Development of All-in-One Radio Communication Analyzer MT8821C supporting 2G, 3G and LTE-Advanced

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[Summary] LTE-Advanced, the latest development in Long Term Evolution (LTE) mobile communications systems is being deployed worldwide alongside LTE to support the urgent need for larger data transmission capacity in mobile networks. We have developed the all-in-one Radio Communications Analyzer MT8821C to support both of these new communications technologies as well as standards used by coexisting legacy GSM and W-CDMA (2G and 3.5G) systems. This article explains RF tests using call connection and other function tests supported by the MT8821C for development of UEs (User Equipments) and chipsets.

1 Introduction

To cope with the massive increase in data volumes resulting from the spread of smartphones and the Internet of Things (IoT), the Long Term Evolution (LTE) technology and its successor LTE-Advanced are being deployed increasingly worldwide. However, second (2G) and third generation (3G) mobile communications technologies, such as GSM, W-CDMA, CDMA2000, TD-SCDMA, as well as 3.5G technologies such as HSPA and EV-DO are still in widespread use. We have developed the Radio Communication Analyzer MT8821C to seamlessly support every mobile specification from 2G to LTE-Advanced. This analyzer supports easy RF tests of mobile devices by operating as a base station simulator to perform call connection. It also supports IP data transfer tests, current consumption tests, antenna tests in an Over The Air (OTA) environment, and other tests. Figure 1 shows the external appearance of the developed MT8821C, which we expect to play a key role in development of UEs and chipsets. The following sections describe the development concept and design details.

Figure 1 Radio Communication Analyzer MT8821C

2 Development Concept

LTE-Advanced is an evolution of the LTE wireless communications technology that offers faster speeds by aggregating multiple communications bandwidth called Component Carriers (CCs) using a technology called Carrier Aggregation (CA). In addition, it also uses a combination of special multiplex called MIMO and multilevel modulation called 256QAM which are other technologies to achieve transfer speeds of at least 1 Gbps. Moreover, LTE-Advanced maintains compatibility with existing mobile networks. Based on this, we developed the MT8821C design using the following concepts.

- To provide all-in-one support for transfer of IP data at 600 Mbps using 4CCs and 2×2 MIMO, incorporate 8 independent RF transmitters each with a Tx bandwidth of 160 MHz to ensure future expandability.
- As well as supporting all frequency allocation (Intra-band contiguous/non-contiguous, and Inter-band) for LTE-Advanced CA specified by 3GPP, add support for Joint CA with mixed FDD and TDD in aggregated CCs. In addition, increase the RX bandwidth to 160 MHz to enable Tx measurement of Intra-band contiguous using one measurement.
- To support LTE Advanced in Unlicensed Spectrum using unlicensed spectrum in the 5 GHz band as well as Licensed Assisted Access using LTE (LAA), increase the upper frequency limit to 6 GHz.
- To suppress complexity in the measurement system resulting from using more CCs, implement an internal front-end unit combining multiple CCs.
- Based on our wealth of experience in developing the MT8820C for 2G/3G/LTE mobile measurement and our

mastery of high-speed switching at call connection for tests using handover, offer full compatibility with 3GPP and 3GPP2-defined measurement functions and user remote-control tools.

- To protect investments in earlier MT8820C hardware and measurement software, offer an assured upgrade path.
- To simplify complex functions for measurement systems, offer an intuitive user interface based on touch-panel operations.

3 Hardware System Design

3.1 RF Unit

The frequency range of the RF unit has been expanded to 6 GHz to support all 3GPP-defined frequencies and LTE-U/LAA. In addition, the Tx and Rx frequency bands have been expanded to 160 MHz to support Intra-band contiguous CA. Moreover, support for 4CA 2×2 MIMO and 2CA 4×4 MIMO has been implemented by incorporating RF units for DL (Downlink)×8/UL (Uplink)×2. Incorporation of multiple RF units required 50% miniaturization which was achieved by circuit optimization using the direct conversion method and by high-density parts mounting using double-sided circuit boards.

3.2 Front-End Unit

LTE-Advanced features communications using multiple CCs and multiple signals must be combined at testing. To solve this problem, we developed a front-end unit capable of combining up to four CCs within the MT8821C. Using this unit eliminates the need for an external combiner and increases user convenience by ensuring instrument level accuracy including the combiner. As shown in Figure 2, this unit switches the DL signal output connector between Main1, Main2, and AUX (Auxiliary) while providing the same output functions at Main1 and Main2 to meet users' various test needs. From the design perspective, in addition to various other combining and switching functions, we also implemented an amplifier to prevent drops in output level at high-frequency bands and provide a fixed maximum output level irrespective of frequency; this was implemented in a compact package (160 × 160 × 20 mm), helping reduce the MT8821C size.

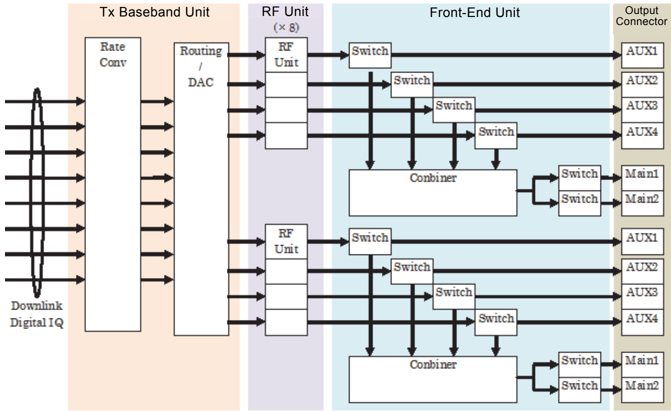

Figure 2 Tx Block Diagram

3.3 Tx Baseband Unit

The 3GPP Rel. 12 specification supports aggregation of up to 5 DL CCs with a total maximum bandwidth of 100 MHz. The Tx baseband unit uses a high-speed DA converter to achieve this and outputs a signal with a bandwidth of 160 MHz. To compensate for deviations in the in-band frequency characteristics caused by increasing the Tx frequency band, a calibration circuit has been implemented using the digital filter, which keeps the in-band frequency characteristics flat. Moreover, the bandwidth increases the digital signal sampling frequency as well as the digital signal transmission rate and a high-speed serial transmission path (over 3 Gbps) was implemented to transfer data using a small bus width.

3.4 Wideband Measurement Unit

The 3GPP Rel. 12 specification supports aggregation of up to two UL CCs. With Continuous CC sending two CCs on adjacent channels, the mobile Tx signal bandwidth is 40 MHz, or twice that of conventional LTE. A frequency of around 130 MHz is required for this spectrum analysis.

The wideband measurement unit in the MT8821C uses the measurement algorithms from its predecessor MT8820C and has a maximum RBW of 160 MHz covering the frequency bandwidth required by LTE-Advanced. Since the MT8821C flatness in the Rx band cannot be ignored, an in-band calibration circuit using a digital filter has been included. In addition, filtering and sampling-rate conversion circuits have been included to provide the optimum bandwidth for each 2G and 3G Tx measurement.

Due to the enormous amount of data per unit time at wideband signal processing, processing in software takes considerable time. Consequently, the signal analysis software in the wideband measurement unit uses a parallel-processing measurement algorithm which implements high-speed measurement processing using the CPU computation functions. For example, modulation analysis processing of an LTE Tx signal (20-MHz channel bandwidth) by the MT8821C requires just 90 ms compared to the 600-ms measurement time of the MT8820C. Figure 3 shows the block diagram of the wideband measurement unit.

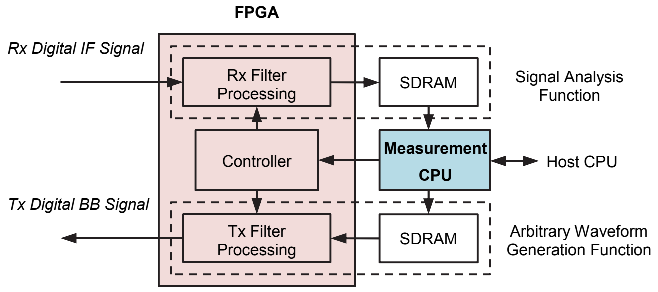

Figure 3 Wideband Measurement Unit Block Diagram

3.5 CPU Unit

To offer the best working conditions, the MT8821C uses one of the latest high-performance CPUs as the host processor as well as high-speed SSD for storage. A large 12.1-inch high-resolution LCD is used for the display coupled with a projection-type capacitive touch panel supporting familiar easy-to-use operability like commonly used mobile phones and tablets. The LCD and touch panel use a resin bonding as shown in Figure 4 for both better visibility and more precise touch operations when viewing the screen at a high angle.

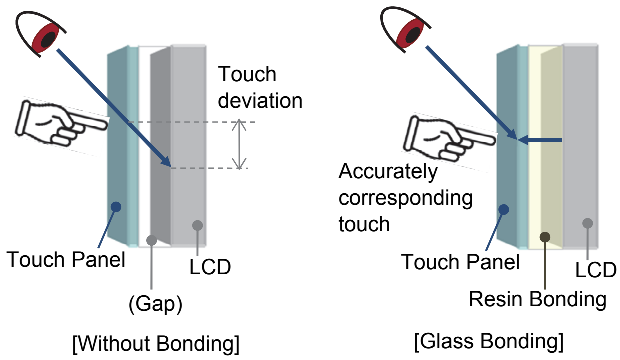

Figure 4 Glass Bonding Effect

3.6 Main Unit Hardware Design

To ensure full compatibility between the new MT8821C and its predecessor MT8820C, the MT8820C signalling unit has been used unchanged in the MT8821C. However, the RF units have been miniaturized (see section 3.1) to facilitate incorporation of up to 8 RF units. Consequently, despite including these 8 RF units and two new front-end units to provide the same functionality as four MT8820C units, the MT8821C is only 8 cm deeper than the MT8820C. Figure 5 shows the internal layout of the MT8821C.

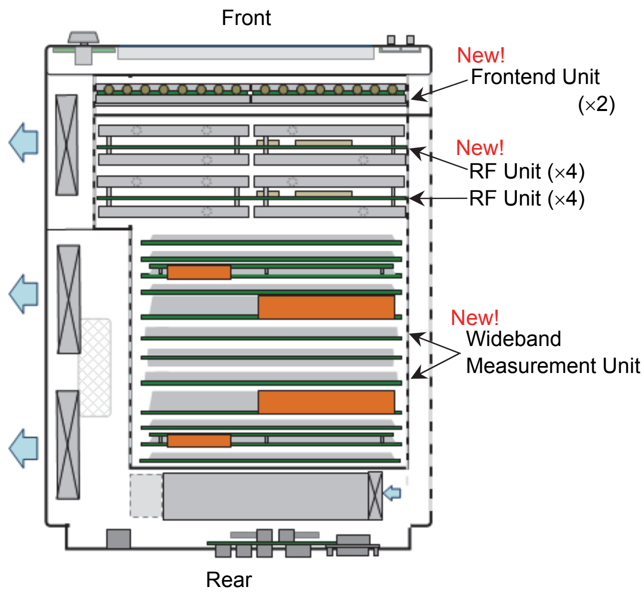

Figure 5 MT8821C Internal Layout

To achieve high board density in a compact space, the cooling system uses a lateral-ventilation design, assuring good cooling efficiency and quiet operation. Additionally, fan control is divided between the RF and digital units to ensure optimum and responsive operation of each fan, keeping the internal temperature constant.

4 LTE-Advanced Design

4.1 LTE-Advanced Carrier Aggregation

4.1.1 LTE Technology Trend

LTE-Advanced aims to increase transmissions speeds using CA and MIMO technologies. In addition, there are also proposals to use the unlicensed band above 5 GHz now being used by W-LAN (wireless Local Area Networks) for LTE. CA offers a method of increasing transmission speeds without needing to acquire bandwidth in the existing 800 and 2-GHz bands. Previously, CA only permitted use of CCs with the same frame structure but Joint CA supporting mixed FDD and TDD CCs is supported since 3GPP Rel. 12. Using this new technology, network operators can flexibly combine their existing FDD and TDD frequency bands to increase data transmission speeds for users. The MT8821C LTE measurement software has added functions for supporting the above-described technology trends and testing needs.

4.1.2 MT8821C LTE-Advanced Design Concept

The MT8821C measurement software is fully compatible with the MT8820C LTE measurement functions, and also supports the new CA and MIMO, etc., technologies. We designed the LTE signalling unit software as follows based on the above-described trends.

- To provide full compatibility with LTE signalling and measurement functions, use the MT8820C signalling unit.
- Expand number of processed CCs from 1CC to 2CCs using one signalling unit.
- Support 4CCs with one MT8821C using two signalling units each processing up to 2CCs.

4.1.3 LTE DL 4CCs

As shown in Figure 6, processing of LTE DL 4CCs is implemented using two LTE signalling units. The DL scheduling data for all CCs is captured by cooperative operation of both units and the HARQ-ACK bit count sent from the UE is calculated; the DL throughput for 4CCs is calculated based on the HARQ-ACK feedback from the UE.

Additionally, the IP data throughput test uses the two LTE signalling units; the two Default EPS and Dedicated EPS bearers are established between the UE and Network sides and the path of the User Plane for the unit operating as the SCC functions as the Dedicated EPS Bearer to implement IP data throughput tests for 3CCs and 4CCs.

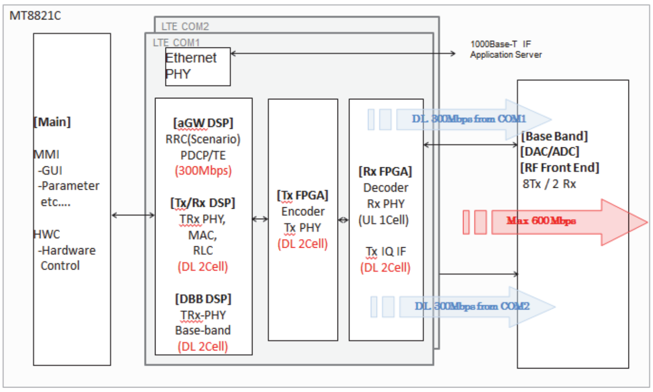

Figure 6 Two-Board Configuration Block Diagram

4.1.4 FDD-TDD Joint CA

3GPP Rel. 12 defines the FDD-TDD Joint CA standard mixing FDD and TDD CCs. The MT8821C combines the CC configuration between two signalling units to support all FDD-TDD 3DL CA combinations.

4.1.5 LTE-U/LAA

The MT8821C signalling functions also support LTE-E/LAA and LTE-U/LAA Rx tests using call connection. Interference from W-LAN is suppressed using Carrier Sensing Adaptive Transmission (CSA) and (LTE-U Discovery Signal) functions offering DL Tx control for LTE-U/LAA cells. As well as supporting special DL scheduling functions like those described above, the MT8821C also supports additional LTE-U/LAA test requirements.

4.1.6 CA Handover Function

3GPP TS36.521-1 describes test cases for performing TRx tests by switching the PCC (Primary CC)/SCC (Secondary CC) frequency channels. The test procedure is extremely complex when changing the parameters for each CC for each test condition. Consequently, we have implemented support for a swap handover function that performs PCC/SC switching in one go. This plays a key role in reducing users' test man hours and also greatly simplifies the test environment.

The handover procedure automatically controls the optimum DL output level and Rx reference level at handover and performs internal control so that the SCC output level does not cause signalling interference to ensure the same stability at handover as acquired at LTE testing.

4.1.7 Future Expandability

The MT8821C supports higher throughput using more CCs and more MIMO antennas. The current 3GPP Rel. 12 specification also provides future support for up to 12 CCs and DL 5CCs. The MT8821C supports all band combinations ranging from 5CCs Contiguous CA to inter-band CA. With respect to DL MIMO, not only does it support 4×4 MIMO, but it also supports Transmission Mode 9 based on the trending beamforming Tx mode for future MIMO TX technology, supporting the expanding OTA test market.

4.2 IP Throughput Design

The MT8821C is a Windows-based system; a built-in application server supports all in one IP data throughput evaluations, eliminating the need for an external server PC. In addition, built-in iperf LTE measurement application software supports throughput evaluation for the IP layer and iperf tests can be run from the user interface and by remote control.

4.3 Tx Measurement

Like its predecessor MT8820C, as well as supporting previous LTE Tx measurements defined in 3GPP TS 36.521-1, the MT8821C also supports UL CA defined in 3GPP Rel. 12.

4.3.1 UL CA Measurement Implementation

Generally, the CA frequency allocation is divided into three CCs as shown below. Figure 7 explains the use of the three CCs.

[1] Intra-band Contiguous CCs
Scenario performing communications using contiguous carriers (PCC and SCC (a)) in the same frequency band

[2] Intra-band non-Contiguous CCs
Scenario performing communications using multiple carriers (PCC and SCC (b)) in the same frequency band

[3] Inter-band non-Contiguous CCs
Scenario performing communications using multiple carriers (PCC and SCC (c)) in different frequency bands

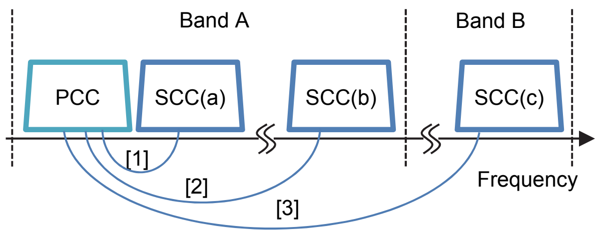

Figure 7 CC Frequency Allocation

Of these three scenarios, scenario [1] requires signal analysis is required because PCC and SCC are alternately adjacent. With an assured maximum resolution bandwidth of 160 MHz, the MT8821C can receive PCC and SCC simultaneously, as well as measure Tx power and TRx signal quality, and perform spectrum analysis simultaneously at a high measurement speed of 350 ms.

Additionally, for scenarios [2] and [3], two UL signals can be measured independently at one Rx port using the fast automatic control of the Rx in the MT8821C.

Furthermore, based on the frequency relationship between PCC and SCC, the MT8821C can perform measurements by automatically distinguishing whether the target UL signal is Contiguous or non-Contiguous, increasing user convenience. The following sections explain the details of required LTE-Advanced TRx measurements.

4.3.2 Tx Power Measurement

Specifications for measuring Tx power differ according to the CC frequency allocation. In scenario [1], the Tx Power is defined as the total power of two UL signals and as the Tx power of each of PCC and SCC; under other conditions, it is defined as only the Tx power of each PCC and SCC. The MT8821C displays all measurement results for each of these test conditions as a whole.

4.3.3 Tx Power Control Measurement

For scenario [1], 3GPP Rel. 12 specifies a new SCC power increase/decrease test for controlled measurement of Tx Power. In the SCC power increase test, as shown in Figure 8, the PCC RB (Resource Block) is fixed and the Tx power is standardized after changing the SCC RB from 1 to 8; processing is repeated by returning RB to 1 again and then changing to 8 and the test continues repeatedly until the Tx power level finally reaches the specified value. The difference in the Tx Power for each of the steps is measured as the Relative Power for evaluation against the standard.

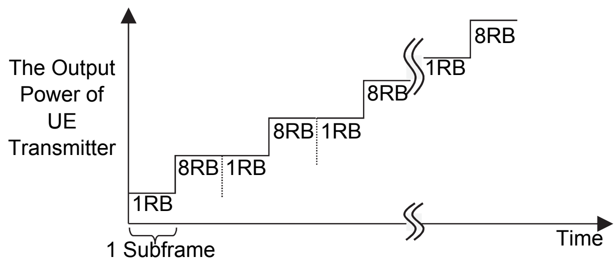

Figure 8 SCC Power Increase Test Outline

Conversely, in the SCC power decrease test, the SCC RB is change from 8 to 1 and the test is performed using the same procedure.

4.3.4 Spectrum Measurement

The Occupied Bandwidth (OBW), spurious and adjacent channel leakage power measurements have different measurement standards depending on the CC frequency allocation. For scenario [1], measurement is specified as the total for the two UL signals; for the other scenarios, it is specified separately for each of the PCC and SCC signals. With its wide resolution bandwidth, the MT8821C can perform total measurement in one go, and it also performs separate Rx frequency measurements using high-speed automatic control; Figure 9 shows an example of these measurement results.

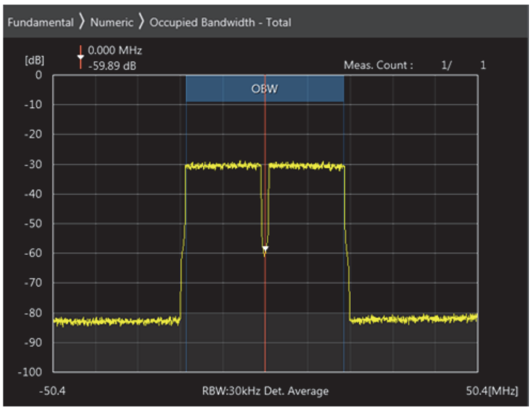

Figure 9 20 MHz + 20 MHz (FullRB) OBW Measurement Results

4.3.5 Modulation Analysis

Modulation analysis measurement is specified separately for each PCC and SCC UL signal irrespective of the CA frequency allocation. This measurement requires consideration of carrier leak locations caused by the UE configuration. For scenario [1], PCC and SCC may be output from one Tx ((1) in Figure 10), or each CC may be output separately from each Tx ((2) in Figure 10). The test contents of the in-band emission and carrier-leak measurements are different, depending on these conditions.

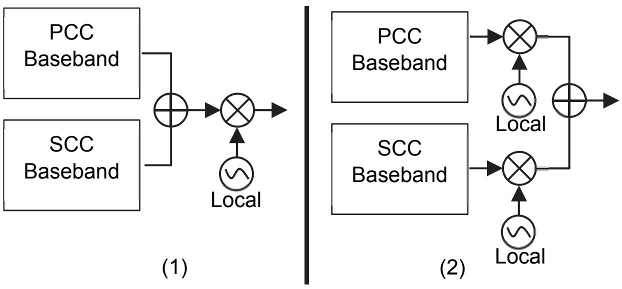

Figure 10 UL CA Frequency Allocation [1] Mobile Tx Configuration

In the case of Figure 10 (1), there is just one PCC/SCC carrier leak as shown in Figure 11 and consequently, at in-band emission measurement, each section for General, Carrier Leak, and IQ-Image is set across both the PCC and SCC bands. Figure 12 shows the measurement results.

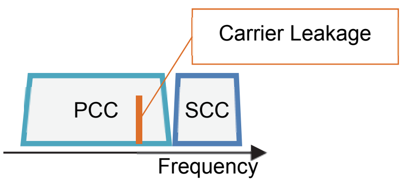

Figure 11 Carrier Leak Measurement Conditions at Output of PCC and SCC from One Transmitter

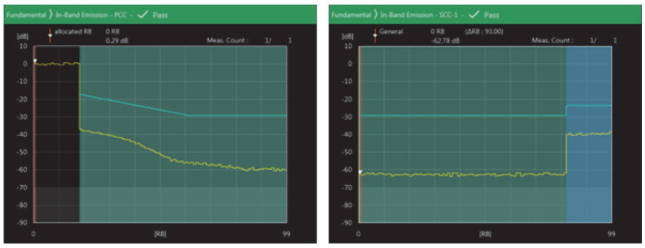

Figure 12 In-band Measurement Results at Output of PCC and SCC from One Transmitter

However, in the case of Figure 10 (2), as shown in Figure 13, there is separate carrier leak for each CC of both the PCC and SCC. As a result, at in-band emission measurement, the General, Carrier Leak, and IQ-Image are evaluated for each CC. Figure 14 shows the measurement results.

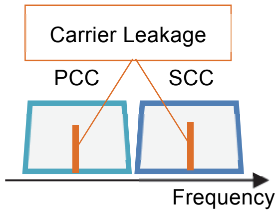

Figure 13 Carrier Leak Measurement Conditions at Output of Each CC from Each Transmitter

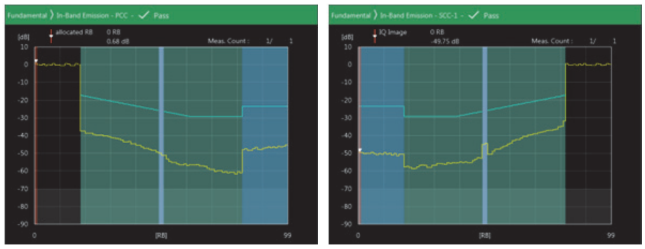

Figure 14 In-band Measurement Results at Output of Each CC from Each Transmitter

4.4 Rx Measurements

At DL 2CCs Rx tests, only the scenario [3] maximum input level and SCC are specified; for other Rx tests, the maximum input level is specified independently for each DL signal irrespective of the CA frequency allocation.

In addition to displaying the results for each standard as a whole, the MT8821C also supports CA tests higher than DL 3CCs as well as FDD-TDD Joint CA Rx tests and Rx measurements for various CA band combinations. Moreover, the newly developed RF front-end unit supports tests using simpler measurement systems even for standards with more CCs.

4.5 VoLTE Echoback Test

The first LTE UEs implemented voice communications by circuit switching using the 3G communications network. With the spread of LTE networks, the Voice over LTE (VoLTE) technology performing voice communications using the LTE IP network has become commonplace. The MT8821C supports all VoLTE UE function tests and VoLTE Echoback tests.

VoLTE tests require an IMS server supporting call connection functions using IP Multimedia Subsystem (IMS) Registration and Session Initiation Protocol (SIP) at UE location registration. With a built-in IMS server developed from the MD8475A Signalling Tester IMS server application, the MT8821C offers all-in-one support for VoLTE Echoback tests.

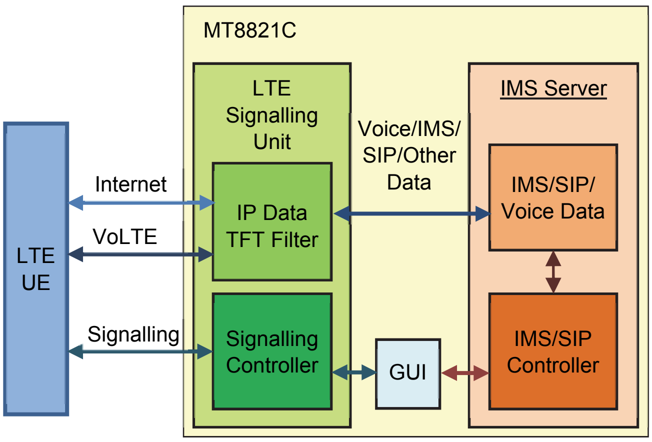

Figure 15 Integration with Built-in IMS Server Application

In addition, to support the VoLTE current consumption test, not only is Echoback performed repeatedly for data and voice, but also fixed-pattern signals can be tested by controlling both the Uplink and Downlink without voice signals.

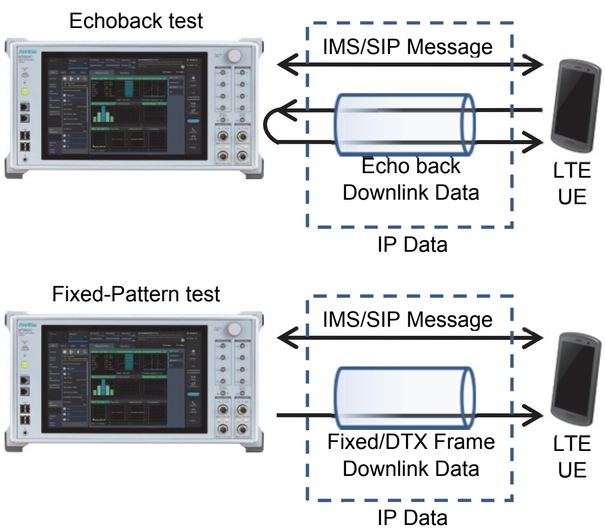

Figure 16 VoLTE Test

5 Platform Design

5.1 Compatibility

Like its predecessor MT8820C, the MT8821C supports 2G and 3G TRx measurements. As well as compatible measurement software, the MT8821C uses the same signalling unit as the MT8820C. As a result, the MT8820C hardware can be reused. Additionally, it is possible to upgrade from the MT8820C (including software) to the MT8821C at minimum cost, helping MT8820C users protect their prior investment. Though software platform is changed to Windows, measurement software changes are kept to a minimum, and this approach maintains a quality of all measurement and signalling functions.

5.2 User Interface Design

The user interface is operated intuitively via a large LCD screen and touch panel as well as an encoder for finer control than offered by touch panels. Figure 17 shows the MT8821C main screen.

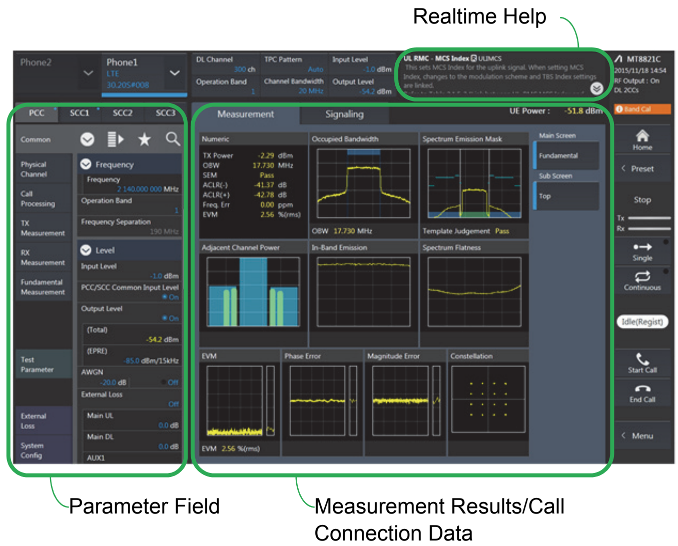

Figure 17 MT8821C Main Screen

A unified parameter entry field at the left side of the screen facilitates input of various parameters (base station parameters, measurement parameters, instrument fixed parameters) for intuitive operation even for first-time users using shared procedures.

The measurement results and call connection information are displayed using tab screens on the right side for seamless screen transitions from list to individual screens.

Displaying parameters on the left and results on the right cuts screen switching by displaying all information simultaneously and assists setting changes while confirming results. In addition, both help and remote control commands are displayed in real-time, enabling confirmation of the manual, detailed confirmation of each setting parameter, and creation of remote control programs.

Figures 18 to 21 show the screen features.

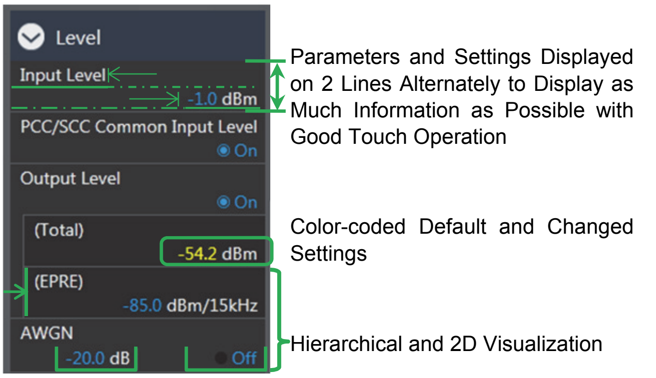

Figure 18 Parameter Section Integrating Information with Touch Fields

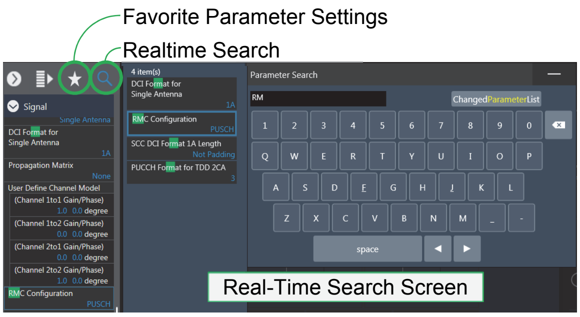

Figure 19 Favorite Real-time Parameter Search Function

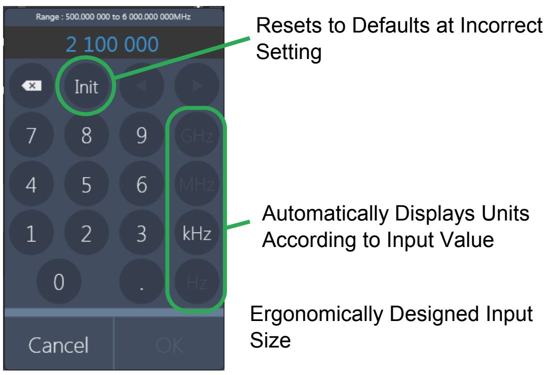

Figure 20 Time-Saving Parameter Entry Fields

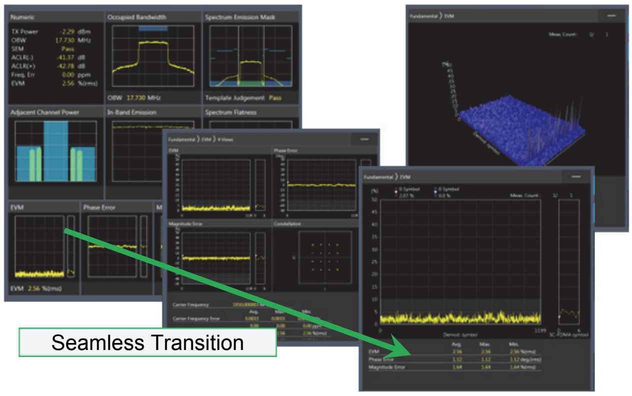

Figure 21 At-a-Glance Seamless Results Screen Transitions

6 Summary

We have developed the Radio Communication Analyzer MT8821C to play a key role in development of UEs and chipsets supporting deployment of the latest LTE-Advanced networks as well as Legacy 2G to 3.9G systems. The MT8821C provides all-in-one support for the main mobile communication standards with RF tests using call connection as well as other function tests. It is used by many vendors to develop the latest EUs and chipsets. Anritsu hopes it will play a key role in assisting future development of new mobile technologies such as future 3GPP standards and 5G mobile communications systems.

References

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2) 3GPP TS36.521-1
"Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: Conformance testing"

3) 3GPP TS36.508
"Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); Common test environments for User Equipment (UE) conformance testing"

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