W-CDMA/LTE Area Optimization using ML8780A/81A

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[Summary] Mobile phone networks in Japan are switching from 3G to 3.9G/4G (LTE hereafter). However, there are some overlapping frequency bands between 3G and LTE. Further, mixed 3G and LTE networks will remain in place for some years due to the high cost of replacing legacy 3G network infrastructure. Consequently, measuring instruments that can obtain stably outcome never affected by interference of W-CDMA/LTE from each other system are needed and then it is necessary for special consideration of difference character betwewn W-CDMA and LTE. The ML8780A/81A Area Tester with new MU878030A/MU878040A test options is ideal for optimizing mixed W-CDMA/LTE service areas.

1 Introduction

Recent development of mobile phone networks is focusing on Self Organizing Network (SON)[1), 2)] technologies for optimizing service areas by exchanging information between terminals and base stations without using measuring instruments. However, direct field measurements are still required for comparing communications quality between carriers, collecting objective and stable measurement data, and examining faults. In other words, use of dedicated measuring instruments to evaluate mobile phone network service areas is not going away.

We have developed the ML8780A/81A Area Tester (figure 1) as a measuring instrument for evaluating these service areas and helping the work of mobile carriers, base station installation companies, and mobile terminal makers.

The ML8780A/81A is a modular design using multiple measurement modules such as the MU878010A supporting W-CDMA measurements and the MU878030A supporting LTE FDD. As part of a new lineup, we have recently launched the MU878030B LTE measurement Unit with lower power consumption than its predecessor MU878030A and supporting both the 700 and 900 MHz bands recently standardized in Japan. With this development, the MU878030B can be used for LTE Signal to Interference Ratio (SIR) stably calculations in a Fading Environment. In addition, to support LTE TDD measurements, we have recently launched the MU878040A TD-LTE measurement unit offering users easy measurement of time-domain switched uplink and downlink signals by identifying just the downlink timing. Combining these new measurement modules makes it easy to measure W-CDMA and LTE systems simultaneously, supporting effective measurement and evaluation of mixed service areas.

Figure 1 ML8780A and ML8781A Area Tester

2 LTE Measurement Items

In W-CDMA systems, usually the Primary Common Pilot Channel (P-CPICH) being transmitted at a fixed level is measured. In comparison, in LTE systems, the measurement target is the Reference Signal used for channel estimates and Channel Quality Indicator (CQI) measurements.

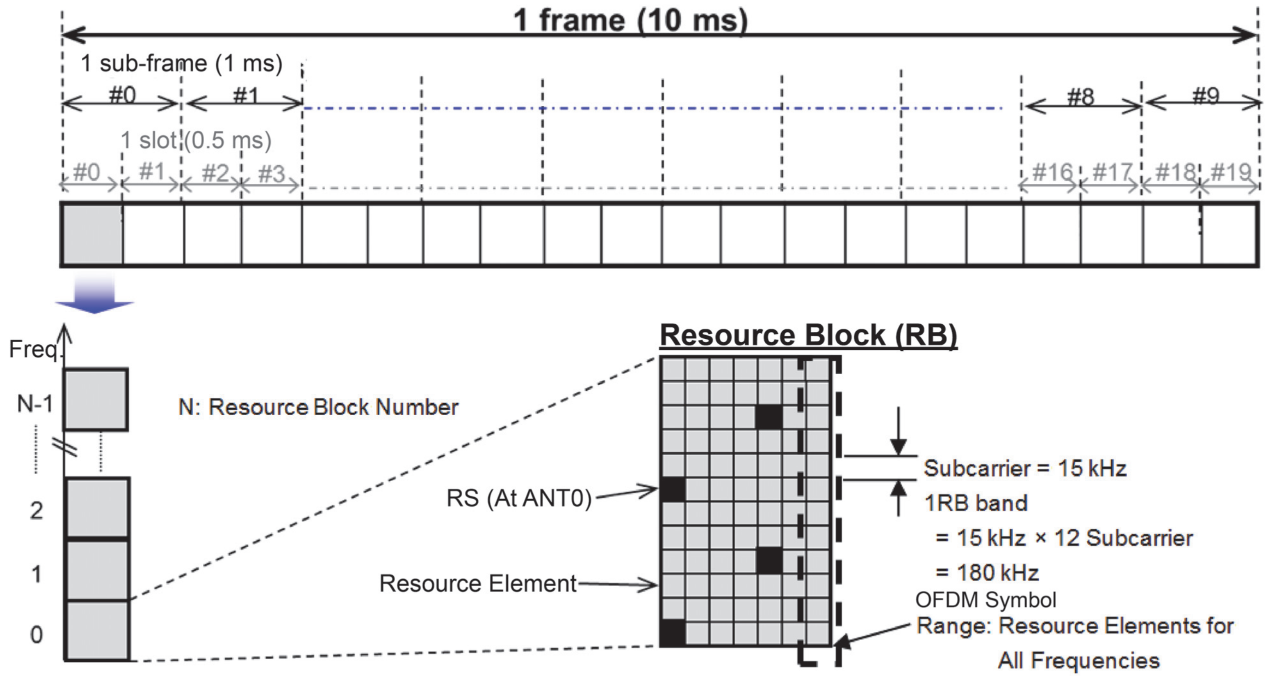


Figure 2 LTE Downlink Frame Structure (FDD Normal CP)

2.1 Key Performance Indicators

The key LTE items measured by the MU878030A/30B/40A are the SRP, RSSI, RSRQ and SIR, which comprise the Key Performance Indicators (KPI) for evaluating the LTE PHY layer[3]. In addition, figure 2 shows the LTE frame structure to help understand the following explanation.

(1) RSRP (Reference Signal Received Power)

RSRP is the RS received power per resource element (15-kHz band). The RS are distributed uniformly in each time and frequency domain and is also unaffected by the traffic volume. As a result, the RSRP is a basic parameter for evaluating the level of the radio wave received from the base station and can be used to broadly determine the base station fixed setting conditions such as the Tx power, antenna direction and height, etc., as well as the measurement environment, such as the distance from the base station, obstructions, etc.

(2) RSSI (Received Signal Strength Indicator)

RSSI is the measured power of all LTE bands at the time of OFDM symbol containing RS (at Normal CP, one OFDM symbol is about 67 μs). Unlike the W-CDMA RSSI, which is measured at any timing irrespective of the frame timing, since it is defined as the timing with RS, LTE RSSI is measured at each Physical layer Cell Identity (PCI). Moreover, RSSI is not only affected by the base station settings and measurement environment, it also changes according to the traffic volumes of the base station to be measured and nearby base stations; generally, as the traffic volume increases, the resources allocated in the LTE frame also increase and the RSSI becomes larger.

(3) RSRQ (Reference Signal Received Quality)

RSRQ is one index expressing the RS reception quality; it is calculated as the ratio of RSRP and RSSI. Moreover, since the RSSI measurement band tends to change with the LTE bandwidth, the resource block number is standardized as shown in Eq. (1).

$$RSRQ = N \times RSRP / RSSI \quad (1)$$

N: Resource Block Number (See table 1.)

Table 1 LTE System Bandwidth and Resource Block Number

Bandwidth [MHz]	1.4	3	5	10	15	20
Resource Block Number	6	15	25	50	75	100

Since the RS number in one resource block is fixed, RSRQ expresses the RS quality, irrespective of the LTE bandwidth.

In the same way that RSSI is influenced by traffic, the RSRQ value also changes according to the traffic volume. In concrete terms, with one Tx antenna, the

Maximum value of RSRQ is –3 dB; with two Tx antennas, it is –6 dB (applies when the reference elements used in the resource block are just RS), and RSRQ becomes smaller as traffic increases. It also becomes smaller as interference from neighboring base stations increases.

(4) SIR (Signal to Interference Ratio)

Like RSRQ, this is one index expressing the RS reception quality. Whereas RSRQ is calculated from the fraction with denominator RSSI, or in other words uses the power of the entire band, SIR is calculated from the fraction whose denominator is just interference power in the resource block as same as RS's resource block 15-kHz band. Since it is difficult to measure interference power directly, the RS ideal signal variance is calculated to find the interference power[4]. The interference power calculated by this method is called the Signal to Interference plus Noise Ratio (SINR) because it includes noise components in addition to signals from adjacent cells in the same band. The ML8780A/81A Area Tester displays SIR without the conventional separation of SIR and SINR; noise components are included in the SIR measurement for both W-CDMA and LTE systems.

A feature of SIR is the ability to measure only interference from other cells (other stations) because it is unaffected by traffic from the same cell (own station) as the RS being measured. However, when there are multipaths with delays exceeding the Cyclic Prefix (CP), care is required about even signals from the same cell becoming interference waveforms.

2.2 Comparison of W-CDMA and LTE

Table 2 shows a comparison of W-CDMA and LTE measurement items. It shows that items used to evaluate W-CDMA areas have LTE equivalents. However, since the values cannot be compared simply, a different index from the W-CDMA index must be created to express LTE area quality.

Table 2 W-CDMA/LTE Measurement Comparison

Item	W-CDMA	LTE	Note
Cell Differentiation	Scrambling Code (SC)	Physical Cell ID (PCI)	
Measurement Target	Common Pilot CH (CPICH)	Reference Signal (RS)	Measurement Band CPICH: 3840 kHz RS: 15 kHz
Measurement Target Rx Power	RSCP [dBm]	RSRP [dBm]	RSCP and RSRP cannot be compared simply because the measurement target band is different.
Total Rx Power	RSSI [dBm]	RSSI, Io [dBm]	LTE RSSI cannot be measured when the PCI is not established.
Proportion to Total Rx Power	Ec/No [dB]	RSRQ [dB]	
Interference ratio	SIR [dB]	SIR [dB]	When the wanted (measurement target) and interference wave powers are the same, SIR [dB], the SIR value is: W-CDMA: 24.1[Note] LTE: 0

(Note) Since W-CDMA SIR is defined in 15-kHz band by dispreading CPICH, it is handled so that there is gain (256 ⇒ 24.1 dB) equivalent to the spreading factor for the interference.

3 LTE Measurement Principles and Measurement Unit Features

3.1 SIR Measurement

Since SIR is hardly affected by own station traffic, SIR has special importance in evaluating areas with different overlapping systems like W-CDMA and LTE.

As explained in section 2.1 (4), LTE SIR is calculated from the demodulated RS symbol variance using the following equation (4). This is analogous to the SIR measurement method for W-CDMA[5].

$$RSRP = I_{ave}^2 + Q_{ave}^2 = \{(1/M)\Sigma I_m\}^2 + \{(1/M)\Sigma Q_m\}^2 \quad (3)$$

$$I_{ot} = (1/M) \cdot \Sigma\{(I_m - I_{ave})^2 + (Q_m - Q_{ave})^2\} \quad (4)$$

$$SIR = RSRP / I_{ot} \quad (5)$$

(I_m, Q_m): Demodulated RS symbols

M: RS Resource Element Number

However, at actual measurement in the field, the ideal RS symbol may change on both the frequency and time axes even when the interference is small, because there are fading effects due to the occurrence of multipaths and movement of the measuring instrument. Figure 3 shows a simulation of how the RS symbol point for each frequency (sub-carrier) changes with multipaths and figure 4 plots the adjacent RS in terms of time at each frequency under the same multipath effect as shown in figure 3.

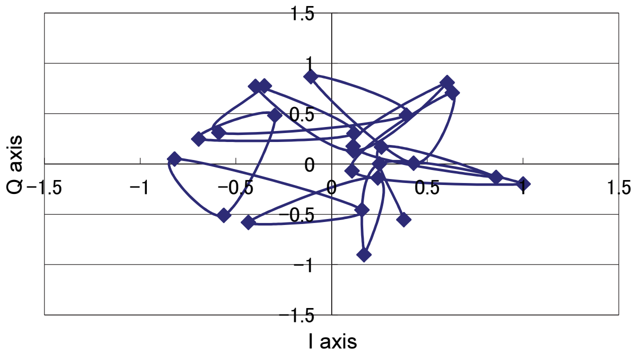


Figure 3 Variation in RS Symbol Due to Multipaths (Freq. axis)

The MU878030A/30B/40A uses Eq. (4)' to calculate the interference power Iot required for the LTE SIR calculation to reduce the effect of multipaths.

Equation (4)' uses the fact that the difference in the level changes between adjacent RS is almost constant on the time axis as shown in figure 4.

$$I_{ot} = (1/4KM)\Sigma\Sigma\,|\{(R_{km} - R_{(k\text{-}1)m}) - (R_{k(m\text{-}1)} - R_{(k\text{-}1)(m\text{-}1)})\}\,|^2 \quad (4)'$$

R_{km}: RS demodulation result (symbol on IQ plane) for kth item on frequency axis and mth item on time axis

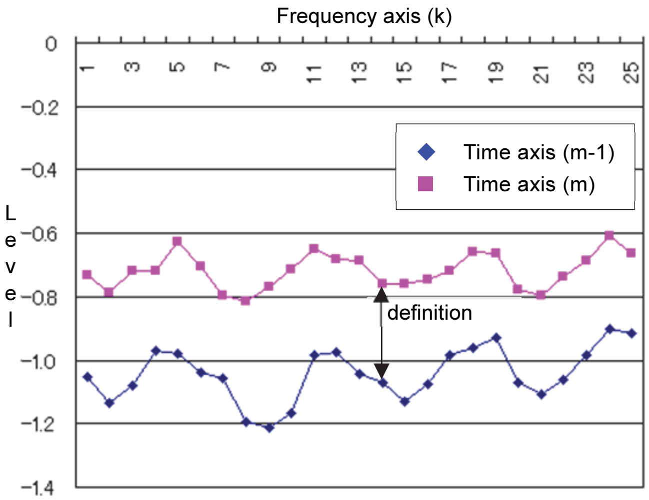
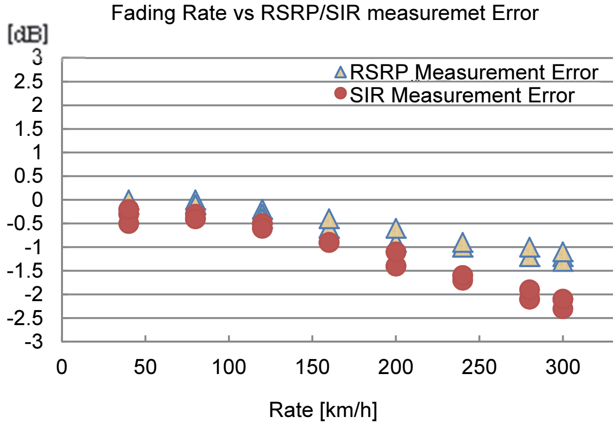


Figure 4 Change in Adjacent RS (R_{km}[I axis]) Level

Figure 5 shows the actual results for RSRP and SIR measured using the MU878030B when multipaths are simulated using a fading simulator.



Conditions: Frequency = 2140 MHz, System Bandwidth = 5 MHz, Number of Paths = 2 (Same Level, 1 μs Delay Spread)

Figure 5 Measurement Data from Fading Environment

Although the specifications guarantee the measurement accuracy at 100 km/h or less, the performance can actually measure power values with errors of ±2 dB for RSRP and ±3 dB for SIR at speeds of 300 km/h.

3.2 Supporting TDD Technologies

As shown in figure 6 and table 3, LTE TDD uses the same carrier frequency for downlink from the base station and uplink from the mobile terminal and switches the downlink and uplink in sub-frame units[6]. The downlink and uplink combinations have the 7 configurations shown in table 3.

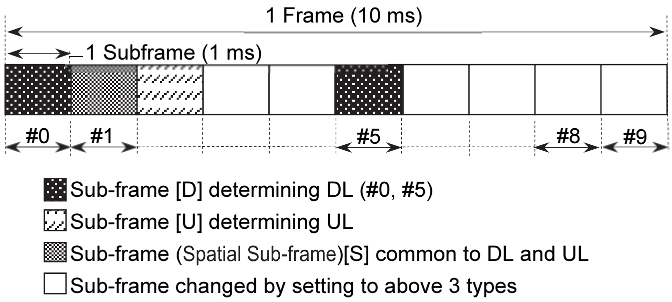


Figure 6 LTE TDD Frame Structure

Table 3 LTE TDD Downlink and Uplink Combinations[6]

Uplink-Downlink configuration	Sub-frame									
	0	1	2	3	4	5	6	7	8	9
0	D	S	U	U	U	D	S	U	U	U
1	D	S	U	U	D	D	S	U	U	D
2	D	S	U	D	D	D	S	U	D	D
3	D	S	U	U	U	D	D	D	D	D
4	D	S	U	U	D	D	D	D	D	D
5	D	S	U	D	D	D	D	D	D	D
6	D	S	U	U	U	D	S	U	U	D

U: Uplink
D: Downlink
S: special sub-frame

The timing for all LTE TDD frames is clarified by the process of detecting the PCI to be measured[4], but if the higher-layer information is not demodulated it is unclear which combination of Downlink and Uplink in the configuration shown in in table 3 is applied. However, the primary objective of area measurement is to be able to measure in environment with a large error rate due to the high-speed PHY layer and interference; even if higher-layer demodulation is not possible, the detected PCI Downlink must be measured with certainty.

Considering a method where the user specifies the sub-frame to be measured, not only is it impossible to set the correct measurement conditions if the settings for the system to be measured are not well known but also it is not possible to handle a system where downlink and uplink switch dynamically.

We decided to only support measurement of sub-frames #0 and #5 using the MU878040A TD-LTE Measurement unit under all circumstances, because sub-frame #0 and #5 are always downlink. As a result, users can obtain downlink measurement results in the same manner as FDD while hardly being aware of the frequent Downlink and Uplink switching.

3.3 Features of LTE Measurement Unit

As described previously, the MU878030A/30B/40A units capture good measurements for LTE multipath and fading environments. Due to the fast measurement speed (table 4), the system is ideal for performing area drive-through tests using an in-vehicle measurement system.

Additionally, the newly developed M878030B has improved and expanded functions compared to the legacy MU878030A (table 3).

Table 4 MU8780A/30B Function Comparison

Item	MU878030A	MU878030B
Measurement Frequency [MHz]	2110.0 – 2170.0 1805.0 – 1880.0 1475.9 – 1510.9 860.0 – 894.0	2110.0 – 2170.0 1805.0 – 1880.0 1475.9 – 1510.9 925.0 – 960.0 850.0 – 894.0 773.0 – 803.0
Number of Measured Carrier Frequencies	8	8
Max. Number of Measured PCI	40	40
Measurement Time(Note 1)	10 ms/PCI	10 ms/PCI
Mass [kg]	0.8 max.	0.8 max.
Dimensions (WHD) [mm]	240 × 170 × 23	240 × 170 × 23
Power Consumption [W] (Only measurement unit)	17	9
Battery Operation Time(Note 2) [h]	>1.5	>2.5

(Note 1) Measuring one carrier frequency with 2 or less antennas

(Note 2) Using new battery pack with ML8780A+(MU878030A or MU878030B)+MU878001A configuration

The MU878030B power has been greatly decreased and up to four LTE measurement units can be connected to one ML8780A/81. At a drive-through test, the number of carrier frequencies is limited to two per measurement unit by the PCI search speed, but the increase in the number of connected measurement units now supports the same number of measured carrier frequencies as competing instruments to increase drive-through test efficiency by measuring W-CDMA and LTE simultaneously, etc.

4 Differences between W-CDMA and LTE

In addition to the actual differences between W-CDMA and LTE measurement items and measured data analysis explained in section 2.2, it may be necessary to understand the differences in the modulation methods and channel multiplexing methods. One main difference is how the cell boundary appears.

With W-CDMA, the 15-kHz CPICH is sent from the base station with a frequency spread of 3.84 MHz using the Scrambling Code. The signal is continuous on both the frequency and time axes and the CPICH of each cell is input in the multiplexed state to the antenna input of the mobile terminal and the measuring instrument.

When the 3.84-MHz spread signal is demodulated to the original 15-kHz signal at the Rx side, although the wanted signal (CPICH objective) Rx power is the same even after demodulation, the received interference waveform component has a power of 1/256 (–24.1 dB) due to the effect of the interference wave modulation changing by 1/256 from 3.84 MHz to 15 kHz after modulation on the CPICH symbols. Consequently, when the interference wave is more than 24.1 dB bigger than the wanted wave, the wanted wave symbols are completely buried in the interference wave, preventing detection (figure 7). In other words, it is impossible to measure cells with an Rx level of 24.1 dB or less compared to cells having the biggest Rx level. When measuring a W-CDMA area, this 24.1 dB value is the theoretical boundary of the measurable cell range.

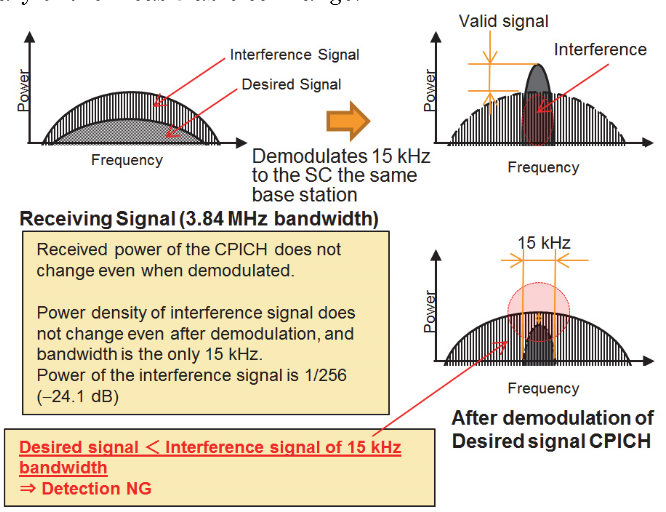


Figure 7 CPICH Modulation of W-CDMA

On the other hand, with LTE, as shown in figure 2, the RS signal is discontinuous in terms of both frequency and time. Even if the RS of one cell overlaps the RS of another cell either in terms of frequency or time, there is no mutual interference. The interference is large when a channel is assigned to a resource element of another PCI that is receiving at the same frequency (sub-carrier) and same timing as the RS of the PCI to be measured; the interference is small when a channel is not assigned. This means that the SIR and RSRQ values change according to the number of mobile terminals and traffic in the area. Although the measurable PCI for terminals and measuring instruments is determined by the lower limit of the measurable SIR, since SIR changes with traffic, the measured PCI number changes with the traffic at measurement. However, even in this case, if the measuring instrument has good resistance to interference, it can measure with better performance than the terminal performance so it is still possible to measure the PCI needed for evaluating the area under normal operations even at measurement under the worst conditions.

The MU878030A/30B guarantees SIR measurements of better than –9 dB and can actually display measurements up to about –15 dB. An SIR value of –9 dB is equivalent to CQI (Channel Quality Indicator) Index 0 (Out of range)[7), 8)] and is smaller than the required terminal performance[9)], so the instrument has sufficient ability to withstand interference.

5 Future Outlook

Measurement of the PHY layer radio-wave environment is used as an objective index at design and evaluation of mobile phone base station areas. On the other hand, it was previously thought impossible to obtain an objective index of area quality because the PHY layer providing the actual terminal communications such as throughput changes with the number of users and traffic in the area. However as competition between carriers becomes more severe, the focus is on throughput, which users heavily emphasize. For example, even if the RSRP is sufficiently large and the interference is small, when there is chronic overcrowding in an area, getting a connection becomes hard and data speeds slow down, which cannot be described as a good environment for users.

In the future, throughput measurements will be required in addition to PHY layer measurements. Since throughput measurement is difficult with an instrument such as an area tester dedicated to downlink measurements, a solution is required that combines area testers with terminals.

Furthermore, recently, service areas have been spreading from above ground to in-building and crowded underground areas, such as shopping malls, railways, subways, etc., where drive-through area testing is impossible. To implement appropriate measurements in these environments, we need both simpler, smaller, and lighter instruments as well as unseen autonomous measurement solutions that reduce the psychological burden on operators.

6 Summary

Anritsu has long experience in developing instruments to help mobile carriers and network installation companies with area evaluation of mobile phone base stations. To develop this new test solution meeting every need, we listened to customers' opinions and issues at every phase from product development to clarification of product features. As well as reporting the completed development of this new LTE measurement unit, this article clarifies the key differences between W-CDMA and LTE that are of concern to customers.

We expect this new measurement unit to play a key role in evaluation of LTE areas and would like to thank our customers using our area testers and other related Anritsu sections for their cooperation in writing this article.

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