Development of MT8820C Radio Communication Analyzer which supports 2G, 3G and LTE

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[Summary] The next-generation mobile communication Long Term Evolution (LTE) system is being introduced worldwide as a solution to increasing mobile data traffic. Anritsu has developed the MT8820C Radio Communication Analyzer test instrument to support LTE as well as existing mobile communication systems (2G to 3.5G) and assist in development and manufacturing of mobile terminals. The MT8820C supports various mobile 2G to 4G communication systems and offers an RF test feature using call processing. To improve mobile terminal manufacturing efficiency the MT8820C also supports sequence measurement to perform high-speed measurement by coordinated operation between the mobile and MT8820C.

1 Introduction

Deployment of the next-generation Long Term Evolution (LTE) communications standard is accelerating worldwide as one countermeasure to the explosive growth in the volume of mobile data traffic resulting from the widespread adoption of smartphones by mobile subscribers. However, existing 2G and 3G GSM, W-CDMA, CDMA2000, and TD-SCDMA mobiles are still in use and are being developed further worldwide as 3.5G systems. Consequently, we have developed the MT8820C to seamlessly support all 2G to 4G (LTE) mobile systems with easy RF and function tests using call processing as well as high-speed sequence measurement functions using coordinated operation between the mobile and MT8820C. This instrument has all the features required for both development and manufacturing of chipsets and mobiles. The following describes the design methods and details of the MT8820C functions.

Figure 1 MT8820C Radio Communication Analyzer

2 Development Concept

The 4G LTE mobile communications standard features a scalable frequency bandwidth, high-order modulation methods such as 64QAM, Orthogonal Frequency Domain Modulation (OFDM), and multiple antenna technology (MIMO) to achieve flexible operation at different frequencies as well as high frequency usage efficiency. However, in the early deployment stages, it must also be able to operate side-by-side with existing older technologies. We developed the MT8820C based on the following concepts while taking the above into consideration.

- Support latest mobile standards based on experience of MT8820B supporting 2G to 3.5G standards to offer seamless support for 2G to 4G (LTE) systems.
- Develop LTE signalling unit based on world-leading MD8430A LTE Signalling Tester.
- As well as supporting 3GPP TS36.521-1 LTE TRx tests, use call processing functions to support high-speed frequency handover, call processing at changing mobile conditions, paging, CS Fallback, etc.
- As well as supporting both FDD and TDD duplexing methods in the LTE-defined frequency range from 1.4 MHz to 20 MHz, support out-of-band measurements such as Adjacent Channel Leakage Power Ratio (ACLR) by measuring three times carrier frequency range (about 70 MHz).
- Support new 3.8 GHz band.
- Support Downlink 2 × 2 MIMO using MT8820C ParallelPhone measurement function.

- Support any IP data transfers on LTE bearer with support for Category-4 mobile peaks rated at 150 Mbps in combination with above-described Downlink 2 × 2 MIMO function.
- Support high-speed sequence measurement using coordinated operation with mobile terminal.
- Reduce hardware footprint by reducing parts count and increase hardware reliability by substituting electronics for mechanical relays.

3 Hardware System Design

3.1 Main Frame Hardware

We developed the main frame hardware to meet the above-described development concepts. The MT8820C main frame cabinet dimensions are the same as the MT8820B (1MW, 5U, 498D) to maintain backwards rack mounting and stacking capabilities. The MT8820B hardware options supporting 2G to 3.5G can all be installed simultaneously in the MT8820C along with up to two of the newly developed LTE Signalling Units (see section 3.2). Figure 2 shows the internal arrangement of the MT8820C main frame; Since the RF unit has been made thinner than the older designs, (see section 3.1.1), there is adequate space for installing the LTE Signalling Units.

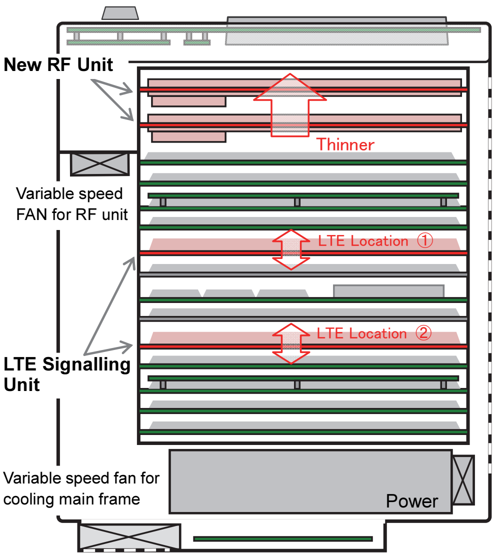

Figure 2 MT8820C Internal Arrangement

Since the internal temperature is expected to increase as a result of adding the LTE Signalling Units, the MT8820C uses a variable-speed fan with better noise performance characteristics to improve heat ventilation. At low to normal ambient temperatures, this new fan turns more slowly than the previous fan design, but speeds up as the internal temperature increases. The variable-speed control makes the MT8820C about 6 dB (@1 kHz) quieter than the MT8820B when operating in low to normal ambient tem-perature environments and assures 20% greater airflows in hot environments, achieving both low noise operation and high heat-radiation efficiency.

3.1.1 Thin, High-Reliability RF Unit

The RF unit in the MT8820C supports all LTE frequencies; in addition to frequencies up to 2.7 GHz supported by the MT8820B, it has an extended Local Oscillator (LO) oscillation frequency and supports the new 3.4 GHz to 3.8 GHz band by substituting new high-frequency parts in the signal circuits. In addition, a new design for the wideband signal processing route supports LTE signal reception up to the 20-MHz band. Moreover, the new thinner design offers higher reliability. The structure of the new RF unit is shown in Figure 3.

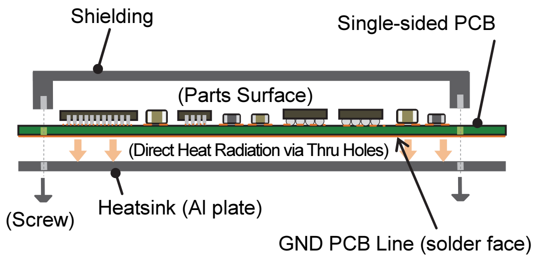

Figure 3 Structure of RF Unit

The RF circuit uses a new direct conversion circuit for the TRx paths and circuit optimization to shrink the unit from a 50-mm thick board to a single-sided 25-mm thick board. In addition, the back side of the board is constructed with an Al-plate heat sink in contact with the PCB ground plane to improve heat radiation; heat generated by the RF circuit is radiated directly from the PCB via through holes to achieve near-perfect heat radiation. In addition, the legacy mechanical attenuators (ATT) used previously have been replaced completely by electronic attenuators. These measures have improved the RF unit reliability by an order of magnitude.

3.1.2 Arbitrary Waveform Generator

Incorporating a new arbitrary waveform generation function in the MT8820C supports low-cost configuration of a non-signalling test environment without call connections or use of a signalling unit.

3.1.3 Temperature Change Band Calibration Function

The MT8820 series uses a high-speed Band Calibration function to assure performance even when the ambient temperature changes. This has been taken a step further in the MT8820C, which monitors internal temperature variations continually to display a Calibration message when the change exceeds a set threshold. As a result, unnecessary Band Calibration is eliminated, helping cut mobile terminal test times.

3.2 LTE Signalling Unit

At LTE mobile terminal testing, the mobile must be in the communicating state. The LTE Signalling Unit simulates base station operations to put the mobile into the communications state. This unit has been developed based on the experience of the MD8430A Signalling Tester used worldwide for development of mobile terminals and chipsets to assure reliable call processing and shorten the development cycle.

3.2.1 Size Reduction

Development of this unit required a huge size reduction in comparison to the MD8430A Signalling Tester. In addition to cutting the chip die surface area by using a next-generation FPGA, general-purpose parts were replaced by equivalent smaller parts to achieve a 66% footprint size reduction by also omitting long-term logging and redundant multiple base station processing functions. Figure 4 shows the block diagram of this unit.

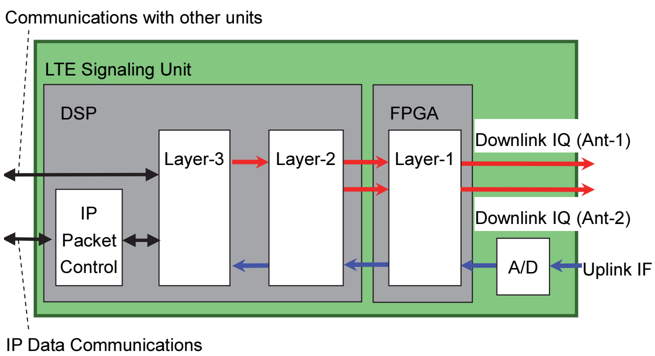

Figure 4 LTE Signalling Unit Block Diagram

3.2.2 Function Portability

Development of signalling supporting the latest mobile terminal standards was performed using the MD8430A Signalling Tester. This unit assures easy and flexible support for the latest changes to the LTE standards so an important part of the design process was assuring portability of functions from the MD8430A. As a result, the latest MD8430A functions can be implemented quickly by the MT8820C. Although the MT8820C and MD8430A LTE Signalling Units use different devices and physical configurations, the impact has been minimized; the FPGA is designed with the same interface and connection between devices only requires modification of the software interface functions. As a result, the software compatibility is 99.7%, excluding the MT8820C new Layer-3 functions.

3.2.3 MIMO Support

The LTE MIMO technology uses multiple antennas to increase the data transmission capacity as well as improving signal transmission path reliability. Supporting MIMO requires independent signal generation for each antenna; one LTE Signalling Unit has a dual signal generation function to support Downlink 2 × 2 MIMO. At the same time, the single LTE Signalling Unit in the MT8820C has been designed so that the generated signal passes to two RF units enabling one MT8820C to support Downlink 2 × 2 MIMO.

3.2.4 Layer-3 Functions

The Layer-3 functions control the mobile terminal using the 3GPP TS36.508 call processing standards; in addition to handling position registration and call processing, the call processing function supports high-speed test condition switching as well as Downlink/Uplink Tx control, and power control to implement 3GPP TS36.521-1 defined mobile terminal TRx tests.

To support standalone call processing functions, a DSP in the MT8820C Signalling Unit integrates the Layer-3 functions handled by the external PC used by the MD8430A. Additionally, the user-defined scenarios used by the MD8430A to control test procedures have been eliminated in the MT8820C, which supports scenario-free control and standards-compliant RF and function tests simply by changing GUI parameters.

Various position registration conditions are supported in consideration of the various mobile terminal connections required for development, manufacturing and maintenance. For example, the position registration sequence requires flexible support for the authentication and security sequences, depending on the profile supported by the test Universal Subscriber Identification Module (USIM). The MT8820C Layer-3 function supports the authentication algorithm used by actual networks called the Milenage algorithm, as well as the Skip function of the authentication and security sequences to implement various connection conditions.

Moreover, when the LTE terminal establishes the Evolved Packet System (EPS) bearer with the IPv6 IP address, the network-side router handling the mobile terminal must perform address allocation by auto-configuring the IPv6 stateless address but since this function is incorporated in the IP layer of the DSP in the Signalling Unit, the MT8820C itself can connect to an IPv6 mobile terminal without using a router.

4 LTE Measurement Functions

4.1 TRx Tests

The MT8820C supports 3GPP TS36.521-1 defined LTE TRx tests based on the 3GPP TS36.508 defined call processing conditions. The following tables outline the tests supported by the MT8820C. The tests are performed at the three Low, Middle and High frequency bands normally supported by mobile terminals in line with the supported multiple frequency bandwidths (1.4 MHz, 5 MHz, and 20 MHz, etc.); frequency, bandwidth and test-item transitions are performed using handover to switch test conditions quickly under call control. Moreover, in addition to supporting both the LTE FDD and TDD duplexing methods, the convenience is enhanced by support for instantaneous switching between FDD and TDD. A Test Parameter function not only improves user operability but also lightens the workload of remote control software creation; one test condition is set at each step and Pass/Fail evaluation is performed for the measurement results. The Test Parameter function increases test efficiency by supporting batch measurements under the same conditions.

With high-speed switching of communications standards between the mobile terminal and MT8820C, CS Fallback (voice calls between LTE packet-switched networks and 2G and 3G circuit-switched networks) test items support mobile terminals supporting multiple communications standards. In addition, the same effect is achieved by the built-in Redirection function for 1xEV-DO of packet switched networks.

4.1.1 Tx Power Measurement

Table 1 lists the Tx Power Test items supported by the MT8820C.

The LTE standard separates the frequency resource into 180-kHz units called Resource Blocks (RBs) and allocates these resources dynamically using the network-side scheduler. Consequently, the number and position of the allocated RBs is changed with the UE Maximum Output Power and the test is performed under the following various conditions.

Table 1 Transmit Power Test Items

Items	Outline
UE Maximum Output Power	Sends command to increase Tx from MT8820C and measures max. Tx power of mobile.
Maximum Power Reduction(*)	MT8820C changes Uplink modulation method (QPSK, 16QAM) and RB allocation and measures above-described max. Tx power.
Configured UE Transmitted Output Power	Changes p-Max (max. power of mobile permitted by base station) notification for MT8820C and measures above-described max. Tx power.
Minimum Output Power	Sends command to decrease Tx from MT8820C and measures min. Tx power of mobile.
(*) Items defined by Additional are measured by changing the Network Signalling Value.	

4.1.2 Tx Time Mask Test

Table 2 lists the Tx Time Mask test items supported by the MT8820C.

Table 2 Tx Time Mask Test Items

Item	Outline
General ON/OFF Time Mask	MT8820C alternately schedules PUSCH On and Off and measures template.
PRACH Time Mask	MT8820C schedules RACH based on Non Contention at PDCCH Order and measures template.
SRS Time Mask	MT8820C schedules Sounding Reference Signal and measures template.

The LTE standard divides the time resource into 1-ms Transmit Time Intervals and allocates resources automatically with the network-side scheduler. The Tx Time Mask Test is important because the Tx signal at this time is a burst signal.

The PRACH Time Mask test is based on Non Contention using PDCCH Order, instead of using PRACH at mobile power-on. However, to measure On Power and Off Power at a high dynamic range, the signal is measured twice in the high range and low range and the Wide Dynamic Range measurement is displayed as a composite waveform. Figure 5 shows the General ON/OFF Time Mask measurement screen using Wide Dynamic Range.

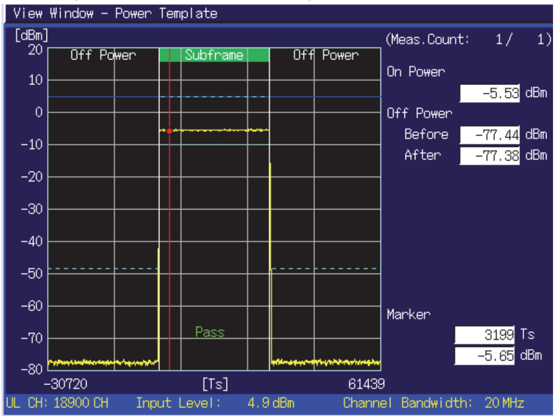

Figure 5 General ON/OFF Time Mask Measurement Result

The results for Figure 5 show an Off Power level of about –77 dBm for an input level of 4.9 dBm measured with a dynamic range of more than 80 dB at a bandwidth of 20 MHz.

4.1.3 Tx Power Control Test

Table 3 lists the Tx Power Control Test items supported by the MT8820C.

Table 3 Transmit Power Control Test Items

Item	Outline
Power Control Absolute Power Tolerance	MT8820C initializes and controls mobile power control to measure mobile initial power.
Power Control Relative Power Tolerance	MT8820C issues power control command and changes RB allocation to measure absolute value of mobile power changes.
Aggregate Power Tolerance	MT8820C mobile performs discontinuous scheduling for mobile to measure mobile power changes.

The LTE standard fine-controls the Tx power of the mobile terminal for each Transmit Time Interval using a power control command from the base station. As explained in section 4.1.1, scheduling the frequency resources dynamically increases and decreases the Tx power at this time in proportion to the number of allocated RBs. The Power Control Relative Power tolerance tests the power change during a continuous sequence. The MT8820C has a built-in Auto mode that automates the sequential test procedure to achieve the target power, etc. In addition, it also has the previously explained Wide Dynamic Range measurement function for measuring at a high dynamic range. The MT8820C design performs measurement processing using the FPGA to shorten measurement times. Figure 6 shows the Power Control Relative Power tolerance measurement screen at measurement in the Auto mode.

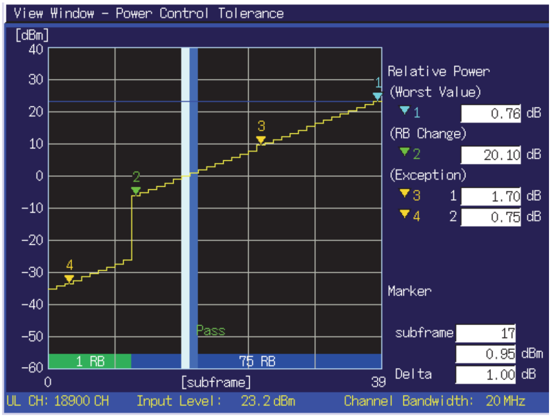

Figure 6 Power Control Relative Power Tolerance Measurement

Figure 6 shows the measurement results when increasing the mobile power in 1-dB steps and changing the number of RBs from 1 to 75 after 10 steps. This measurement can be achieved at one time using the Wide Dynamic Range measurement function in parallel with the Auto mode.

4.1.4 Tx Signal Quality Test

Table 4 lists Tx Signal Quality Test items supported by the MT8820C.

Table 4 Transmit Signal Quality Test Items

Item	Outline
Frequency Error	Sets Downlink to Rx sensitivity level and measures mobile frequency error.
Error Vector Magnitude (EVM)	Measures EVM for each of PUSCH, PUCCH, PRACH. For PUSCH EVM, measures under various conditions by changing Uplink power and RB allocation.
Carrier Leakage	Measures mobile carrier leak.
In-band Emissions for Non Allocated RBs	Measures spurious emissions for non-allocated RBs.
EVM Equalizer Spectrum Flatness	Measures in-band flatness when RB allocated completely in-band.
PUSCH-EVM with Exclusion Period	Changes RB scheduling at sub-frame timing to measure EVM when RB allocation changing.

As explained in section 4.1.1, the LTE standard evaluates the In-band emissions for non-allocated RBa and the EVM equalizer spectrum flatness after demodulation to dynamically schedule frequency resources.

LTE PUSCH evaluation requires the demodulation signal axis, the Demod symbol axis and the SC-FDMA symbol axis. The MT8820C displays two axes continuously on View windows to support seamless verification of error relatedness. Figure 7 shows the PUSCH-EVM with Exclusion period measurement screen.

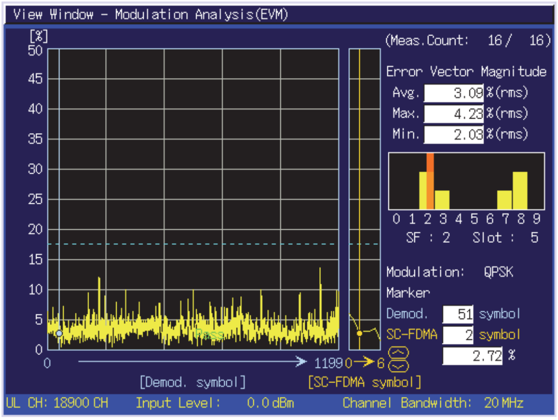

Figure 7 PUSCH-EVM with Exclusion Period Measurement

Figure 7 shows the measurement results for Slot 5 EVM with Demod. symbol 51 displayed on the SC-FDMA axis (screen center) and SC-FDMA symbol 2 displayed on the Demod. symbol axis (left side of screen).

4.1.5 Tx Spectrum Emission Test

Table 5 lists the Tx Spectrum Emission Test items supported by the MT8820C.

Table 5 Transmit Spectrum Emissions Test Items

Item	Outline
Occupied Bandwidth	Allocates all in-band RBs and measures bandwidth with 99% of total power.
Spectrum Emission Mask(*)	Measures carrier adjacent spurious with RBW defined for each segment.
Adjacent Channel Leakage Power Ratio	Measures adjacent channel leakage power for LTE band as well as W-CDMA or TD-SCDMA bands.
(*)Items defined by Additional are measured by changing the Network Signalling Value.	

In addition to the LTE Adjacent Channel Leakage Power, the LTE Adjacent Channel Leakage Power Ratio measurement also considers sharing with 3G mobile communications and measures the leakage power in the W-CDMA band for FDD, and in the TD-SCDMA band for TDD. To measure out-of-band spurious emissions, the MT8820C can also test up to the 70-MHz band.

4.1.6 Rx Test

Table 6 lists the Rx Test items supported by the MT8820C.

Table 6 Rx Test Items

Item	Outline
Reference Sensitivity Level	Sets Downlink to low level. QPSK modulation and low data rate (high coding rate) and evaluates mobile Rx performance as throughput.
Maximum Input Level	Sets Downlink to high level, 64QAM modulation and high data rate (low coding rate) and evaluates mobile Rx performance as throughput.

The LTE standard uses the best modulation method matching the mobile Rx conditions by selecting the optimum modulation and error correction encoding. In this test, the modulation and encoding rate are simulated for both good and bad Rx conditions. In addition, the LTE TRx test uses the MAC Padding Bit but not the Loopback Mode used by 3G mobiles. Consequently, the TRx test does not evaluate the bit error rate using Downlink signal loopback data but instead evaluates the MAC layer throughput calculated from the ACK, NACK, DTX Downlink detection data reported by the mobile.

4.1.7 General Functions

The measurement results can be evaluated at a glance using the various View windows shown in Figure 8.

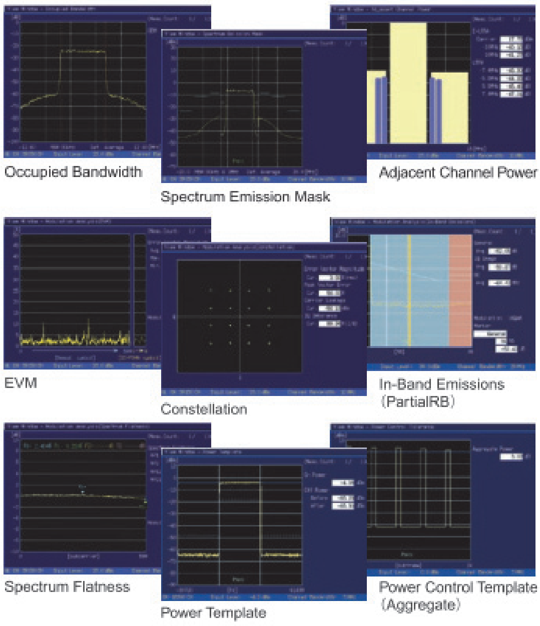

Figure 8 View Windows

To specify call processing verification and call control related bugs, the MT8820C has a built-in Signalling Trace Function for displaying signalling data about connection with the mobile. Figure 9 shows this Signalling Trace screen.

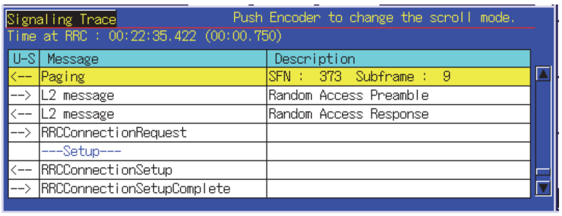

Figure 9 Signalling Trace Screen

4.2 Function Tests

This section explains non-TRx test functions and other unique functions of the MT8820C.

4.2.1 IP Data Transfer

At mobile TRx testing, the transferred data uses MAC Padding Bits created by the MAC layer. In addition, to perform mobile function tests in an environment closely mimicking a real usage environment, the MT8820C can simulate data communications between the mobile and server by selecting the IP Data Transfer option, which supports IPv6 and can perform data transfer tests using transfer rates up to 150 Mbps when used in combination with the MIMO option. Furthermore, the TDD Uplink and Downlink allocations can be changed using the TDD frame configuration; Downlink supports the configuration offering the maximum conditions, while TDD supports a maximum data transfer rate of 131 Mbps.

4.2.2 Current Consumption Test

The rapid spread of smartphones has increased the importance of the current consumption test, because battery life has a significant impact on mobile operation time. The MT8820C can set both the DRX (Discontinuous Reception) and Neighbor Cell Allocation significantly impacting mobile power consumption to test power consumption under various conditions. In addition, to perform tests under realistic conditions mimicking actual usage environments, the MT8820C supports the Dynamic (SR/BSR) Scheduling function that issues scheduling requests from the mobile under various IP data transfer conditions and performs auto-scheduling according to the buffer status reports.

4.2.3 Antenna Evaluation

Antenna evaluations are becoming increasingly important due to changes in mobile unit design and used frequency bands. The MT8820C presupposes use of an OTA (Over The Air) test environment for evaluating mobile antennas; it has a high Uplink Rx performance design as well as a Ro-bust Connection Mode for setting base station parameters preventing disconnection from the mobile side.

5 Sequence Measurement Functions

Mobile manufacturing requires short test times to help cut production costs. Test times have been shortened from standard RF measurements using call connection by using non-signalling measurements (method simulating call connection status in short time) but the focus in recent years has been on sequence measurements. Sequence measurements pre-program the mobile and measuring instrument with the measurement frequency and level as well as corresponding measurement items to perform batch measurements as a continuous sequence. This method is expected to offer advantages of much finer sequential control than previously possible as well as large cuts in test times. Figure 10 shows the concept of sequence measurement.

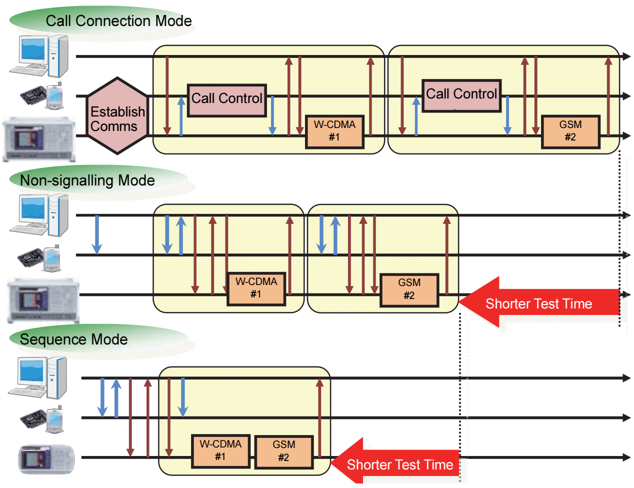

Figure 10 Sequence Measurement Outline

Execution of the sequence requires that both the measuring instrument and mobile have the sequence operation function. The latest mobiles have both high performance functions and hardware, and developments to support high-level test functions like sequence measurement are in progress. The MT8820C supports sequence measurements using the configuration described below.

5.1 Hardware

Sequence measurement software can be installed in the MT8820C main frame with LTE measurement hardware. The LTE measurement hardware is designed as a high-accuracy digital signal processing unit supporting LTE call processing functions with flexible sequence measurement functions.

5.2 Software

The sequence measurement software supports sequence measurements for the key mobile communications standards simply by selecting the target communications standards as parameters without needing to switch measurement applications, offering fast measurement of multi-standard mobile terminals. In addition, it incorporates a general-purpose Tx power measurement function and a signal generation function using sequence control to support fast adjustment of mobile TRx signals. The sequence measurement software is composed of the Tx and Rx test functions shown below.

5.3 Tx Tests

The sequence measurement software provides mobile test functions centered on Tx power. The measurement bandwidth and measurement period can be changed to support the different measurement standards. For example, installing the LTE measurement software supports sequence measurements of LTE FDD/TDD Uplink Tx power, carrier frequency, modulation accuracy, in-band emissions, occupied frequency band, spectrum emission mask, and adjacent channel leakage power.

5.4 Rx Tests

Mobile Rx tests supporting sequence measurement operation can evaluate the Rx performance with high efficiency using the optimum sequence operation at the mobile side without using the previous mobile loopback BER (Bit Error Rate) and BLER (Block Error Rate) measurements. The sequence measurement software has a built-in ARB (arbitrary waveform) signal generator for creating the signals required by the mobile Rx test. It supports the required specifications for the mobile communications standards.

6 Summary

We have developed the MT8820C Radio Communication Analyzer to support development and production of both next-generation LTE mobiles as well as existing 2G to 3.5G mobiles. The all-in-one MT8820C supports all the main mobile communications standards and can perform both RF performance tests using call processing as well as function tests. In addition, it also has a sequence measurement function for executing high-speed measurements using coordinated operation between the mobile and MT8820C. The MT8820C is the ideal test solution used by vendors worldwide for development and production of market-leading chipsets and mobiles. Anritsu has developed it as a flexible future-proof instrument for supporting future new developments in 3GPP standards and communications technologies.

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