In the frequency domain, sub-carriers are located as described on the following figure. The key benefit of OFDM compared to FDMA is that it achieves better frequency utilization. For FDMA, there is a limitation of tone spacing due to neighboring sub-carriers may affect each other causing mutual interference. As compared with FDMA, OFDM uses null function characteristics of FFT algorithm so that the interference between neighboring sub-carriers is minimized. For example, a 10 kbps data signal has null points, where the amplitude of the signal is minimized; at every 10 kHz takes its FFT so that the sub-carriers allocated at 10 kHz spacing do not act as an interference to the neighboring sub-carriers.

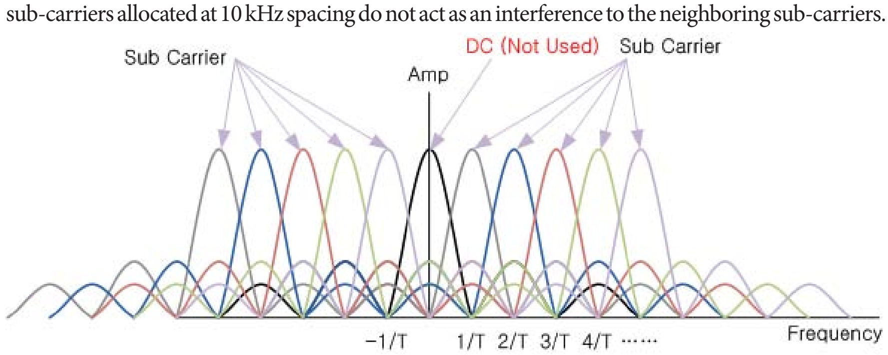


Figure 1-2 Sub-carrier allocation spacing vs. null periods

Channel Coding

The channel coding stage consists of the following steps:

- Data randomization
- Encoding
- Interleaving
- Modulation

The following diagram shows the coding processes of WiMAX PHY. The first process is related to forward error correction (FEC), and includes channel encoding, rate matching, interleaving, and symbol mapping. The next process is related to the construction of the OFDM symbol in the frequency domain. During this process, data is mapped into the appropriate sub- channels and sub-carriers. Pilot symbols are inserted into the pilot sub-carriers, which allow the receiver to estimate and track the channel state information (CSI). This stage is also responsible for any space/time encoding for transmission diversity such as MIMO, if implemented. The final process is related to the conversion of OFDM symbols from the frequency domain to the time domain and eventually to an analog signal that can be transmitted over the air.

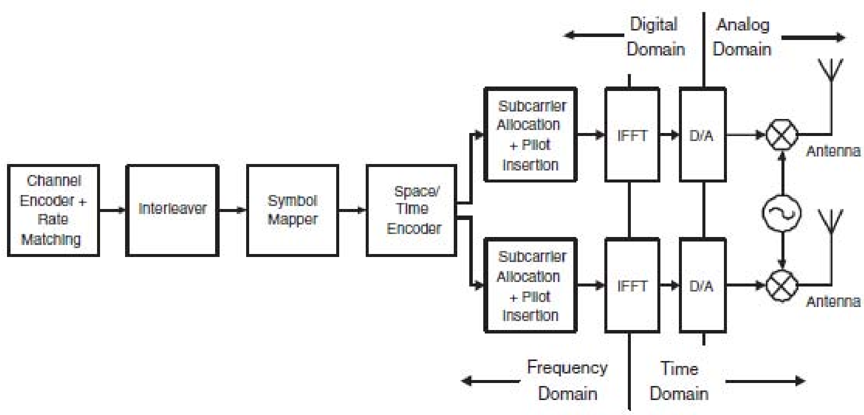


Figure 1-3 functional stages of WiMAX PHY

Randomization

Data randomization is performed on all data transmitted on the down-link (DL) and up-link (UL), except the Frame Control Header (FCH), using the output of a maximum length shift register sequence that is initialized at the beginning of every FEC block.

Encoding

The coding method used as the mandatory scheme is the tail-biting convolutional encoding specified and the optional modes like block turbo coding (BTC) or convolutional turbo codes (CTCs) are also supported.

Interleaving

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of coded bits per the encoded block size (N_{cbps}). The interleaver is defined by a two-step permutation. The first ensures that adjacent coded bits are mapped onto nonadjacent sub-carriers. The second ensures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, avoiding long runs of lowly reliable bits.

Modulation

After the repetition block, data bits are entered serially to the constellation mapper. Gray-mapped QPSK and 16-QAM (shown in the following figure) shall be supported, whereas the support of 64-QAM is optional. The constellation shall be normalized by multiplying the constellation point with the corresponding factor c in order to achieve similar average power.

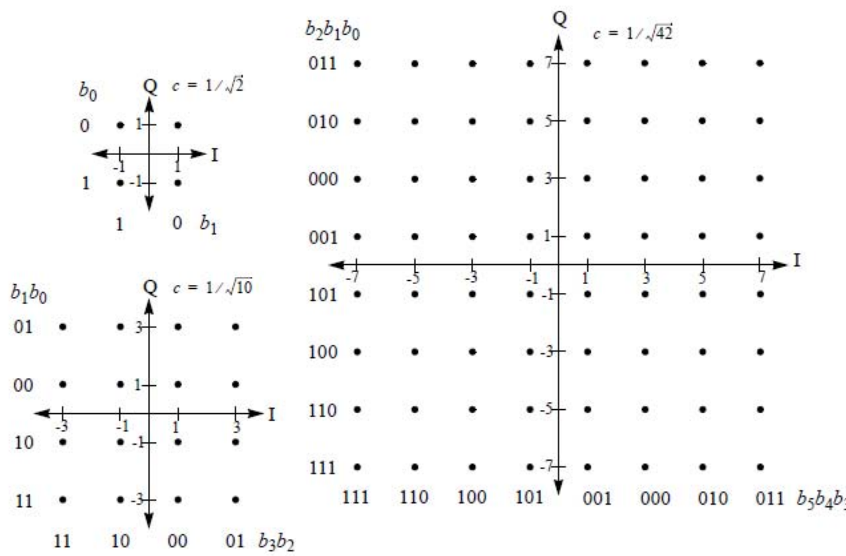


Figure 1-4 QPSK, 16QAM and 64-QAM constellations

OFDM Symbol

Data symbol periods get shorter as data rate gets higher since the symbol period is proportional to 1/(data rate). As the symbol period is shorter, ISI (inter symbol interference) become more severe in a wireless environment where there are many multipath (reflective) signals which have different time delays. It is known that ISI mainly affects the beginning part of each symbol causing data loss.

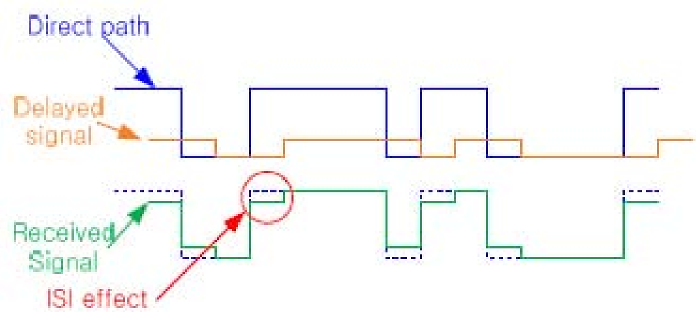


Figure 1-5 Distortion of received signal due to ISI

Relatively long symbol periods of OFDM gives an improved capability against multipath. In addition to this, OFDM prepositioned CP (cyclic prefix) in front of every symbol by copying the last part of the symbol and pasting it in front of that symbol. By increasing CP ratio (CP length vs. effective symbol length), the system is more robust but, as a trade-off, it decrease the data rate capacity.

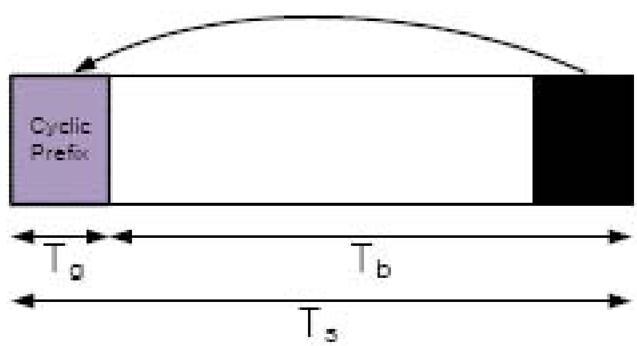


Figure 1-6 Symbol Structure

The following table 1-1 shows the basic symbol parameters of WiMAX with a CP ratio of 1/32 and a variable bandwidth.

Bandwidth	**7 MHz**	**8.75 MHz**	**10 MHz**
Sampling Factor	1 1/7	1 1/7	1 3/25
FFT Size	1024	1024	1024
Tone Spacing (kHz)	7.81	9.77	10.94
Tb (µs)	128.00	102.40	91.43
Tg (µs)	4.00	3.20	2.86
TS (=Tb+Tg) (µs)	132.00	105.60	94.29
TTG (µs)	52.00	87.20	102.90
Num. of Symbol	37	46	51
RTG (µs)	64.00	55.20	88.53

Table 1-1 WiMAX Symbol parameters

Sub-Channelization

WiMAX adopts a sub-channelization scheme to get more robust and flexible transmission system against the irregular wireless environment. Sub-channelization means a selection and grouping of sub-carriers, and it is classified as follows

- **Distribute Sub-Channelization** is the sub-carrier selection method that composes a sub-channel by selecting a number of sub-carriers which is not adjacent with each other, minimizing the influence of frequency selective fading. The channel formats using this method are partial usage of sub carrier (PUSC) and full usage of sub-carrier (FUSC).
- **Adjacent Sub-Channelization** is the sub-carrier selection method that composes a sub-channel by selecting number of sub-carriers which are adjacent with each other. This format can be used under the circumstance where there is no severe frequency selective fading. The typical channel format of this method is adaptive modulation and coding (AMC).

Tables 1-2 and 1-3 show the sub-carrier allocation for PUSC and FUSC channelization format.

Parameter	Value	Comments
Number of guard sub-carriers, Right	86	
Number of used sub-carriers (Nused)	851	Number of all sub-carriers used within a symbol, including all possible allocated pilots and the DC sub-carrier.
Pilots		
VariableSet #0	12	0, 24, 48, 72, 96, 120, 144, 168, 192, 216, 240, 264, 288, 312, 336, 360, 384, 408, 432, 456, 480, 504, 528, 552, 576, 600, 624, 648, 672, 696, 720, 744, 768, 792, 816, 840
ConstantSet #0	2	72*(2*n + k) + 9 when k=0 and n=0..5, DC sub-carrier shall be included when the pilot sub-carrier index is calculated by the equation.
VariableSet #1	12	36, 108, 180, 252, 324, 396, 468, 540, 612, 684, 756, 828, 12, 84, 156, 228, 300, 372, 444, 516, 588, 660, 732, 804, 60, 132, 204, 276, 348, 420, 492, 564, 636, 708, 780
ConstantSet #1	2	72*(2*n + k) + 9 when k=1 and n=0..4 DC sub-carrier shall be included when the pilot sub-carrier index is calculated by the equation.
Number of data sub-carriers	768	
Number of data sub-carriers per sub-channel	48	
Number of sub-channels	16	
PermutationBase		6, 14, 2, 3, 10, 8, 11, 15, 9, 1, 13, 12, 5, 7, 4, 0

Table 1-2 DL sub-carrier allocation of WiMAX using 1024-FFT size and FUSC format

Parameter	Value	Comments
Number of DC sub-carriers	1	Index 512
Number of guard sub-carriers, left	92	
Number of guard sub-carriers, right	91	
Number of used sub-carriers (Nused) including all possible allocated pilots and the DC sub-carrier.	841	Number of all sub-carriers used within a symbol.
Renumbering sequence	6, 48, 37, 21, 31, 40, 42, 56, 32, 47, 30, 33, 54, 18, 10, 15, 50, 51, 58, 46, 23, 45, 16, 57, 39, 35, 7, 55, 25, 59, 53, 11, 22, 38, 28, 19, 17, 3, 27, 12, 29, 26, 5, 41, 49, 44, 9, 8, 1, 13, 36, 14, 43, 2, 20, 24, 52, 4, 34, 0	Used to renumber cluster before allocation to sub-channels
Number of carriers per cluster		
Number of clusters		
Number of data sub-carriers in each symbol per sub-channel		
Number of sub-channels		
PermutationBase6 (for 6 sub-channels)		
PermutationBase4 (for 4 sub-channels)		

Table 1-3 DL sub-carrier allocation of WiMAX using 1024-FFT size and PUSC format

Frame Structure

In licensed bands, the duplexing method shall be either frequency division duplex (FDD) or time division duplex (TDD). FDD subscriber stations (SSs) may be half-duplex (H-FDD). In license exempt bands, the duplexing method shall be TDD.

The JD7105A supports the TDD method and this document only describes the TDD structure.

When implementing a TDD system, the frame structure is built between the base station (BS) and subscriber station (SS) transmissions. Each frame in the DL transmission begins with a preamble followed by DL-Map and FCH transmission period and an UL transmission period. In each frame, the transmit/receive transition gap (TTG) and receive/transmit transition gap (RTG) shall be inserted between the DL and UL and at the end of each frame, respectively, to allow the BS to turn around.

The following Figure 1-7 shows the frame structure of WiMAX using TDD.

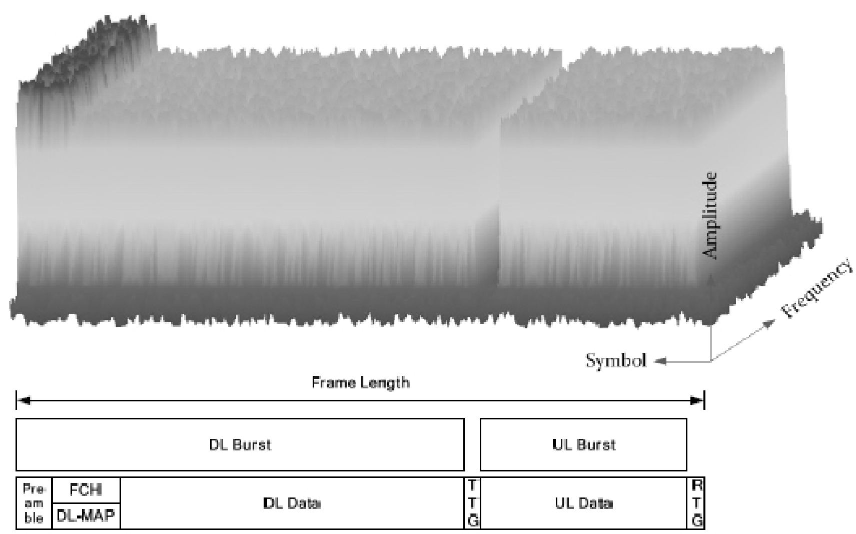


Figure 1-7 Frame structure of WiMAX signal using TDD

Modulation or channelization formats can be relocated at the symbol boundary in the time domain or sub-carrier in the frequency domain.

The following Figure 1-8 shows various sub-frame formats that can be assigned in a single concurrent DL-Frame.

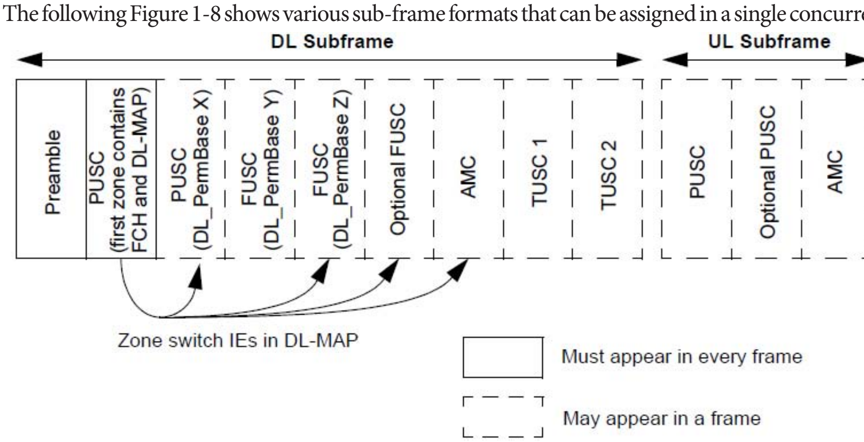


Figure 1-8 OFDMA frame consisted with multiple zones

WiMAX Measurement

The standard IEEE-802.16e recommends performing the following tests to verify the transmitter's performance.

- Power level control
- Spectral flatness
- Constellation error
- Spectral emission mask

The following tests are not mandatory but highly recommended in order to ensure the performance of transmitter.

- Occupied bandwidth
- Complementary cumulative distribution function (CCDF)

The JD7105A provides the following measurement functions to test and analyze the transmitter's operation.

- Transmitter's performance:
  - Channel power
  - Occupied BW
  - Spectral emission mask (SEM)
- Modulation accuracy
  - Power vs. time frame (P vs. T)
  - Constellation
  - Spectral flatness
  - Error vector magnitude (EVM) vs. carrier
  - Error vector magnitude (EVM) vs. symbol
  - Complementary cumulative distribution function (CCDF)

Among the versatile profiles defined by IEEE workgroup, the JD7105A covers the following most commonly used profiles described in Table 2-1.

Band index	Frequency band	Channel Bandwidth	OFDM FF size	Duplexing
1	2.3G ~ 2.4G	8.75 MHz	1,024	TDD
		10 MHz	1,024	TDD
2	2.305 ~ 2.320 GHz 2.345 ~ 2.360 GHz	10 MHz	1,024	TDD
3	2.496 ~ 2.69 GHz	10 MHz	1,024	TDD
4	3.3 ~ 3.4 GHz	7 MHz	1,024	TDD
		10 MHz	1,024	TDD
5	3.4 ~ 3.6 GHz	7 MHz	1,024	TDD
		10 MHz	1,024	TDD

Table 2-1 JD7105A mobile WiMAX profiles

Measurement Setup

To measure WiMAX signals properly, the following parameters should be properly set before performing any test.

Bandwidth

Sets the mobile WiMAX signal bandwidth, including: 7 MHz, 8.75 MHz and 10 MHz.

All are derived from a 1024 FFT size.

Frame

It provides the following parameters to define the frame testing of the mobile WiMAX signal.

- **Frame length** sets the frame length of OFDMA.
- **DL symbol** refers to the number of symbols allocated for downlink. Number of DL symbol is used to calculate the Downlink Burst power in the P vs. T measurement.
- **UL symbol** refers to the number of symbols allocated for uplink. Number of UL symbol is used to calculate the Uplink Burst power in the P vs. T measurement.
- **TTG (RTG):** TTG refers to the time gap between downlink burst and uplink burst, whereas RTG refers to the time gap between uplink burst and downlink burst.
  TTG is fixed regardless of frame length and CP ratio. Only RTG is variable by altering frame length or CP ratio.
- **CP ratio** is the length of cyclic prefix and represented as the relative length compared to the effective length of one OFDM symbol. Table 2-2 shows the example of default TTG and RTG values of 10 MHz WiMAX signal for each different CP ratio and frame length.

Frame Length	CP Ratio	Nsymbol/frame	TTG	RTG	Remarks
5 ms	1/4	42	102.9 µs	97.1 µs	
5 ms	1/8	47	102.9 µs	62.81	
5 ms	1/16	50	102.9 µs	39.96 µs	
5 ms	1/32	51	102.9 µs	88.53 µs	
10 ms	1/4	86	102.9 µs	68.53	
10 ms	1/8	96	102.9 µs	22.81	
10 ms	1/16	101	102.9 µs	85.67	
10 ms	1/32	104	102.9 µs	91.39	

Table 2-2 Default parameters of 10MHz WiMAX frame

Sync Type

Sync type sets the type and input path of external timing reference signal.

- **Internal** sets the trigger path to internal.
- **External** sets the trigger path to External.
- **GPS** sets the trigger path to built-in GPS receiver.
- **Free** sets the trigger mode to free run.

Channel Estimations

It enables or disables the error vector magnitude (EVM) correction function. IEEE standard requires channel estimation when measuring the channel quality measurements such as EVM vs. symbol, EVM vs. sub-carriers, spectral flatness and constellation. When activated, error detected in the preamble channel is regarded as a correctable error occurred during an over-the-air transmission test and is used as a reference for compensating the errors of remaining channels.

- **Default setting:** Channel estimation "On"
- Channel estimation can be applied to the following measurement.
  - Constellation
  - Spectral flatness
  - EVM vs. carrier
  - EVM vs. symbol

Caution: Measuring the constellation or EVM of preamble channel while the channel estimation is enabled returns a meaningless result due to the JD7105A self correction.

Modulation Type

The DL zone format can be set manually or automatically, manual setting prevents error due to wrong detection. In general an OFDMA DL zone can be sectorized by time and sub-channel and can be allocated with data which is modulated with different formats.

- **Auto** allows the test JD7105A to assign the modulation format of each zone automatically.
- **QPSK/16QAM/64QAM:** If the DL zone is formatted with single modulation format, manually selects the proper modulation format.

Symbol

Symbol key sets the measurement interval by symbols unit for a single OFDMA frame.

Minimum interval is one OFDMA symbol period and the setting scheme is as follow.

- **Start symbol** is the first symbol of measurement interval. Start point of assigned symbol is set as a start point of the measurement interval.
- **Stop symbol** is the last symbol of measurement interval. End point of assigned symbol is set as a stop point of the measurement interval.

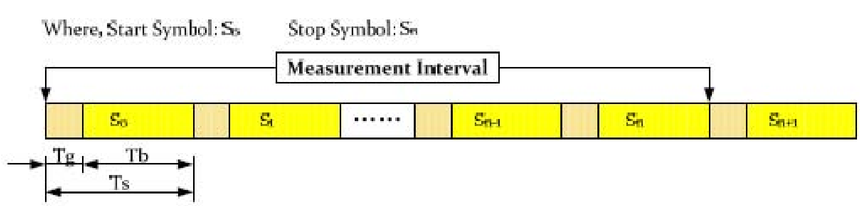


Figure 2-1 Measurement interval setting

Note: If it is required just to measure a specific symbol then it must be set the same symbol number at the start/stop symbol.

Freq. Offset

Freq. offset key sets the center frequency (CF) offset of the OFDMA carrier under test. As a result, freq. offset setting may affect the measured frequency offset value in the constellation measurement.

Gate Delay

Gate delay adjusts the starting point of a measurement interval. The following figure shows the scheme of gate delay setting.

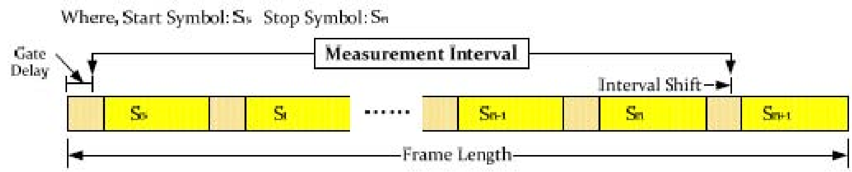


Figure 2-2 Gate delay setting

Preamble Code

This parameter defines the PHY preamble.

- **Auto** identifies the preamble code automatically.
- **Manual** identifies the preamble code manually.

CCDF Length

CCDF length sets the complementary cumulative distribution function (CCDF) measurement length by symbol.

DL Zone

DL zone sets the sub-carrier allocation format of DL zone.

- **Auto** sets the JD7105A to assign the sub-carrier allocation format of DL zone.
- **PUSC** is used when the sub-carrier allocation format of DL burst is PUSC.
- **FUSC** is used when the sub-carrier allocation format of DL burst is FUSC.
- **AMC2X3** is used when the sub-carrier allocation format of DL burst is AMC.

Mask Name

Mask name key loads a user-defined Pass/Fail Mask file. By recalling the user-defined mask file, user can apply customized pass/fail mask to the following measurement items.

- Channel power
- Occupied BW
- Spectral emission mask

TX Power Level Control

IEEE 802.16e standard recommended that the transmitter shall support monotonic power level control of 45 dB (30 dB for license-exempt bands) minimum with a single step size accuracy requirement specified in the following table.

Single step size power (m)	Required relative power accuracy
|m| = 1dB	± 0.5 dB
|m| = 2dB	± 1 dB
|m| = 3dB	±1.5 dB
4dB < |m| ≤ 10dB	± 2 dB

Table 2-3 Single step size relative power accuracy

For TX power level control accuracy measurement, the base station under test must be set to various output power setting. The JD7105A is used to measure the relative power variation for each power setting.

JD7105A provides two different methods to measure the transmitting power.

- Channel power
- Power vs. time (P vs. T)

Channel power is a frequency domain measurement and shows the spectral shape across the frequency range of a given period of time among one OFDMA frame interval.

P vs. T is a time domain measurement and shows the power variation across one OFDMA frame for a given integral bandwidth.

Channel Power Measurement

Channel power is the sum of the spectral power contained in a predefined integral bandwidth.

The following screen shows the channel power measurement result of a WiMAX signal which has a 8.75 MHz bandwidth and 5 ms frame length. Predefined bandwidth is highlighted on the trace and the level of trace within this region is calculated and presented as channel power.

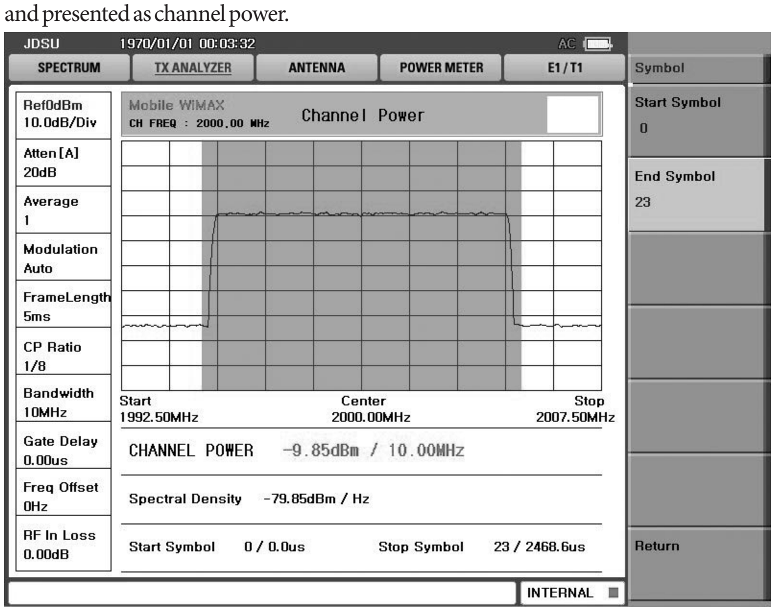


Figure 2-3 Channel Power Measurement screen

Under the trace the resulting channel power is displayed with the integral bandwidth setting. Spectral density shows the power contained in the 1 Hz integral bandwidth and is obtained by dividing the channel power by the integral bandwidth. The measurement interval setting is displayed at the bottom of the screen.

Due to WiMAX signal's inherent burst characteristic, it is required to know and set the proper data burst length and measurement symbol interval.

When selecting the channel power function, the following parameters are set as default values by the JD7105A.

- RBW: 100 kHz
- VBW: 30 Hz
- Span: 15 MHz
- Attenuation: Auto
- Reference level: Auto

The following setting can affect the measurement accuracy and some consideration must be taken.

- Bandwidth
- Symbol
- Freq. offset
- Gate delay

P vs. T Measurement

P vs. T shows the integrated power variation during one frame interval. The following screen shows the P vs. T measurement result of a WiMAX signal which has a 8.75 MHz bandwidth and 5 ms frame length. The trace shows the power contained in a predefined integral bandwidth and the corresponding time. The upper section at the beginning of the frame is the preamble symbol followed by DL data burst, and the lower section of the frame is for UL data burst.

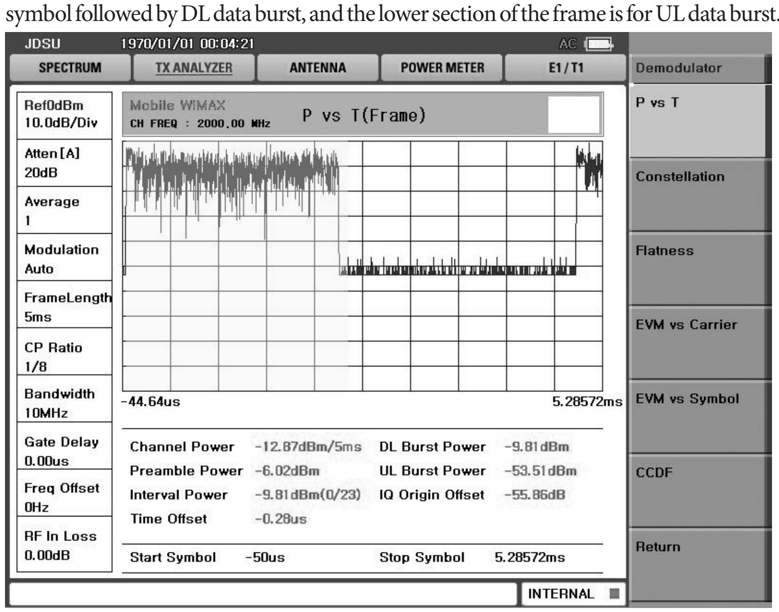


Figure 2-4 P vs. T measurement screen

At below of the trace, the average power of each burst is displayed. The interval setting for each item the following:

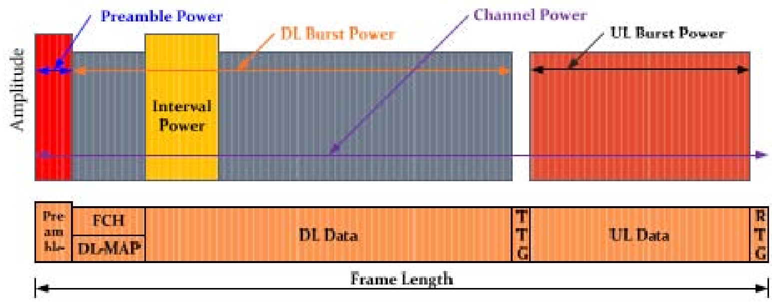


Figure 2-5 P vs. T measurement scheme

- **Channel power** is the average power of a full OFDMA frame including TTG and RTG. Hence preamble, DL burst, TTG, UL burst and RTG are all included.
- **Preamble power** is the averaged power of preamble symbol. Since the preamble symbol is 9 dB higher and only one of the third symbols is transmitted, it is about 4.23 dB higher than the DL burst power.
- **Interval power** is the average power of user-defined measurement symbols interval. It is useful to measure the power of a symbol or symbols while monitoring the power variation per burst. Since the measurement interval is defined by start/stop symbol, TTG or RTG may be included in the integrating interval according to the user setting.
- **DL burst power** is the average power of DL data burst excluding preamble or TTG. DL burst length must be user-defined and is not automatically assigned by the JD7105A.
- **UL burst** is the average power of UL data burst excluding TTG and RTG. DL burst length must be user-defined and is not automatically assigned by the JD7105A.

When selecting the P vs. T function, the following parameters are set as default values by the JD7105A.

- RBW: 100 kHz
- Attenuation: Auto
- Reference level: Auto

The following settings can affect the measurement accuracy and some consideration must be taken.

- Bandwidth
- Frame length
- DL symbol
- UL symbol
- CP ratio
- Symbol (measurement interval)
- Freq. offset
- Gate delay

Spectral Flatness

Spectral flatness is the degree of uniformity of the sub-carriers. IEEE802.16e defines this measurement as follows;

- All requirements on the transmitter apply to the RF output connector of the equipment. For equipment with integral antenna only, a reference antenna with 0 dBi gain shall be assumed.
- The average energy of the constellations in each of the n spectral lines shall deviate no more than indicated in the following table 2-4. The absolute difference between adjacent sub-carriers shall not exceed 0.1 dB; excluding intentional boosting or suppression of sub-carriers, channel state information at the transmitter (CSIT) sounding symbols and peak-to-average power ratio (PAPR) reduction sub-channels are not allocated.

Spectral lines	Spectral flatness
Spectral lines from $-N_{used/4}$ to −1 and +1 to $N_{used/4}$	± 2 dB from the measured energy averaged over all N_{used} active tones
Spectral lines from $-N_{used/2}$ to $-N_{used/4}$ and $+N_{used/4}$ to $N_{used/2}$	+2/−4 dB from the measured energy averaged over all N_{used} active tones

Table 2-4 Spectral flatness Requirement

- The power transmitted at spectral line 0 shall not exceed −15 dB relative to total transmitted power.
- These data shall be taken from the channel estimation step.

Spectral Flatness Measurement

During normal operation, the WiMAX signal always begins with a preamble and it is used for SS such as synchronization with the cell or various channel estimation. Since the preamble uses QOSK and has no embedded BPSK pilot, all activated sub-carriers are boosted equally, therefore it is required to measure the signal's spectral flatness.

DL data burst is divided by symbols and sub-channels to form zones for specific users. Each zone may or may not be modulated with same format such as QPSK, 16QAM, or 64QAM; moreover there are embedded BPSK pilots which are 3 dB higher.

The JD7105A performs a spectral flatness measurement for any specific symbol or a symbol interval. During the measurement, all boosted symbols are excluded according to the IEEE recommendation and the gain differences among different modulated zones are compensated followed by the channel estimation.

The following screen shows the spectral flatness measurement result of a WiMAX signal which has a 8.75 MHz bandwidth, 5 ms frame length and a partial usage of sub-channels (PUSC). The measurement interval is set to periods of 3 symbols, equivalent to 345.6 µs, from 14^{th} to 16^{th} symbols.

The trace shows the relative power of sub-carriers on average sub-carrier power reference with high/low limit lines.

Under the graph, four sub regions are denoted accordingly and relative maximum peak power (MAX), minimum peak power (MIN) and average power (AVG) within each subregion on the average sub-carrier power reference.

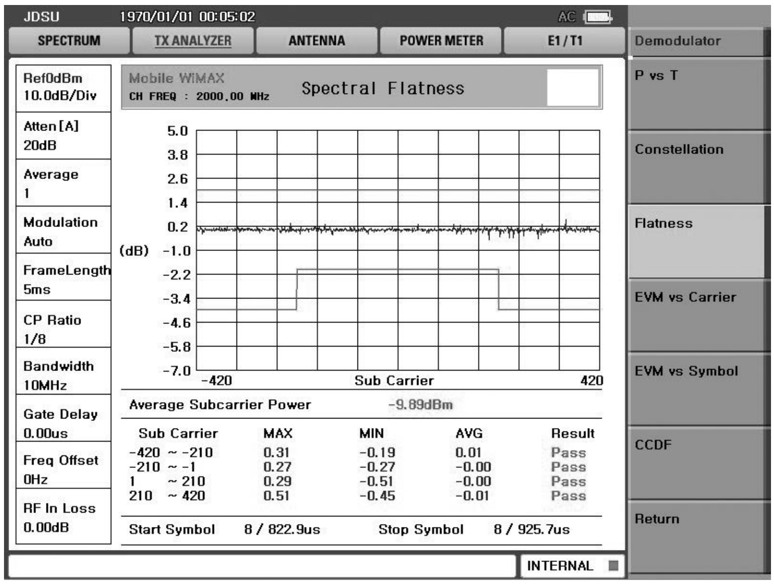


Figure 2-6 Spectral Flatness measurement screen

When selecting P vs. T function, the following parameters are set as default values by the JD7105A.

- RBW: 100 kHz
- Attenuation: Auto
- Channel estimation: On

The following settings can affect the measurement accuracy and some consideration must be taken.

- Bandwidth
- Frame length
- DL symbol
- CP ratio
- Symbol (measurement interval)
- Freq. offset
- Gate delay

Constellation Error

To ensure that the receiver's signal to noise ratio (SNR) does not degrade more than 0.5 dB due to the transmitter's SNR, the relative constellation RMS error, averaged over sub-carriers, OFDMA frames, and packets, shall not exceed a burst profile dependent value according to the following table 2-5. When measuring the transmitter's constellation error, it should be noted that if multiple permutation zones are present in a DL sub-frame, the pilot level may shift when transitioning from zone to zone as the BS attempts to maintain constant power density throughout the frame.

Burst type	Relative constellation error for BS (dB)	EVM (%)
QPSK-1/2	-15	17.78
QPSK-3/4	-18	12.59
16QAM-1/2	-20.5	9.44
16QAM-3/4	-24	6.31
64QAM-1/2	-26	5.01
64QAM-2/3	-28	3.98
64QAM-3/4	-30	3.16

Table 2-5 Allowed relative constellation error versus data rate

The relative constellation error is similar to the EVM and is an signal modulation quality indicator, having the following relationship:

$$\text{Relative Constellation Error} = 20 \times \text{Log}(\text{EVM}(\%))$$

When measuring the RMS constellation error of a base station DL, the JD7105A performs the measurement in compliance with IEEE802.16e recommendation as follow.

a) Locates the preamble.

b) Performs timing and frequency estimation and compensates the timing offset and frequency offset as estimated.

c) Estimates the complex channel response coefficients for each sub-carrier.

d) Divides each sub-carrier's value by the complex estimated channel response coefficient.

e) For each data-carrying sub-carrier, finds the closest constellation point and compute the Euclidean distance from it.

When measuring constellation error, the following parameters are set as default values by the JD7105A.

- Channel estimation: On

The following settings may affect the measurement accuracy and some consideration must be taken.

- Bandwidth
- Frame length
- DL symbol
- CP ratio
- Symbol (measurement interval)
- Freq. offset
- Gate delay

EVM vs. Symbol Measurement

This function provides a comprehensive and intuitive EVM measurement result for a full WiMAX frame. This measurement ensures the modulation quality of each symbol measured over the corresponding sub-carriers in the transmission bandwidth.

The following figure shows the data selection scheme for this measurement. When selecting EVM vs. symbol mode, the JD7105A samples data from all sub-carriers corresponding to the same symbol number, then calculates the rms/peak EVM for that symbol. By repeating this process, the JD7105A obtains the full measurement data.

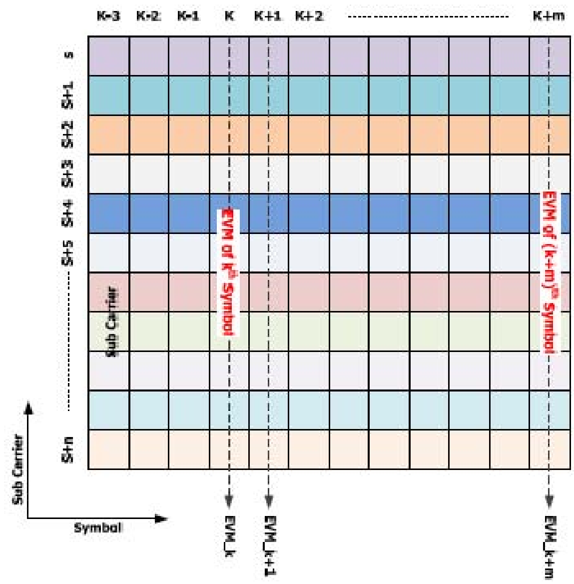


Figure 2-7 EVM vs. Symbol measurement scheme

The following diagram shows the EVM vs. Symbol measurement result of a 8.75 MHz, 5 ms OFDMA frame with PUSC.

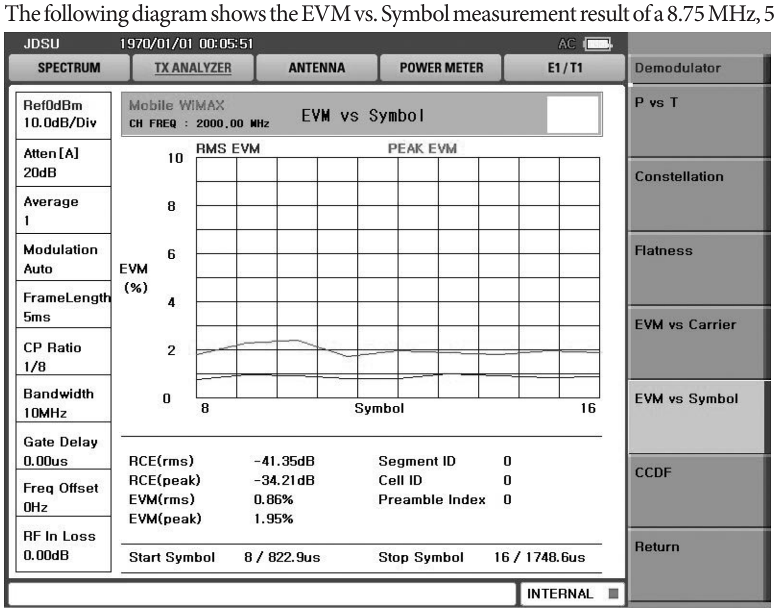


Figure 2-8 EVM vs. symbol measurement screen

The following items correspond to the overall error status of the measured OFDMA signal;

- **RCE (rms)** refers to the RMS value of the relative constellation error of a full WiMAX frame.
- **RCE (peak)** refers to the relative constellation error of a symbol which has the largest error.
- **EVM (rms)** refers to the RMS value of error vector magnitude of a full WiMAX frame.
- **EVM (peak)** refers to the error vector magnitude of a symbol which has the largest error.
- **Frequency error** refers to the frequency difference between detected DC sub-carrier and user defined center frequency.
- **Segment ID** refers to the Sector ID of the base station (0, 1 or 2). According to the segment ID, it is decided which preamble will be boosted.

- **Cell ID** refers to the base station ID. The available ID's range is different with the FFT size.
- **Preamble index** refers to the unique hexadecimal code. Preamble index is decided by the combination of segment ID and cell ID.

EVM vs. Sub-carrier Measurement

This measurement provides additional information of the sub-carrier corresponding to a specific symbol or symbols. If the EVM vs. symbol measurement result is poor for a specific symbol, it is recommended to measure the individual sub-carrier's EVM for one or several symbols interval to isolate the fault frequency position.

The following figure shows the data selection and measurement interval setting scheme for the given user-defined measurement condition as follows:

- Start symbol #: k
- Stop symbol No: k+m

Under this configuration, the JD7105A measures the EVM of an individual sub-carrier over m symbol intervals then takes an average to obtain the EVM of each sub-carrier.

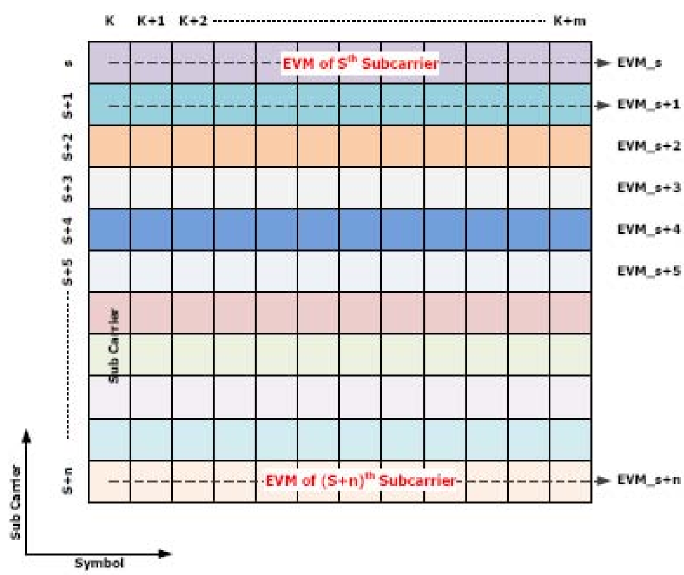


Figure 2-9 Frequency and time Interval setting scheme for EVM vs. Sub-carrier measurement

The following screen is the EVM vs. sub-carrier measurement result of a WiMAX signal which has a 8.75 MHz bandwidth, 5 ms frame length with PUSC.

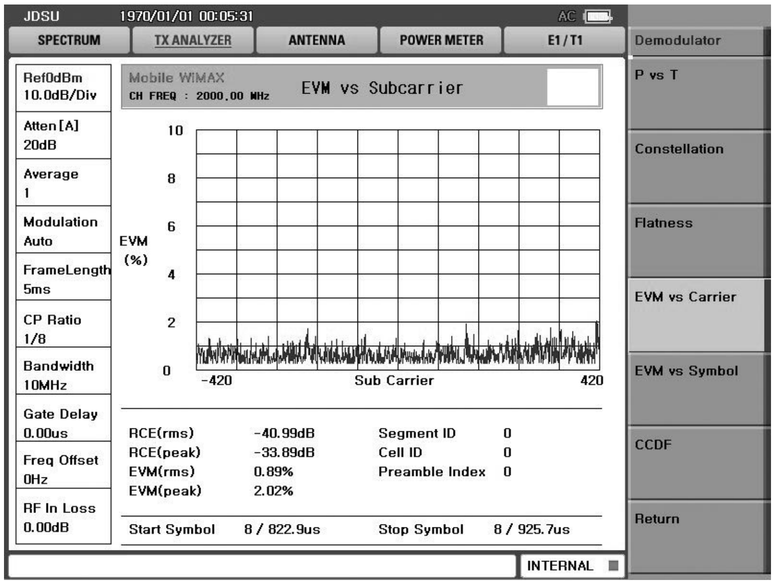


Figure 2-10 EVM vs. Sub-carrier Measurement screen

The upper graph shows the individual EVM of each sub-carrier, and the modulation errors are displayed at the lower half of the screen.

The meaning of each item listed on the screen is as follow;

- **RCE (rms)** refers to the RMS value of the relative constellation error of a full sub-carrier corresponding to the selected symbol/symbols.
- **RCE (peak)** refers to the relative constellation error of a sub-carrier which has the largest error.
- **EVM (rms)** refers to the RMS value of error vector magnitude of the sub-carriers corresponding to the selected symbol/symbols.
- **EVM (peak)** refers to the error vector magnitude of a sub-carrier which has the largest error.
- **Frequency error** refers to the frequency difference between the detected DC sub-carrier and the user-defined center rrequency.
- **Segment ID** refers to the sector ID of the base station (0, 1 or 2). According to the segment ID, it is decided which preamble will be boosted.
- **Cell ID** refers to the base station ID; available ID's range is different with the FFT size.
- **Preamble index** refers to the unique hexadecimal code. Preamble index is decided by the combination of segment ID and cell ID.

Constellation Measurement

Constellation measurement is similar to EVM measurement used in many other digital communication standards. Constellation measurement can only be done for one OFDMA symbol interval. Hence this measurement can be used if the EVM vs. symbol and EVM vs. sub-carrier measurement result indicate that a specific symbol has a problem, and the constellation of that symbol will show whether there is an I-Q symbol problem such as digression, shifting, or offset.

For this measurement, the JD7105A receives the OFDMA signal over one symbol interval for all sub-carriers corresponding to the designated symbol and demodulates the signal to obtain I, Q data. The following diagram shows the schematic of constellation measurement for a given symbol setting.

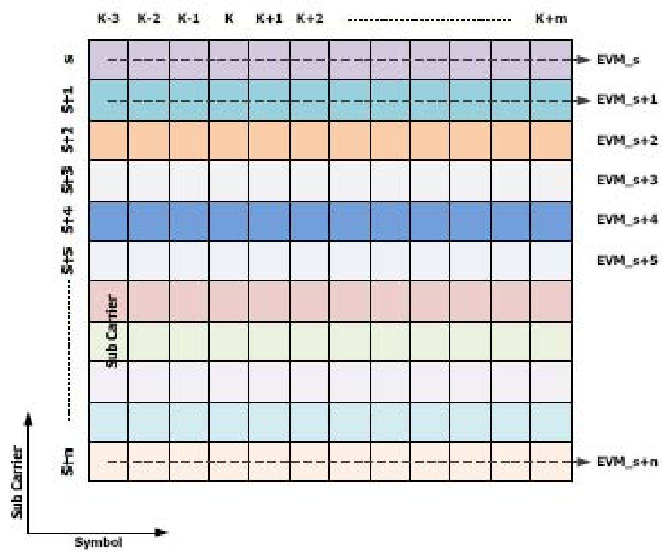


Figure 2-11 Sub-carrier selection scheme for RCE measurement

The following screen shows the constellation measurement result for a WiMAX signal which has a 8.75 MHz bandwidth, 5 ms frame length. Two points located at the far end of both side are for BPSK modulated pilot symbols, and the remaining points correspond to the data symbols.

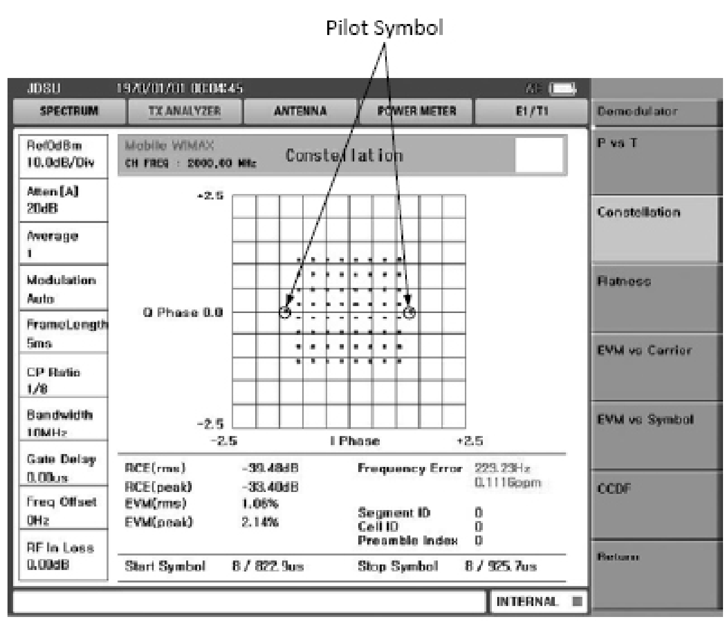


Figure 2-12 Constellation diagram

The meaning of each item listed on the screen is the following;

- **RCE (rms)** refers to the RMS value of the relative constellation error of the sub-carrier corresponding to the selected symbol.
- **RCE (peak)** refers to the relative constellation error of an associated sub-carrier which has the largest error.
- **EVM (rms)** refers to the RMS value of the error vector magnitude of the sub-carriers corresponding to the selected symbol.

- **EVM (peak)** refers to the error vector magnitude of a sub-carrier which has the largest error.
- **Frequency error** refers to the frequency difference between the detected DC sub-carrier and user-defined center frequency.
- **Segment ID** refers to the sector ID of the base station (0, 1 or 2). According to the segment ID, it is decided which preamble will be boosted.
- **Cell ID** refers to the base station ID; available ID's range is different with the FFT size.
- **Preamble index** refers to the unique hexadecimal code. Preamble Index is decided by the combination of segment ID and cell ID.

TX Spectral Mask

This test measures the amount of unwanted emission radiated from the transmitter. IEEE802.16e does not attempt to specify a standard mask for OFDMA signals. Therefore this measurement should be performed based on a user-defined mask. Even though the IEEE802.16e does not specify the Spectral Mask for OFDMA, it's not because the unwanted emission is not essential, but because the spectral Mask should be defined according to the local regulation.

TX Spectral Mask Setup Procedure

In order to edit and apply a user-defined Spectral Mask, a dedicated Application S/W, JDViewer, should be used.

Mask editing

1. Run JDViewer
2. Select [Utility]-[SA Editor]
3. Assign the mask name then put the proper mask value including reference setting.
4. Save the mask file on USB memory stick with a user-defined name.

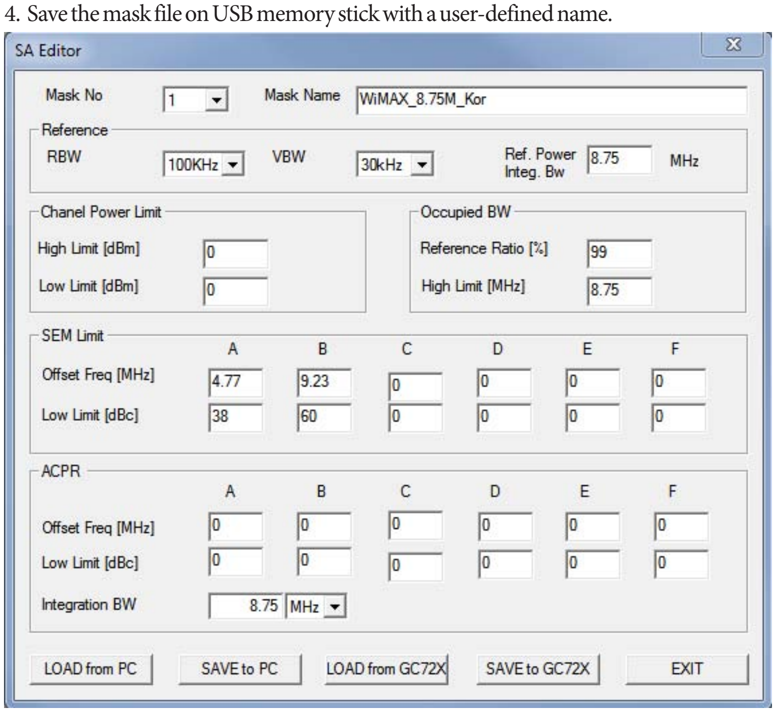


Figure 2-13 SA Editor Screen of Application S/W

Mask downloading and applying

1. Connect the USB memory where in the mask file is stored.
2. Select [Load From] then set USB.

3. Select [Load]-[Load SA Edits] then select the name of user's mask file.
4. Select [Measure Setup]-{More}-[Mask Name]. Be sure the JD7105A is in WiMAX mode.
5. If JD7105A is connected to the PC through a RS-232, Ethernet or USB, the mask file can be directly saved to the JD7105A. Please refer to JDViewer's help file for additional information.

The following figure shows the SEM measurement screen of a WiMAX signal which has a 8.75 MHz bandwidth, and 5 ms frame length.

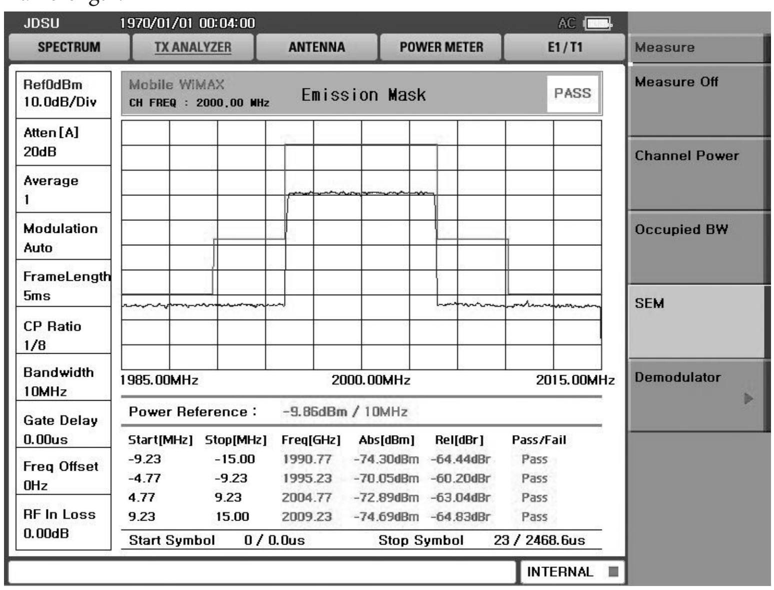


Figure 2-14 SEM measurement screen.

When selecting P vs. T function, the following parameters are set as default values by the JD7105A.

- Attenuation: Auto

The following settings can affect the measurement accuracy and some consideration must be taken.

- Symbol (measurement interval)
- Freq. offset
- Gate delay

CCDF

Complementary cumulative distribution function (CCDF) measures the power distribution of the transmitted signal. CCDF is not a mandatory measurement, but it is a useful parameter to optimize the base station output power to cover a wide area without degrading QoS. Since a high-rate modulation scheme like 16 QAM or 64 QAM is used, and WiMAX frames may consist of several zones that have different modulation formats, WiMAX signals presents a high PAR. High PAR requires a wide-range amplifier to deliver a large amount of data without loss or distortion.

The following figure 2-15 shows the measurement scheme of CCDF. If the length of CCDF is set as a symbol unit, then the JD7105A triggers to the Preamble and measures the power with 100kHz RBW across the bandwidth for each symbol over the assigned symbol number.

Since there is no power transmission during TTG, UL Data Burst and RTG, improper length setting cover DL burst and UL Burst may return invalid result. Therefore it is required to have the exact information about the DL symbol length of the signal under test.

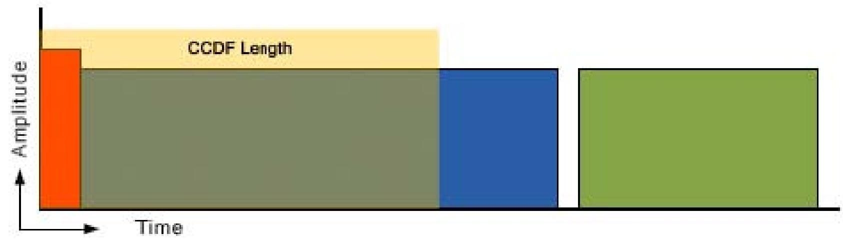


Figure 2-15 CCDF length setting scheme

The following figure 2-16 is the CCDF measurement result screen. Gaussian distribution curve is displayed as a reference line, but it does not act as a pass/fail limit.

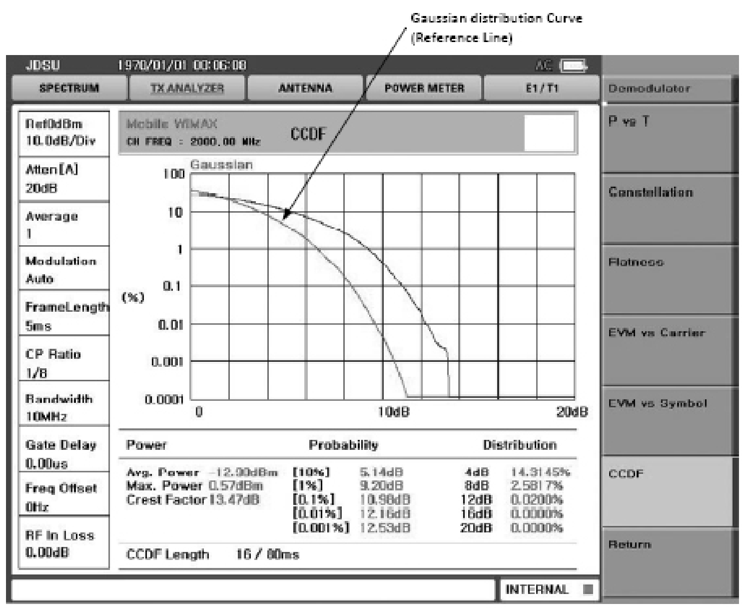


Figure 2-16 CCDF measurement screen

Each items displayed under the CCDF trace is described as follows;

- **Avg. power** is the average power of user defined symbol measured over signal bandwidth.
- **Max power** is the highest power among the measured data.
- **Crest factor** is obtained by subtracting avg. power from max power.
- **Probability** refers to the power data located within prepositioning percentage from the average power.
- **Distribution** refers to the percentage of data located beyond prepositioning power difference form average power, e.g. if 4 dB is 9.36% then it means 90.64% of measured power data are lower than 4 dB of the average power.

When selecting P vs. T function, the following parameters are set as default values by the JD7105A.

- RBW: 100 kHz
- Attenuation: Auto

The following settings may affect the measurement accuracy and some consideration must be taken.

- Freq. offset
- Gate delay

Occupied Bandwidth

Occupied bandwidth has a similar meaning as spectral emission. If the spectral emission is the measurement to determine how much power is radiated and influenced to the adjacent channel, occupied bandwidth shows the frequency span in which 99% of transmitted signal power is contained. Hence occupied bandwidth can give a useful concept for specifying the spectral properties of a given emission in the simplest possible manner.

Occupied bandwidth measurement procedure is as follow;

1. Measures the spectrum of the transmitted signal across a span of 15 MHz. The selected resolution bandwidth (RBW) filter of the JD7105A is 100 kHz.
2. The spectrum is measured at 1,500 points across the measurement span.
3. Computes the total power (P0) of all the measurement cells in the measurement span.
4. Computes the power outside the occupied bandwidth (P1) on each side. P1 is half of (100 % - (occupied percentage)) of P0. For the occupied percentage of 99 %, P1 is 0.005 times P0.
5. Determines the lowest frequency (f1) for which the sum of all power in the measurement cells from the beginning of the span to f1 exceeds P1.
6. Determine the highest frequency (f2) for which the sum of all power in the measurement cells from the end of the span to f2 exceeds P1.
7. Computes the occupied bandwidth as f2 - f1.

The following figure 2-17 shows the measurement screen for the occupied bandwidth measurement result of a 8.75 MHz, 5 ms WiMAX signal.

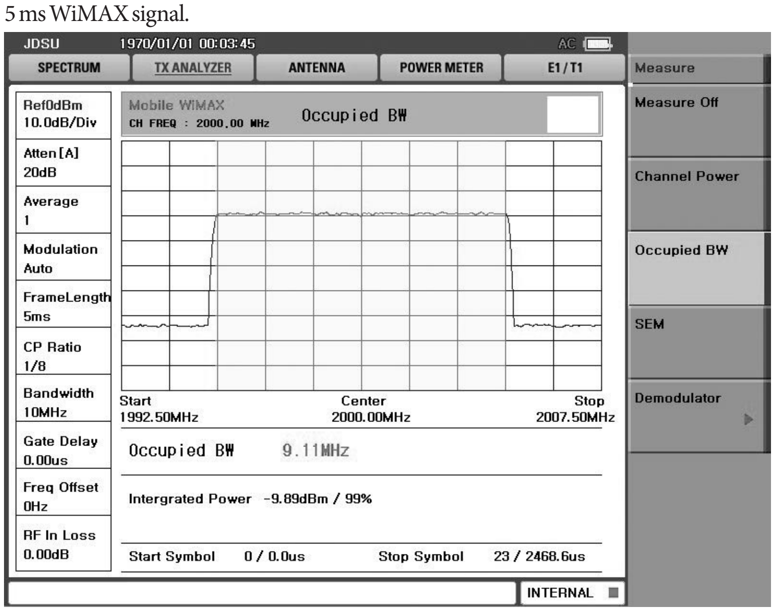


Figure 2-17 Occupied Bandwidth measurement screen

Since IEEE802.16e does not propose any requirement for occupied bandwidth measurement, the JD7105A does not attempt to propose any default limit, rather it lets the user to set limit values with the application software JDViewer. Detailed procedure for making and applying limit to JD7105 is the same as described in the spectral mask measurement.

When selecting occupied bandwidth function, the following parameters are set as default values by the JD7105A.

- RBW: 100 kHz
- Attenuation: Auto

The following settings may affect the measurement accuracy and some consideration must be taken.

- Gate delay

References

IEEE-802.16. Part 16. Air Interface for Fixed Broadband Wireless Access Systems.

IEEE-802.16e Part 16. Air Interface for Fixed and Mobile Broadband Wireless Access Systems.

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