Development of MT8000A Base Station Manufacturing Solution for 5G NR Mobile Communications (sub-6 GHz/mmWave)

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[Summary] Base station (BTS) vendors are configuring high-volume mass-production lines for the 5G wireless infrastructure market and require all-in-one expandable test instruments for BTS TRx tests. In addition, deployment of multi-antenna BTS is driving demand for multiport testers facilitating parallel measurement. To meet these requirements for testers supporting 5G BTS manufacturing, Anritsu has released the modular, all-in-one Radio Communication Test Station MT8000A with up to four ports for both independent and simultaneous measurement on BTS production lines for BTS testing covering macro to small cells using the sub-6 GHz to mmWave frequency bands.

1 Introduction

Following the 2019 start of the world's first commercial 5G mobile services, the market for 5G wireless infrastructure is continuing to grow and there are high expectations for further development driven by wireless network open standards, including expansion into the IoT field, and base stations (BTS). With implementation of open standards, large BTS vendors targeting development and production of conventional wireless infrastructure now face increasingly severe competition in winning market share due to the new market entrants. In addition, the growing spread of 5G coverage, especially into crowded indoor environments, such as shopping malls and sports venues, requires dense deployment of small cells using many BTS to achieve fast data rates for multiple users (MU), which is increasing demand for small, low-cost BTS.

This increased demand for BTS manufacturing caused by the spread of 5G services coupled with cost reductions and rising competition is driving BTS vendors to configure dense, high-capacity, BTS production lines. Base-station manufacturing uses a combination of conventional benchtop signal analyzers (SA) and signal generators (SG) as well as all-in-one testers for BTS TRx tests. However, supporting the sub-6 GHz/mmWave frequency bands and multiple antennas used by 5G is increasing demand for parallel measurement using multi-port test equipment.

To meet market demand for all-in-one test equipment for manufacturing 5G BTS, we have developed the additional Base Station Test Suite for NR sub-6 GHz MX800046A and Base Station Test Suite for NR mmWave MX800045A supporting sub-6 GHz/mmWave modules installed in the Radio Communication Test Station MT8000A released in 2018 for testing 5G UE. The key feature of this development is support for both independent and simultaneous measurement at 4 ports, which cuts test times on BTS production lines for higher test efficiency to satisfy production throughput requirements. Figure 1 shows the external appearance of the MT8000A.

Figure 1 MT8000A Front Panel

2 Design Concept

The design concept described below focused on developing a modular type all-in-one tester to implement the sub-6 GHz/mmWave TRx tests required to manufacture 5G NR BTS while maintaining compatibility with previously released benchtop test equipment.

(1) Compatibility with Current SA/SG

Development was advanced by bearing in mind how to cut equipment upgrade costs by assuring remote-command compatibility between the MX800045A/MX800046A and the Signal Analyzer MS2850A (5G Standard Measurement Software MX285051A/MX269051A) and the Vector Signal Generator MG3710A/E.

(2) Support for sub-6 GHz/mmWave BTS TRx tests

This development aimed to support frequency measurements in the 0.4 to 6 GHz band as well as measurements in the 24.25 to 29.5 GHz and 37 to 43.5 GHz bands using the RF MT8000A-020/021 option and Multiband RF Converter MA80003A, respectively, installed in the MT8000A. The required application software can be selected from the Base Station Test Suite for NR sub-6 GHz MX800046A and the Base Station Test Suite for NR mmWave MX800045A.

(3) 4-port Independent and Simultaneous Measurement

The 4-port independent measurement function is used to perform separate TRx tests at each port as well as to separately measure different frequency bands. Each TRx port installed in the several slots of MT8000A can function as an independent test instrument. So up to 4 ports are operated independently.

The 4-port simultaneous measurement function is used when simultaneously sending and receiving signals to test a multi-antenna (MIMO) DUT. It is used to evaluate degraded waveforms caused by leak signals (crosstalk) between antennas as well as time alignment error between antennas.

As a result, this function helps cut costs to configure a BTS production line, and production times of BTSs.

(4) MT8000A SoC (System on Chip) and PC Application

During production, manufacturers perform measurement and parameters calibration across the device full operation range to correct out-of-specification values followed by post-calibration verification to confirm operation. Calibration tests the Tx performance using a CW signal and measures the narrowband signal power. Verification measures the wideband signal using the actual modulation signal to evaluate the Tx performance.

This development shortens measurement times using analysis with the fast MT8000A internal System-on-Chip (SoC) for narrowband tests coupled with a fast control PC for wideband tests.

3 Key Design Points

This section explains the key design points. First, we explain the structure of the MT8000A and the internal module configuration. Second, an outline of MX800045A/MX800046A. At last, an introduction of the MX800045A/MX800046A functions.

3.1 MT8000A

The MT8000A has the modular architecture (shown in Figure 2) targeted at testing 5G NR UE[1)].

The Control Module MT8000A-001 (Figure 2 top right) controls installed modules in MT8000A.

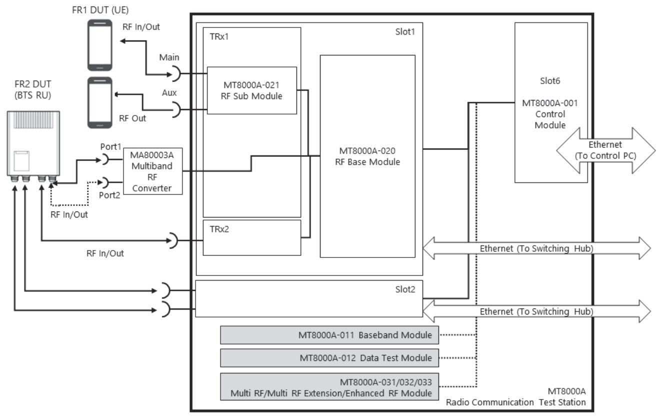

Figure 2 MT8000A Module Configuration and Test System

Users can select which modules to install in the MT8000A abased on their requirement of test items. Table 1 lists available Anritsu modules.

Table 1 Key MT8000A Modules

Model	Name
MT8000A-001	Control Module
MT8000A-009	Multi-box Data Connection
MT8000A-011	Baseband Module
MT8000A-012	Data Test Module
MT8000A-020	RF Base Module
MT8000A-021	0.4 GHz – 6 GHz RF Sub Module
MT8000A-022	3 GHz – 12 GHz RF Sub Module
MT8000A-023	Extend RF 2.4 GHz – 3 GHz
MT8000A-024	Extend RF 6 GHz – 7.125 GHz
MT8000A-031	0.4 GHz – 6 GHz Multi RF Module
MT8000A-032	0.4 GHz – 6 GHz Multi RF Extension
MT8000A-033	0.4 GHz – 7.125 GHz Enhanced RF Module

Users can use those modules in combination to test various functions and performances in line with evolving communications standards. As an example, sub-6 GHz 2 × 2 MIMO RF measurements are supported by installing one RF Base Module and one 0.4 GHz – 6 GHz RF Sub Module in the MT8000A.

Adding the Multiband RF Converter MA80003A to the above configuration supports mmWave RF measurements.

Additionally, adding a chamber such as the RF Chamber MA8171A or CATR Anechoic Chamber MA8172A supports measurements in an over-the-air (OTA) test environment. The MT8000A main unit has no built-in screen but is controlled by the user from an external control PC by launching the Application Launcher software for switching to various test applications (Table 2) for conducting Protocol tests, RF TRx tests, etc.

Table 2 Key MT8000A Software

Model	Name	Application
MX800000A	Platform Software	Basic functions
MX800010A	NR TDD Measurement Software	UE RF TRx test, Call connection test, SAR (radiation exposure test)
MX800045A MX800046A	Base Station Test Suite for NR mmWave Base Station Test Suite for NR sub-6 GHz	BTS RF TRx test
MX800050A	Rapid Test Designer Platform (RTD)	Protocol test, Layer 1, 2, 3, Coding/Decoding
MX800060A	Control Software	Non-StandAlone (NSA) environment test coordinated with LTE Signalling Tester
MX800070A MX800078A MX800079A	SmartStudio NR LTE/NR Platform Software for SmartStudio NR Platform Software for SmartStudio	UE Call connection test, Throughput test, Voice call test, IMS test, VoLTE call test, Mobility test

3.2 MT8000A BTS Manufacturing Solution

3.2.1 Hardware Configuration

The MT8000A BTS manufacturing solution targets physical (PHY) layer tests. So, it includes the MT8000A-001/020 module in its configuration (Figure 3).

Note that MT8000A-021/MA80003A are indicated as TRx1/2 in Figure 3.

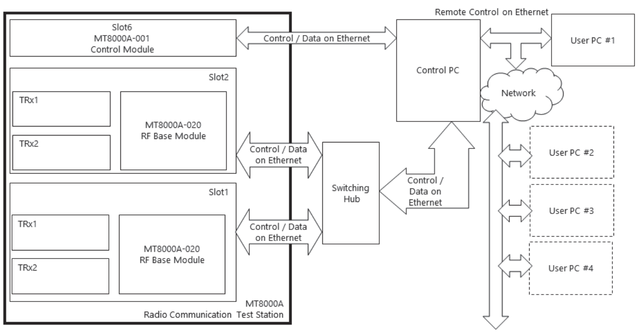

Figure 3 MT8000A BTS Manufacturing Solution Module Configuration and Setup Example

3.2.2 Software Configuration

The MT8000A is controlled in two ways (top-right two interfaces in Figure 4). One is the GUI in the MX800045A/MX800046A software running on the Control PC (Control PC in Figure 3). The other is the remote controlling from the users' PCs (User PC #1 thru #4 in Figure 3).

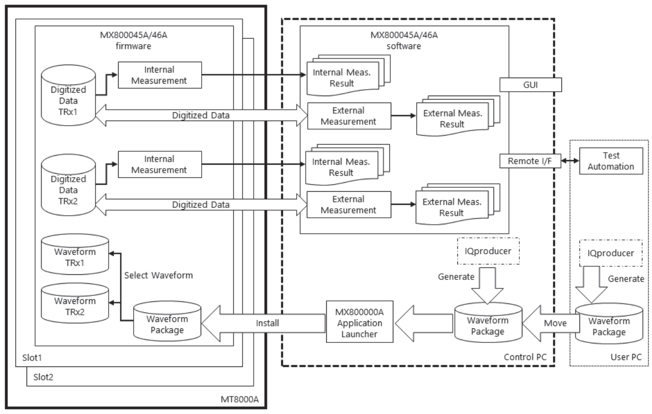

Figure 4 MT8000A BTS Manufacturing Solution Software Configuration and Data Flow

The MX800045A/MX800046A software is installed in the Control PC while the MX800045A/MX800046A firmware is installed in the MT8000A main unit.

In addition to providing the GUI, the MX800045A/MX800046A software on the control PC also runs the signal analysis function, called external analysis hereafter (Figure 4 center).

The MX800045A/MX800046A firmware controls the hardware and signal analysis using the MT8000A internal SoC, called internal analysis hereafter (Figure 4 left side).

Furthermore, the user can generate 5G NR waveform data for BTS Rx tests with the IQproducer software. Waveforms can be generated either at the control PC or on the user's PC (Figure 4 bottom).

The following sections explain the key design points according to the design concepts.

3.3 Independent/Simultaneous Measurement

As described in item (3) of section 2, the MX800045A/MX800046A software supports two types of measurement: Independent and Simultaneous.

Switching between these two measurements offers the following advantages to users.

(A) Independent measurement saves space by supporting up to four different measurements using one MT8000A.

(B) Simultaneous measurement supports Rx testing using multiple ports and antennas, such as MIMO and Carrier Aggregation (CA).

(C) Switching between independent and simultaneous measurement facilitates either SISO or MIMO tests according to the test target and optimizes infrastructure investment.

3.3.1 Independent Measurement of Each TRx Port

This section describes the design enabling regarding each MT8000A TRx port as an independent measurement instrument (SA or SG). Figure 5 shows a measurement example.

Implementing independent measurement faced the following challenges:

- Using one physical remote-control interface to control up to four TRx ports simultaneously (section 3.3.1.1)
- Preventing SG signal leak affecting SA test results (section 3.3.1.2)
- Supporting waveform selection and trigger operation at each TRx port (section 3.3.1.3, 3.3.1.4)

The solutions to each of these challenges are explained below.

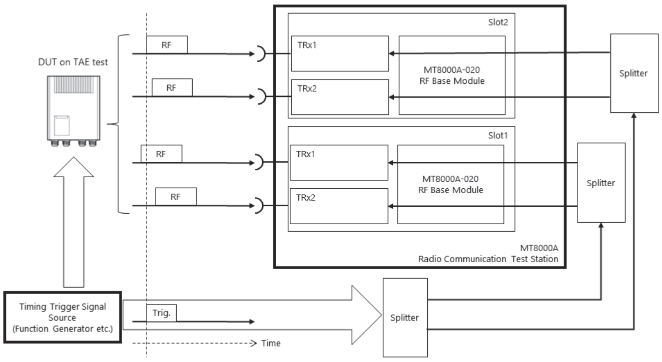

Figure 5 Independent Measurement Setup

3.3.1.1 Added Remote-Control Interface

Generally, exclusive control is used for the remote-control interface of measurement instrument. In other words, commands are received only from a single control PC to which measurement results, captured data, etc. are sent.

However, implementing simultaneous independent measurement using one physical remote-control interface for up to four TRx ports is challenging.

Namely, command and data communications must be implemented for each TRx port (four combinations of Slot1/2 and TRx1/2) via the control PC Ethernet port (the equivalent to MT8000A physical remote-control interface).

Consequently, the Application Launcher software has logical remote-control interfaces (Figure 6) corresponding to each TRx port (each combination of Slot1/2 and TRx1/2).

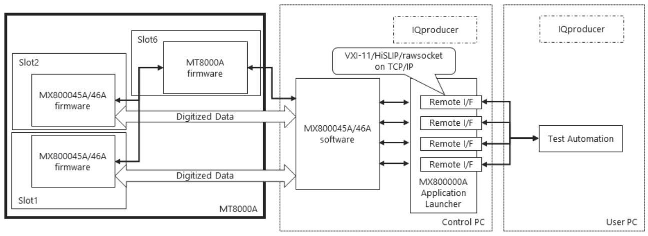

Figure 6 Remote Interface Design

As described above, using a Module Configuration with the most TRx ports, remote-control users can simultaneously use the four TRx ports in one MT8000A as a group of four independent test instruments (SA and SG). Figure 7 shows an example of controlling the MT8000A from four users' PCs.

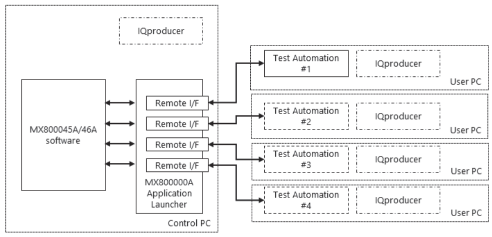

Figure 7 Remote Setup with Four User PCs

3.3.1.2 Arbitration

As part of the independent control, the user can select either the SA mode (signal analyzer function) or the SG mode (Signal generator function) for each TRx Port of the MT8000A.

However, there was a problem that the loopback output of the SG passes into the SA measurement due to the MT8000A hardware configuration when focusing on one TRx port.

The SG output degrades the electrical performance in the SA mode because it became spurious noise in the signal received by the SA.

Consequently, the MX800045A/MX800046A software implements arbitration processing to prevent the SG mode running during measurement in the SA mode, and to prevent the SA mode starting while the SG mode is running.

As a result, this arbitration prevents unexpected occurrence of spurious in the SA measurement, resulting from the SG output.

3.3.1.3 Added Dual ARB Function

A Dual ARB function was implemented to select and output arbitrary waveform at each TRx port. Consequently, each of the two TRx ports in the same slot can be operated as an independent SG, within a certain condition by its hardware.

3.3.1.4 Added SG Trigger and Waveform Restart Functions

Cellular systems require very precise clock synchronization between multiple BTS as well as between a BTS and a UE. The BTS synchronizes clocks using GPS signals, etc. and then distributes a reference signal to the UE.

Consequently, test equipment for BTS Rx tests must have 1 PPS signal accuracy equivalent to GPS and must operate synchronously with a Frame trigger signal supplied from the BTS.

The following two functions were added based on the above.

(A) SG Trigger function using an external trigger signal to instruct the MT8000A to begin to output of the inspection waveform as well as SG Trigger Delay function for adjusting the timing of the signal output relative to the external trigger.

(B) A Waveform Restart function to return the MT8000A to the trigger-waiting state again after once having output the inspection waveform using the external trigger signal.

3.3.2 Simplified Simultaneous Measurement using Trigger Signal

When performing Tx tests simultaneously for each antenna of the BTS, synchronizing the measurement start between the several pieces of test equipment requires use of splitters for the trigger signal wiring with the same electrical length. Additionally, the measurement-start trigger signal must be input at the prepared timing to each test instrument.

Consequently, in the simultaneous measurement mode, an external trigger signal to the Event Trigger Input connector #1 on the MT8000A back panel facilitates instructs all TRx ports to start measurements in the SA mode (Figure. 8).

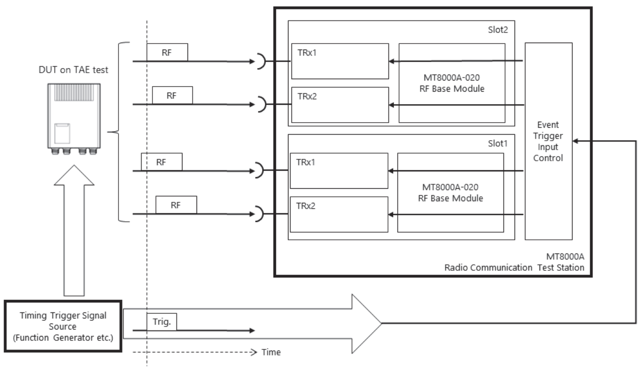

Figure 8 Simultaneous Measurement Setup after Function Upgrade

3.4 Fast Measurement Speed by Selecting Optimum Analysis Environment

To improve mass-production efficiency and cut tact times, the MT8000A BTS manufacturing solution requires faster measurement speeds. External analysis was implemented to solve this issue.

To confirm the improved measurement speed, actual measurement time data were collected (Table 3).

From the captured measurement time data, analysis using the control PC of FR2 8CA measurements required about 8.6 s compared to a relatively long time of about 23 s using the MT8000A internal analysis. At measurement of 1 Carrier, external analysis by the control PC required about 4.8 while internal analysis using the MT8000A was faster at about 2.9 s. These results confirmed that the measurement speed is improved by choosing the optimum analysis environment. The reason for using external analysis by the control PC is to is to achieve faster measurement for a wide frequency band width such as 8CA. Additionally, measurement speed can also be increased further by substituting a high-performance PC for the control PC.

Table 3 1 Carrier and 8 Carrier Measurement times

Analysis Environment	1 Carrier	8 Carriers
Analysis using control PC	Approx. 4.8 s	Approx. 8.6 s
Analysis using MT8000A	Approx. 2.9 s	Approx. 23 s

3.4.1 Utilization of MT8000A Main Unit Internal Analysis

As described in section 3.4, since the 1CA measurement speed is faster, the internal measurement analysis function is used.

Consequently, at Adjacent Channel Leakage Power Ratio (ACLR) measurement is cut to about 1/5 while the measurement time, and the CW Peak Search function is cut to about 1/25.

Table 4 ACLR Measurement Times

Analysis using control PC	Approx. 2 [s]
Analysis using MT8000A	Approx. 0.4 [s]

Table 5 CW Peak Search Measurement Function Times

Analysis using control PC	Approx. 2 [s]
Analysis using MT8000A	Approx. 0.08 [s]

3.5 Spectrum Analysis and 5G NR Modulation Analysis

3.5.1 Spectrum Analysis

Spectrum analyses, such as ACLR measurement, OBW measurement, Operating Band Unwanted Emission (OBUE) measurement, etc., require a maximum analysis BW of 980 MHz; for example, the sub-6 GHz n77 Operating Band is 900 MHz but OBUE measurement requires ±40 MHz for outside of the Operating Band further.

Since the RF unit MT8000A-020 analysis BW cannot obtain the required data in one capture for this 980 MHz BW, the capture is split into several frequency spectrums that are combined to obtain the required data.

3.5.2 5G NR Modulation Analysis

5G NR modulation analysis measures the NR Carrier Bandwidth equivalent analysis BW. For example, sub-6 GHz Contiguous 2CA analysis requires a 200 MHz BW (100 MHz BW × 2 Carriers) equivalent analysis BW.

The required analysis BW for 5GNR modulation analysis is narrower than the bandwidth required by spectrum analysis and the data can be obtained by a single capture. As a result, if the user is only performing 5G NR modulation analysis, the optimum processing matching the measurement objective is selected automatically to perform only one capture at 5G NR analysis, which improves the measurement speed by cutting the number of data captures.

3.6 ACLR Noise Cancel Function

BTS ACLR measurement has more severe performance requirement than for UE measurement. We implemented a Noise Cancel function to improve the ACLR performance and satisfy the 3GPP Specification (45 dBc) + Margin (10 dB) requirement. The ACLR Noise Cancel function overall processing estimates the noise included in the actual measured value from measured value obtained from the internal noise, which is reflected in the ACLR value after subtraction. Table 6 lists the results before and after applying the ACLR Noise Cancel function.

Table 6 ACLR Measurement Results Before/After Noise Canceling

(Waveform = FR1-TM1.1, Center Frequency = 3.6 GHz, Carrier Bandwidth = 100 MHz)

Noise Cancel	ACLR [dBc]			
	−50 MHz Offset	+50 MHz Offset	−150 MHz Offset	+150 MHz Offset
Off	−49.90	−49.66	−50.60	−49.99
On	−53.92	−53.85	−55.59	−55.39

We planned to upgrade the ACLR Noise Cancel function since, excluding cases where the temperature environment changes, the internal noise level does not change if the measurement parameters are not changed. When using the ACLR Noise Cancel functions two or more times, if comparison of parameters (slot, port, SA frequency, input level) related to noise subtraction are all unchanged compared to the previous measurement, noise measured is now skipped and the previous noise data are used (reducing the ACLR measurement time from 8.1 to 4.1 s). Figure 9 shows the operation flowchart for the first and second uses of the software ACLR Noise Cancel function.

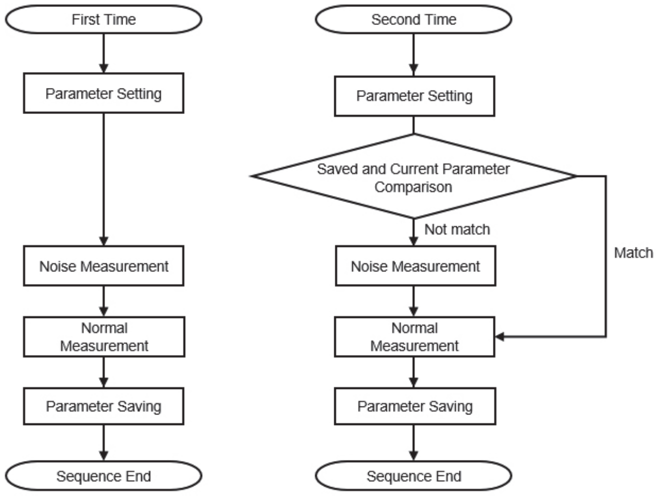

Figure 9 ACLR Noise Cancel First and Second Measurement Results

4 Conclusion

We have developed the MT8000A base station manufacturing solution targeted at the developing wireless infrastructure market. This test solution covers macro to small cells for the sub-6 GHz to mmWave bands with up to four ports to test base stations on production lines using both independent and simultaneous measurement and support cost-effective and efficient testing per port.

Anritsu is continuing with future development of lower-cost and more-efficient test solutions for the growing 5G wireless infrastructure market to assist the evolution and advancement of wireless communications.

References

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