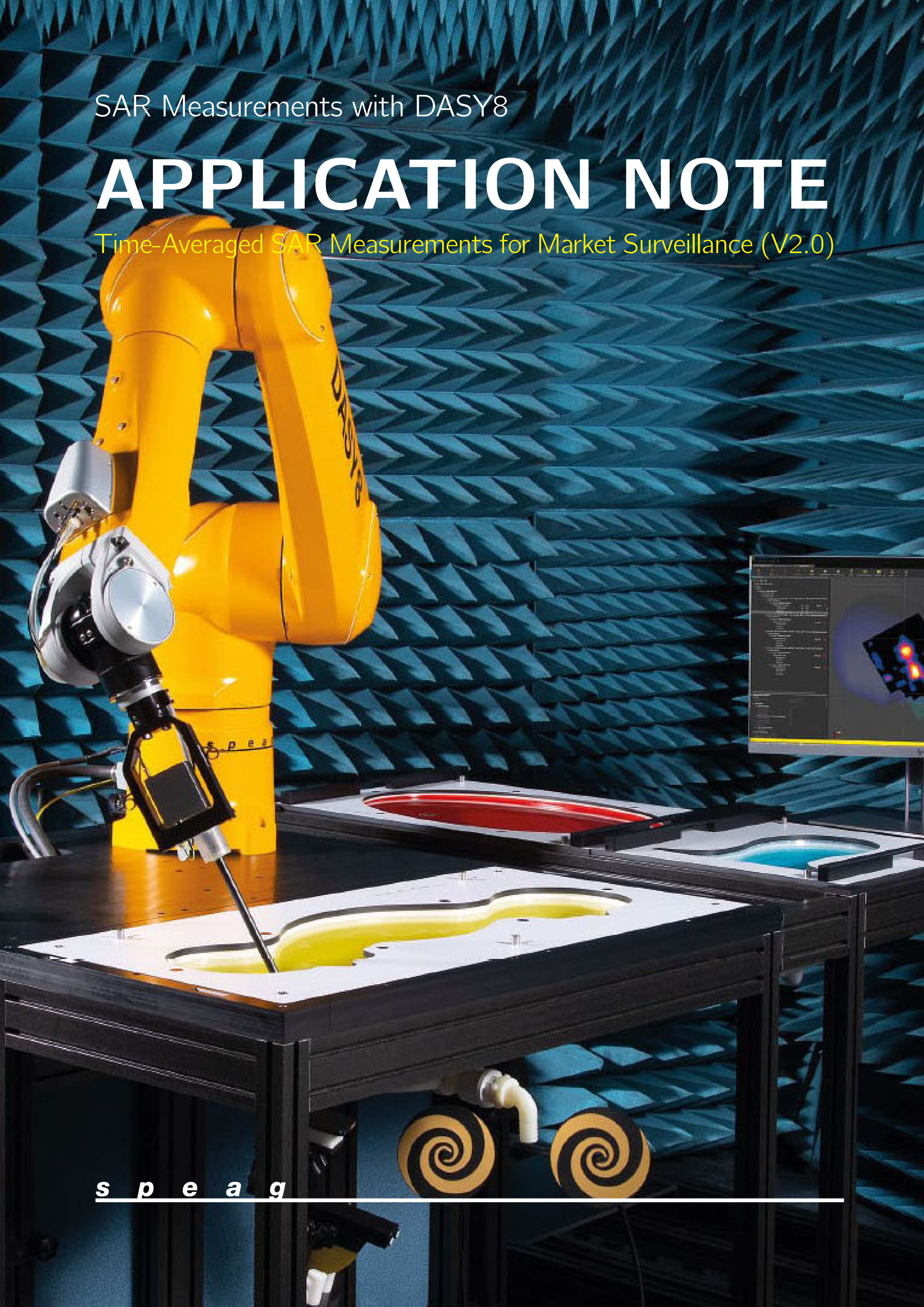
SAR Measurements with DASY8

APPLICATION NOTE

Time-Averaged SAR Measurements for Market Surveillance (V2.0)



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Contents

Time-Averaged SAR Measurements for Market Surveillance

1 Summary

In this application note, we provide a workflow for time-averaged specific absorption rate (SAR) measurements of commercial test samples without the need to use manufacturer tools or specific test modes, e.g., in the context of market surveillance. In Section 3, we define a simplified test procedure and the conditions under which it can be applied in DASY8 Module V16.4+. In Sections 4 and 5, we demonstrate the complete workflow using the actual measurement results of two commercial test samples. This is followed by a discussion of the results and conclusions in Section 6.

Revision V2.0 of this application note includes a test procedure for devices based on power monitoring algorithms with simultaneous transmission on different frequency bands.

Note 1: In the base station simulator (BSS) screenshots and instructions are shown a Rohde & Schwarz® CMW500 radio communication tester and an Anritsu® MT8821C. The steps to be followed with other BSS models are similar.

Note 2: The test procedure for situations where manufacturer tools are needed is described in the DASY8 manual.

Note 3: The test procedure described herein is for DASY8 but is also applicable to DASY6 systems.

2 Time-Averaged SAR Introduction

The procedures in IEC/IEEE 62209-1528:2020 require test devices to maintain a fixed output power during SAR compliance measurements. Modern mobile devices implement dynamic power control and exposure time-averaging (DPC-ETA) to improve link quality while maintaining compliance with SAR limits. The concept of DPC-ETA has been introduced to enable SAR compliance control of wireless devices in real time. In DPC-ETA, the radiofrequency (RF) power is recorded by the modem and time-averaged over a specified window duration. Device output power control is based on the linear SAR-to-power relationship established for a specific wireless operating mode and exposure condition. When the maximum time-averaged power is controlled by DPC-ETA, brief durations of higher instantaneous power may be applied without exceeding the maximum allowed time-averaged SAR. DPC-ETA may lead to temporal fluctuations of the device output power / SAR during the test period. The methods for validating dynamic power control and dynamic exposure time-averaging algorithms used in wireless devices are described in IEC TR 63424-1. While DASY8 SAR measurement systems can accurately test the time-averaged SAR for DPC-ETA-enabled devices, the tests usually require manufacturer access and/or test modes to selectively enable or disable the DPC-ETA algorithm, which severely complicates any independent testing scenarios, e.g., for market surveillance. A solution for this market surveillance test problem is presented in this application note.

3 Test Procedure

The procedure used in DASY8 as described in Section F.2.2 of IEC TR 63424-1 – the single-point SAR method – consists of two steps:

1. Disabling the power control algorithm and forcing the device to operate at P_{limit}, followed by performance of an Area / Zoom Scan to measure the $\text{psSAR}_{1\text{g}10\text{g}\,P_{\text{limit}}}$, which is the $\text{psSAR}_{1\text{g}10\text{g}}$ measured at P_{limit} of the wireless mode being tested, with a full SAR measurement according to IEC/IEEE 62209-1528:2020 and IEC 62209-3:2019 requirements. P_{limit} is the maximum time-averaged output power specified to ensure SAR compliance for the given operating state of the device under test (DUT).

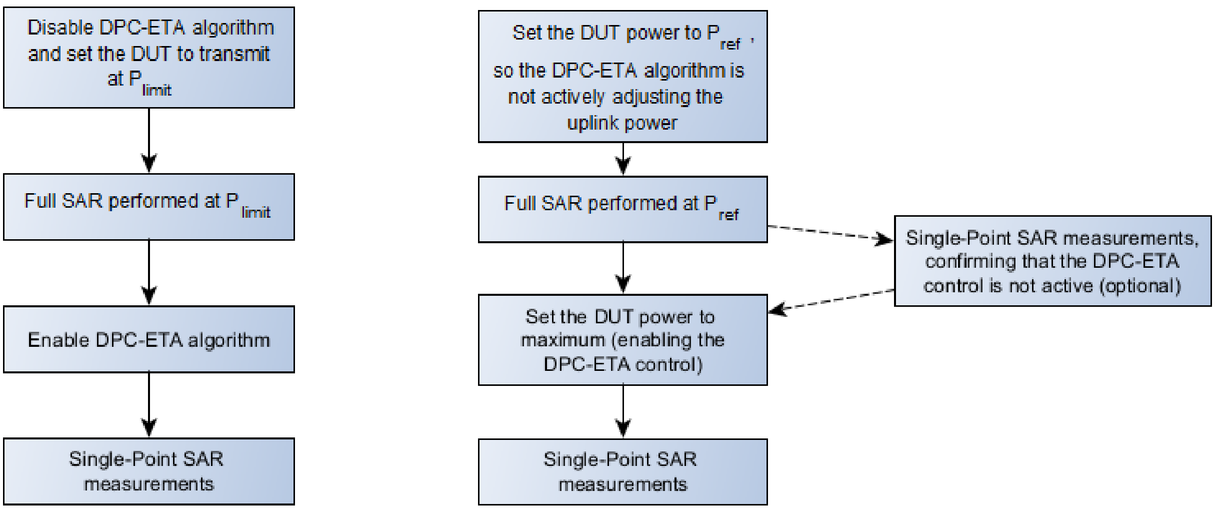
2. Enabling the power control algorithm, followed by performance of a time-averaged SAR scan, whereby single-point SAR measurements, $\text{pointSAR}(t)$, are performed at the peak SAR location identified during the Zoom scan. $\text{pointSAR}_{P_{\text{limit}}}$ is also measured at the same location at P_{limit} to scale the single-point SAR to $\text{psSAR}_{1\text{g}10\text{g}}$, according to the following equation:

$$\text{psSAR}_{1\text{g}10\text{g}}(t) = \frac{\text{pointSAR}(t)}{\text{pointSAR}_{P_{\text{limit}}}} \times \text{psSAR}_{1\text{g}10\,P_{\text{limit}}} \tag{1.1}$$

Step 1 presents a significant limitation for independent testing, in that disabling the power control algorithm requires access to manufacturer tools. A small modification of Step 1 can be performed to overcome this limitation. The DPC-ETA algorithms actively adjust the uplink power only at relatively high output power levels. Once the DUT output power is lower than a certain threshold, the transmission power and resulting SAR will stay constant. Lowering the output power of the DUT can therefore be used to prevent uplink power adjustments caused by the power control algorithm, which allows a full SAR measurement to be performed in step 1 at a power that is lower than P_{limit}, and P_{limit} of Equation 1.1 is replaced with P_{ref} in Equation 1.2:

$$\text{psSAR}_{1\text{g}10\text{g}}(t) = \frac{\text{pointSAR}(t)}{\text{pointSAR}_{P_{\text{ref}}}} \times \text{psSAR}_{1\text{g}10\,P_{\text{ref}}} \tag{1.2}$$

The proposed modification is compared with the original IEC TR 63424-1 procedure in Figure 1.1.



(a) IEC TR 63424-1 Procedure (b) Modified Procedure

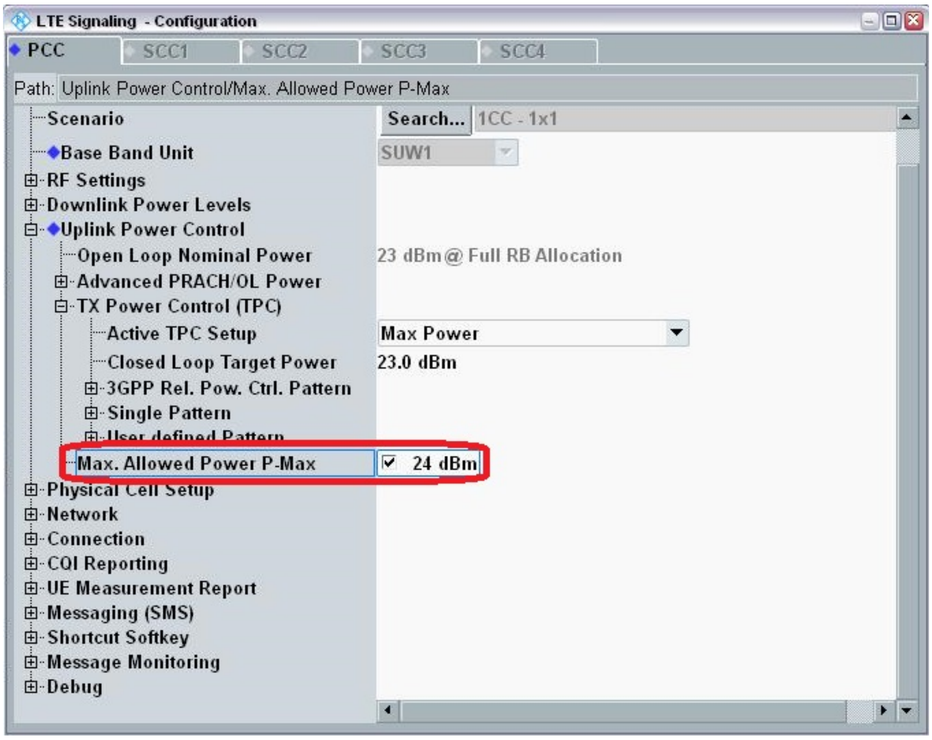
Figure 1.1: Comparison of workflows of the original IEC TR 63424-1 procedure and modification proposed in this application note.

Here, P_{ref} should be carefully selected – values that are too high might trigger adjustments in the power control algorithm, while values that are too low values might result in SAR levels too similar to the noise floor of the measurement system (DASY8 has an outstanding sensitivity of 10 mW/kg). P_{ref} should be set low enough that the DPC-ETA algorithms do not actively adjust the uplink power, e.g., 13 dBm in the case of the LTE and NR frequency bands. If this level results in SAR values that approach the noise floor of the measurement system, P_{ref} can be increased to a level at which the power control remains inactive, which can be confirmed with single-point SAR measurements (marked as optional in Figure 1.1b). In cases where the user has no additional guidance about the choice of P_{ref}, this confirmation becomes more or less mandatory.

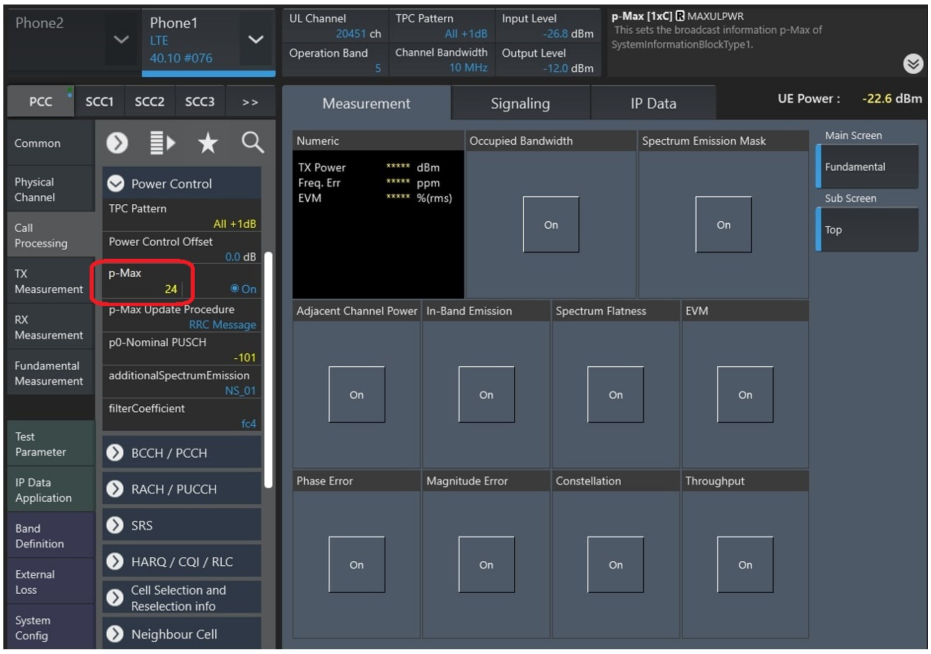
Note that the procedure described in this application note is valid for only a single radio configuration. When different channels, bands, or communication systems are tested, the workflow described in Figure 1.1b should be repeated for each new configuration.

3.1 Uplink Power Control

The uplink power control in 2G and 3G mobile standards is relatively simple – the device is set to transmit at a fixed level. Setting this level (in this case P_{ref}) can be performed in the BSS. The uplink power control in 4G and 5G standards is more flexible – instead of having fixed power levels, 4G and 5G make use of the so-called transmit power control (TPC) mechanism. In this algorithm, there are no fixed levels – instead, the base station prompts the user equipment (UE) to increase or decrease in steps of 1 dB. To test at a fixed power that is not the maximum UE power, the maximum allowed power (P-Max) parameter, which specifies the maximum allowed output power for the UE in the cell, is used. The setting of the BSS is shown in Figure 1.2. Here, the active TPC setup is set to P-Max, i.e., the device is prompted to continually increase its uplink power in steps of 1 dB. The output power is limited by the P-Max value, effectively fixing the UE output power at P-Max.



(a) Rohde & Schwarz CMW500



(b) Anritsu MT8821C

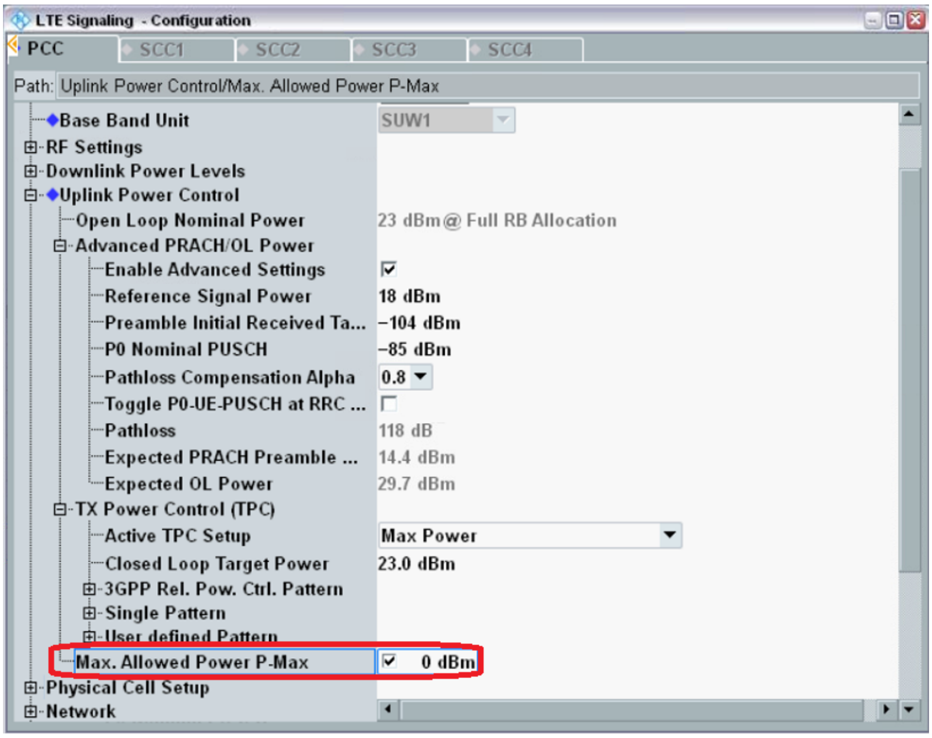
Figure 1.2: The P-Max setting in the BSS.

3.2 Test Sequences

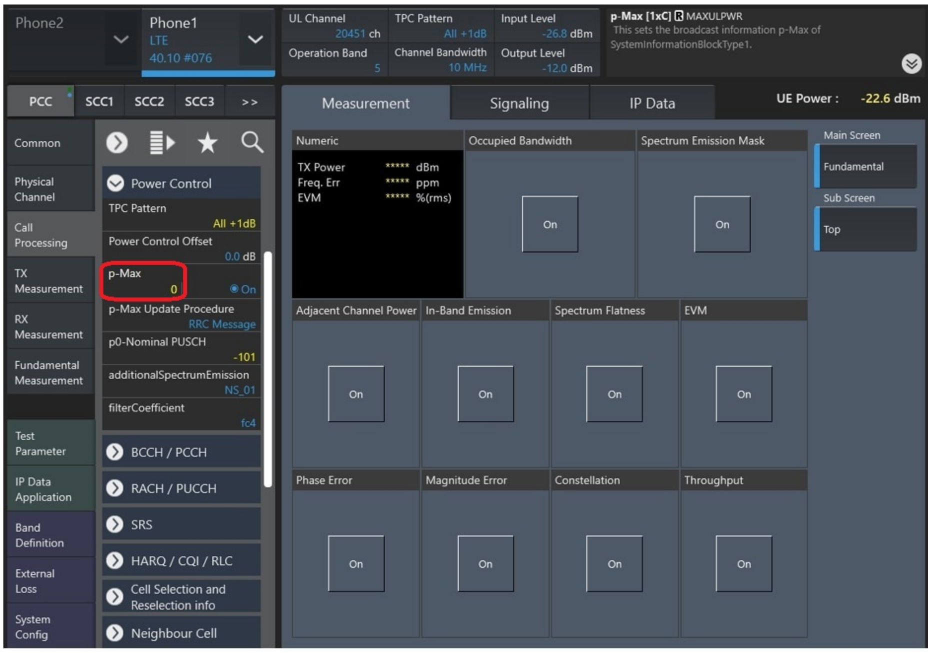
The procedure described in this application note is based on a fixed maximum uplink power for evaluation of the DPC-ETA algorithm. If desired, different test sequences that are more similar to real-life deployment scenarios, e.g., sequences with random uplink power changes, simulated fading, etc., can be used instead of the fixed output power setting. Alternative test sequences, which can be achieved by running external scripts to control the BSS, are not within the scope of this application note but are documented in the DASY8 system handbook, Section 7.3.

3.3 Clearing the DPC-ETA Averaging Buffers

The DPC-ETA algorithm continuously monitors and controls the transmit (TX) power over the defined averaging window. To reset the algorithm, the UE power should be set to a low level, e.g., 0 dBm, for a duration of at least as long as the time-averaging window, e.g., 360 s, 100 s, or 60 s. The corresponding setting is shown in Figure 1.3. An alternative way to clear the buffers is to drop the call, go to airplane mode, or turn off the phone for the same duration.



(a) Rohde & Schwarz CMW500



(b) Anritsu MT8821C

Figure 1.3: Setting P-Max to 0 dBm to clear the DPC-ETA buffer.

3.4 Additional Considerations

- This procedure is not applicable for devices that utilize transmit antenna diversity or MIMO in the uplink direction. In such cases, the cSAR3D vector array system, which captures the entire SAR distribution in intervals of 0.35 s, can be used. This information is used to automatically calculate psSAR or Volume Time-Averaged SAR, as described in section F.2.4 of IEC TR 63424-1.
- Mobile phone designs are constantly evolving, and the DPC-ETA algorithms nowadays use not only the uplink power but also information from one or more sensors inside the device as inputs. These inputs can be from proximity sensors, motion sensors, user settings (e.g., WiFi tethering via hotspot mode), selected audio mode (e.g., headset vs. hands-free operation), etc. For example, some phones trigger time-averaging only when held close to the body, i.e., triggered by a proximity sensor, or in hotspot mode selected in the phone settings. Some phones might also make use of the Mobile Country Code (MCC) and/or Mobile Network Code (MNC) as inputs – see Appendix 2 for details.

4 Measurements in DASY8: Stand-Alone Configuration

In this section, time-averaged SAR (TAS) measurements, as described in Section 3, of a commercially available phone as the DUT are demonstrated with DASY8 V16.4. The DUT selected for this purpose has a power monitoring algorithm enabled when it transmits in LTE Band 2. The antenna is located at the bottom of the device. The exact test configuration is summarized in Table 1.1.

Technology	Band	Chan.	Freq. (MHz)	BW (MHz)	RBs	RB Pos.	Modulation	Position	Spacer (mm)
LTE	2	18900	1880	20	50%	mid	QPSK	bottom	10

Table 1.1: DUT Test Configuration

The project created in DASY8 Module SAR for this measurement includes a Fast Area Scan and a Zoom Scan, followed by a Time-Averaged Scan anchored to the peak location identified in the Zoom Scan. For better visualization, the averaging duration in this example is set to 300 s, as shown in Figure 1.4. The averaging window of the DUT is 100 s, meaning that three averaging periods are displayed in the results.

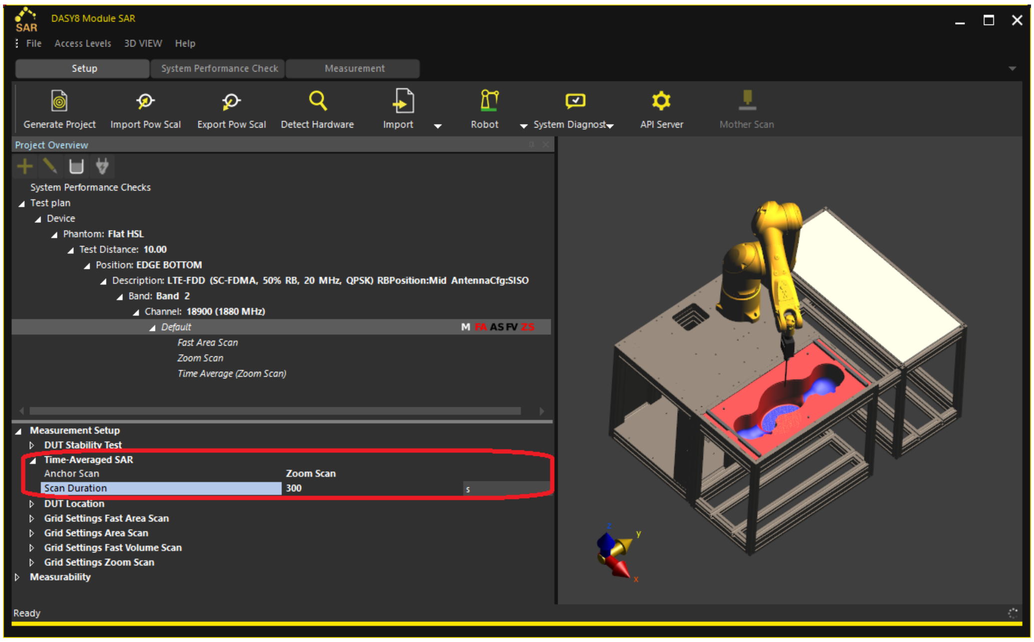
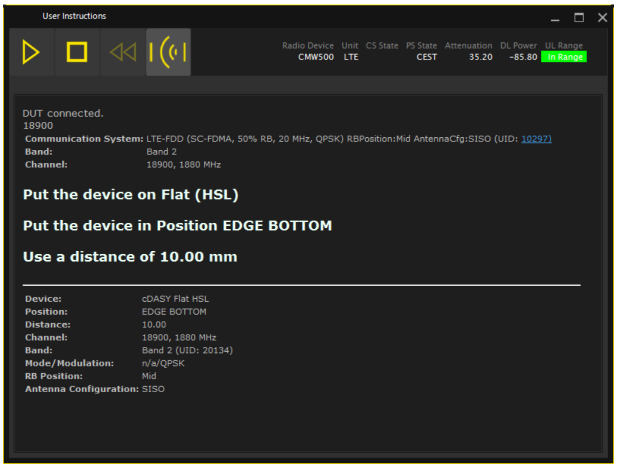
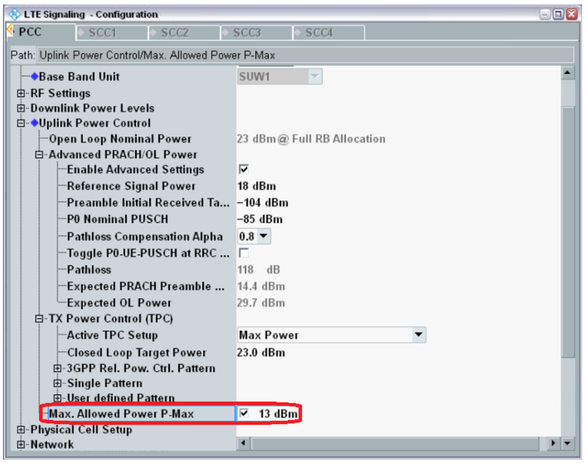


Figure 1.4: Time-Averaged Scan settings.

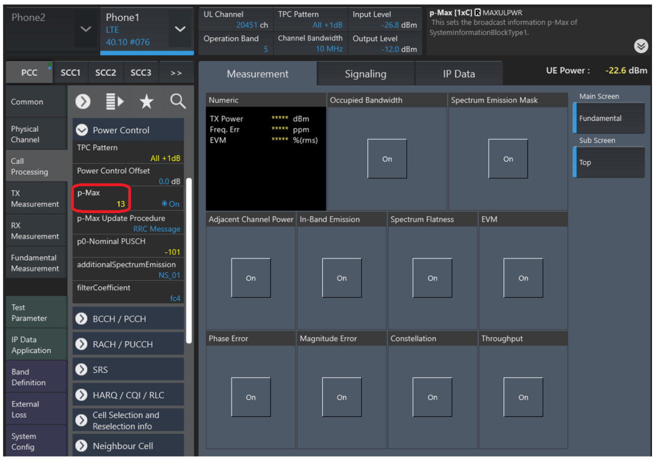
DASY8 controls the BSS, which sets up the call and adjusts the path loss when the measurement is started. The call is successfully established when the User Instructions window indicates "DUT Connected" (see Figure 1.5a). Before proceeding with the actual Fast Area and Zoom Scans, the DUT output power is set to a P_{ref} of 13 dBm by manually adjusting the "Max. Allowed Power P-Max" as shown in Figure 1.5b below. Adjustment of the output power is performed by the end-user and will not affect the other settings established by the DASY8 automation.



(a) User Instruction window showing an established call



(b1) Rohde & Schwarz CMW500



(b2) Anritsu MT8821C

(b) Setting the maximum allowed UE power to 13 dBm

Figure 1.5: Reducing the uplink power of the DUT before proceeding with the Fast Area and Zoom Scans.

When the uplink power is decreased to P_{ref}, the DPC-ETA control stops actively adjusting it. Once the Fast Area and Zoom Scans are finished, the dialogue box of DASY8 shown in Figure 1.6 prompts the user to activate the power monitoring algorithm.

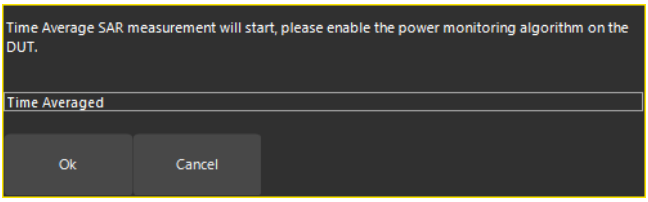


Figure 1.6: DASY8 dialog box prompting the user to enable the power monitoring algorithm.

At this point, optional single-point SAR measurements shown in Figure 1.7 can be performed to confirm that the DPC-ETA algorithm is not controlling the output power. Here, we use the option to repeat the Time-Averaged Scan multiple times. Thus, the first run is used to confirm that the output power level is stable with the uplink power maintained at 13 dBm, and the second run is used for the actual DPC-ETA measurement, with the uplink power increased to its maximum to activate the DPC-ETA control.

Here, the Time-Averaged Scan is performed in the same batch as the Zoom Scan, allowing the reference measurement to be reused. If another TAS measurement is performed later, a new reference measurement would be triggered. For the scaling to be correct, the DUT power must be reduced to low (13 dBm in this example) during this reference measurement.

Another critical point is the positioning of the DUT – once the Fast Area and Zoom Scans are underway, the device should not be moved until all steps are completed. Re-positioning the device after the Zoom Scan is performed invalidates the reference measurement used for scaling the time-sweep results and leads to reporting of incorrect result. This should not present a difficulty to the testing laboratories, since uplink power modifications are pperformed over the air in the BSS.

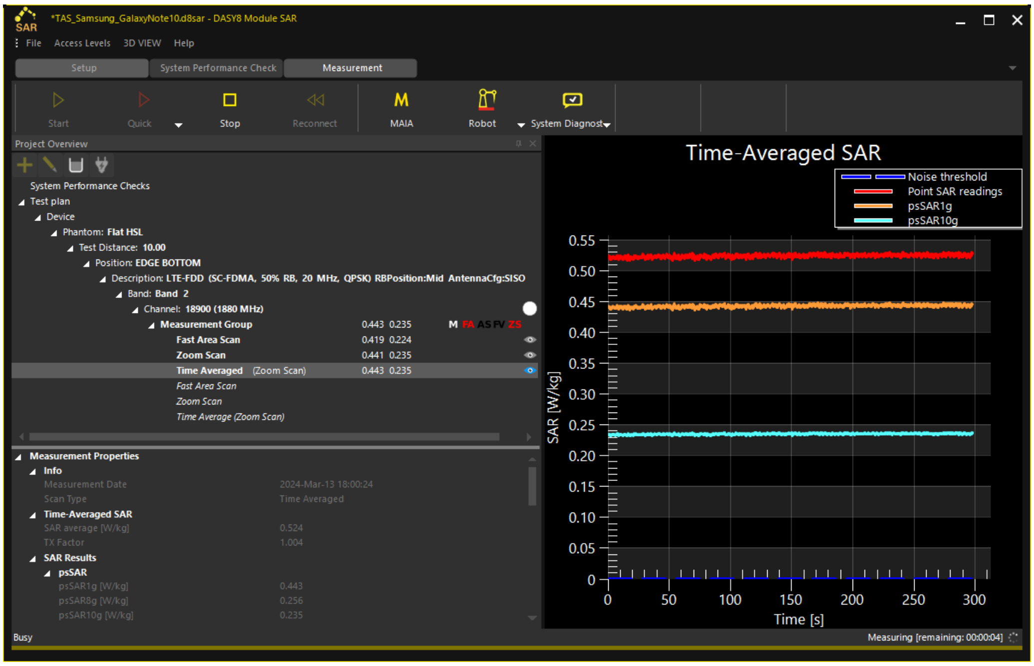
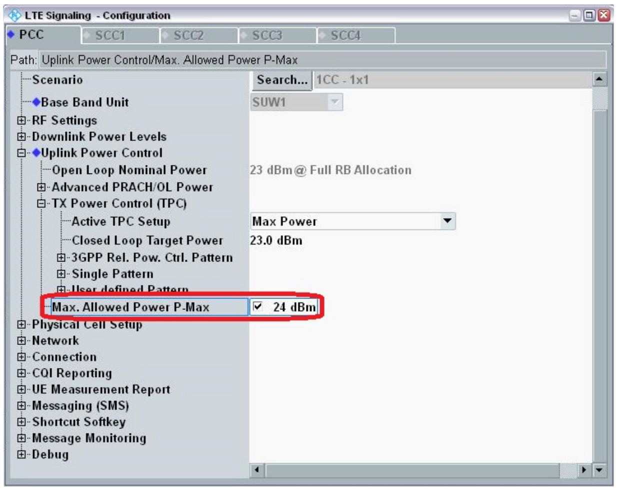
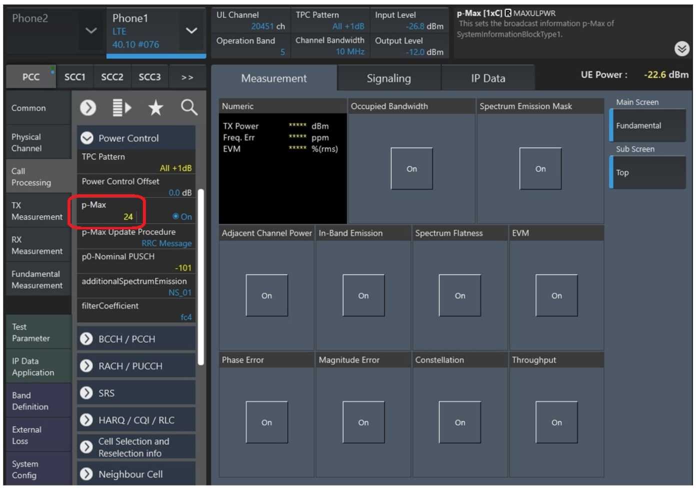


Figure 1.7: Optional single-point SAR measurements confirming that the output power of the phone is stable and not under the control of the DPC-ETA algorithm.

Next, the maximum allowed power is set to 24 dBm in the case of devices having Power Class 3 (or 1 dB above the maximum allowed uplink power) manually from the BSS screen – the corresponding settings are shown in Figure 1.8a. Optionally, before doing so, the P-Max can be set to 0 dBm for one time-averaging period to clear the DPC-ETA buffer, as described in Section 3.3, before starting a Time-Averaged Scan.

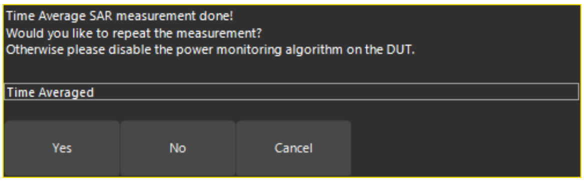


(a1) Rohde & Schwarz CMW500



(a2) Anritsu MT8821C

(a) Setting the maximum allowed UE power to 24 dBm



(b) DASY8 dialog window prompting the user to repeat the Time-Averaged Scans with the DPC-ETA control on

Figure 1.8: Steps for enabling DPC-ETA control.

The Multimeter View, shown in Figure 1.9, can be used to monitor the DPC-ETA control in real-time while the measurement is running.

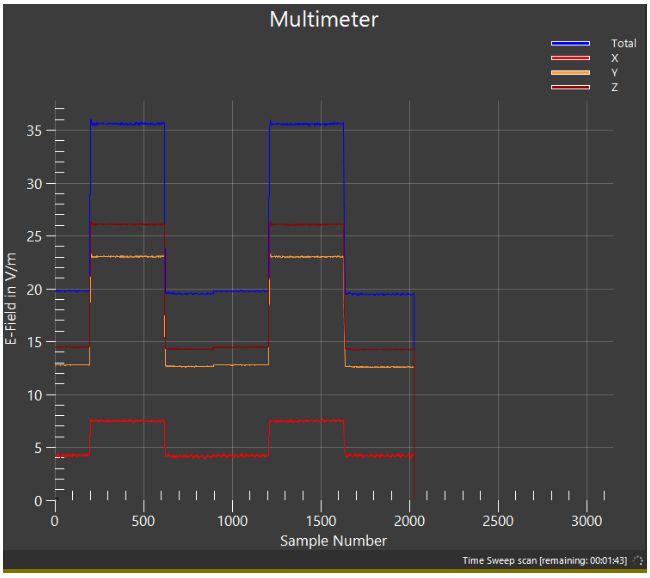


Figure 1.9: Multimeter View used to visualize the DPC-ETA control in real-time.

The Time-Averaged Scan results are shown in Figure 1.10. The 2D plot showing the sensor SAR readings during the 300 s measurement window represents the pointSAR(t) term in Equation 1.2.

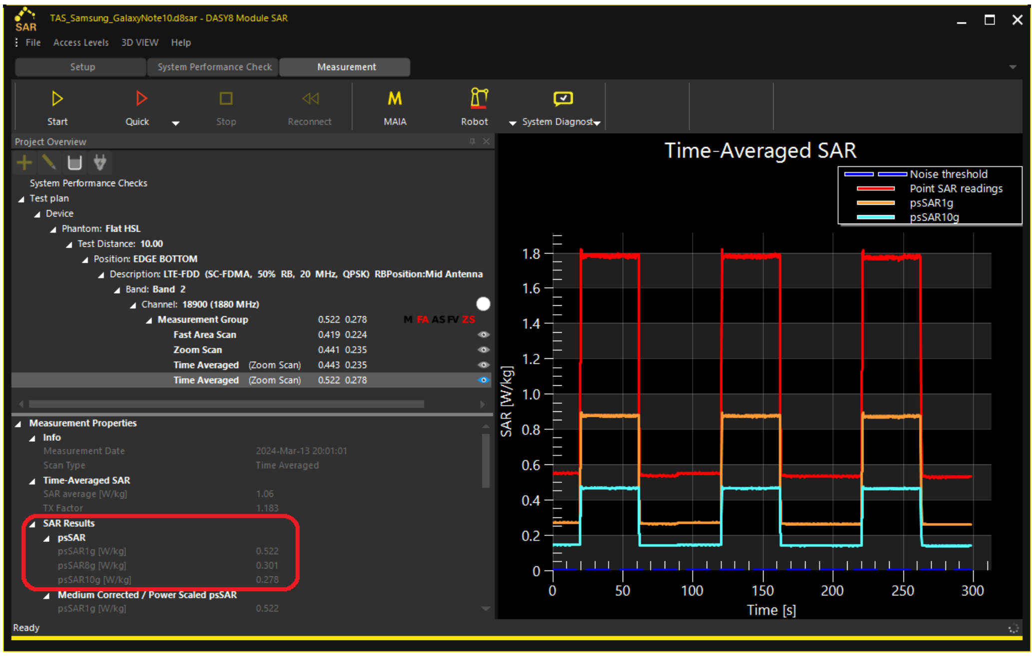


Figure 1.10: DASY8 Time-Averaged Scan results.

The psSAR results are summarized in Table 1.2.

Test Case	Freq. (MHz)	SAR Zoom Scan @ 13 dBm (W/kg)		Time-Averaged SAR @ 24 dBm (W/kg)	
		1g	10g	1g	10g
LTE, 20 MHz, 50% RB, QPSK	1880	0.441	0.235	0.522	0.278

Table 1.2: DASY8 Time Averaged Scan Results

DASY8 calculates the Time-Averaged SAR over the duration of the whole measurement. If different averaging intervals are required, the raw data can be exported in .csv format for post-processing in an external program, e.g., Excel, etc., accomplished by right-clicking on the Time-Averaged SAR node and selecting Export, as shown in Figure 1.11.

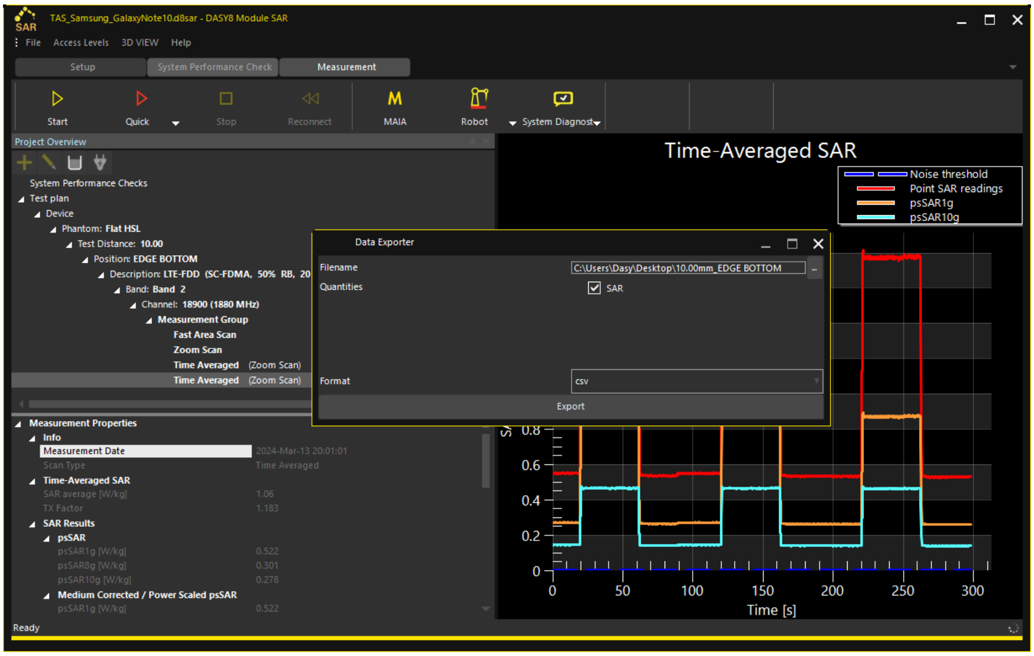


Figure 1.11: Export of Time-Averaged SAR results in .csv format.

5 Measurements in DASY8: Multi-TX Evaluations

In this section, we describe a measurement procedure for devices with a power monitoring algorithm enabled when transmitting on different frequency bands simultaneously.

The DUT used in this example supports the LTE-FDD band 5 and the Wi-Fi 2.4 GHz band. The power monitoring algorithm is disabled when the device transmits in a single frequency band, but is enabled for Wi-Fi when transmitting on the two bands simultaneously with hotspot mode on. Note that the hotspot mode engages the power monitoring algorithm for this specific device. Since the power monitoring algorithm can be enabled/disabled, the low-power approach described in section 4 is not needed: all measurements can be performed at full power.

The two stand-alone configurations were measured sequentially with Fast Area, Area, and Zoom Scans. The psSAR results from the Zoom Scan are summarized in Table 1.3.

Test Case	Freq. (MHz)	SAR Zoom Scan (W/kg)	
		1g	10g
LTE band 5, 10 MHz, 100% RB, QPSK	836.5	2.05	1.04
Wi-Fi 2.4 GHz, DSSS, 1 Mbps	2447	2.57	1.20
LTE + Wi-Fi	836.5 / 2447	4.27	2.15

Table 1.3: Zoom Scan psSAR Results with Power Monitoring Algorithm Disabled

The total psSAR with the LTE and Wi-Fi configurations transmitting simultaneously at full power, with the power monitoring algorithm disabled, has been assessed with the DASY8 Multi-TX Evaluator. The two Zoom Scans are selected in the DASY8 Project Overview, then combined by selecting "Combine" from the context menu. The combined psSAR10g is 2.15 W/kg, which is greater than the 2 W/kg limit.

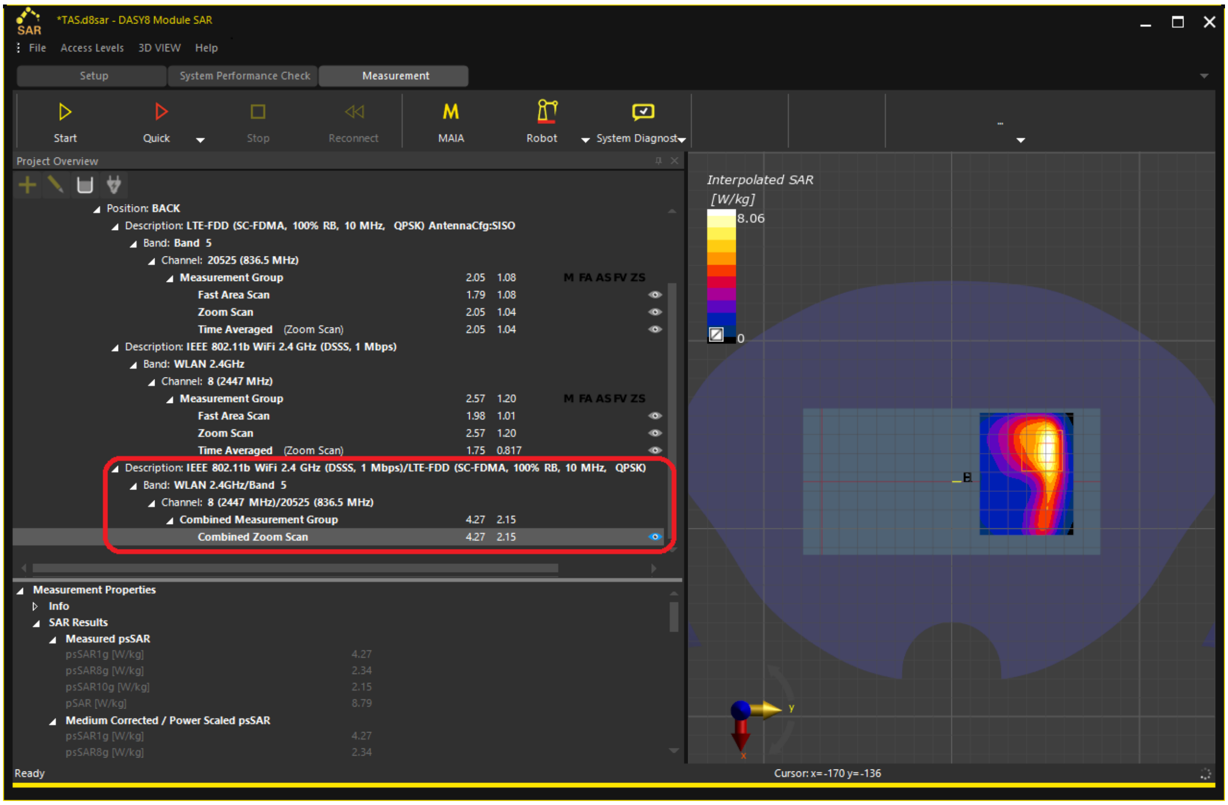
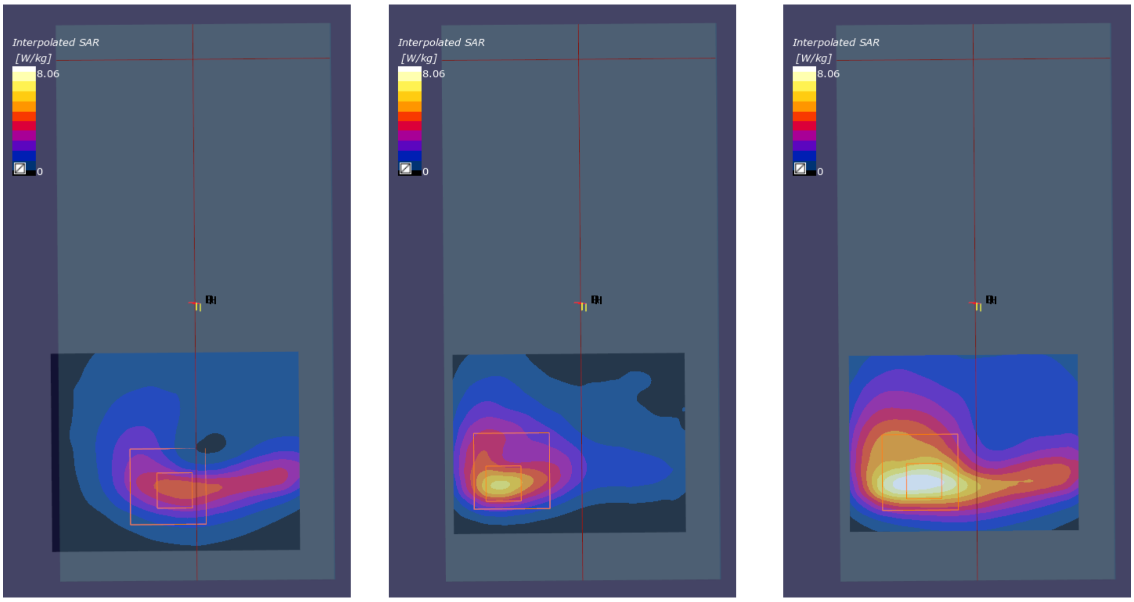


Figure 1.12: The results from the DASY8 Multi-TX Evaluator with the Power Monitoring Algorithm disabled; the combined configuration is highlighted in red.

The SAR distributions of the stand-alone and multi-TX configurations are shown in Figure 1.13.



(a) LTE-FDD band 5

(b) Wi-Fi 2.4 GHz band

(c) LTE-FDD band 5 and Wi-Fi 2.4 GHz band combined with Multi-TX Evaluator

Figure 1.13: Zoom Scan SAR distributions with the Power Monitoring Algorithm disabled.

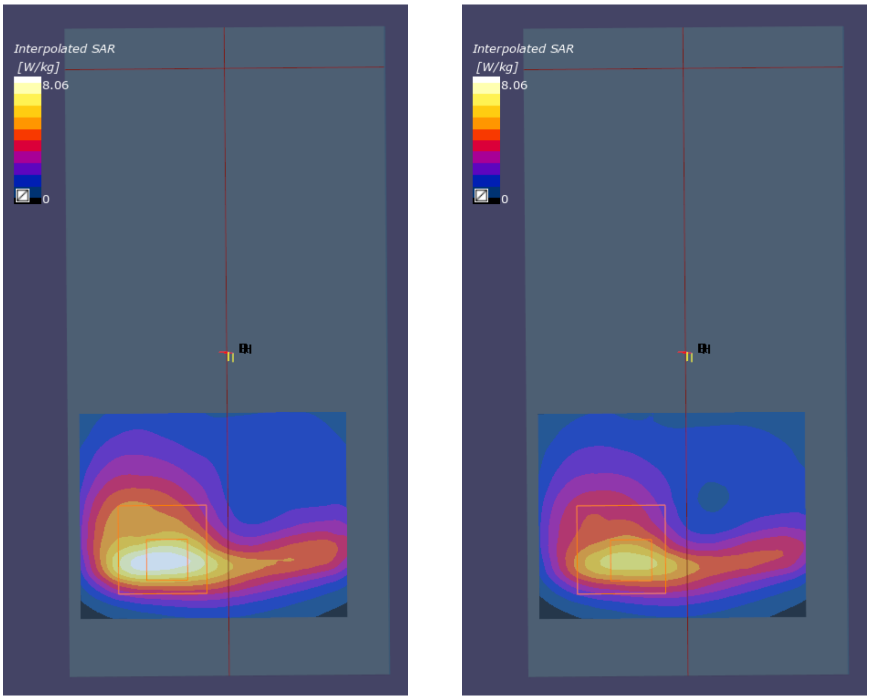
The Wi-Fi measurement is repeated with hotspot mode activated, which enables the power monitoring algorithm on the DUT. Hotspot mode is enabled when the DASY8 software prompts the user to do so (see Figure 1.6).

The psSAR results are summarized in Table 1.4. With the power monitoring algorithm enabled for Wi-Fi 2.4 GHz (and the device transmitting at full power on LTE band 5), the combined $psSAR_{10g}$ is 1.78 W/kg, which is lower than the 2 W/kg limit.

Test Case	Frequency. (MHz)	SAR Zoom Scan (W/kg)	
		1g	10g
LTE band 5, 10 MHz, 100% RB, QPSK	836.5	2.05	1.04
Wi-Fi 2.4 GHz, DSSS, 1 Mbps	2447	1.75	0.817
LTE + Wi-Fi	836.5 / 2447	3.50	1.78

Table 1.4: Zoom Scan psSAR Results with the Power Monitoring Algorithm Enabled.

The SAR distributions of the multi-TX configuration Wi-Fi 2.4 GHz + LTE band 5 with the Power Monitoring Algorithm enabled and disabled are shown in Figure 1.14. Note that the SAR levels are reduced when the algorithm is enabled.



(a) Power Monitoring Algorithm disabled (b) Power Monitoring Algorithm enabled

Figure 1.14: Zoom Scan SAR distributions of LTE-FDD band 5 and Wi-Fi 2.4 GHz band combined with Multi-TX Evaluator. Note the reduction of the maximum level when the power monitoring algorithm is enabled.

6 Conclusions

DASY8 Module V16.4+ can be used to evaluate the Time-Averaged SAR of commercial samples for market surveillance. A simplified procedure for this evaluation is presented in this application note, along with the results of an actual measurement of a commercial sample. The simplified procedure consists of measuring the reference SAR value of the device at a lower power level (P_{ref}), at which the DPC-ETA algorithms are not actively adjusting the uplink power. Measurements on a commercial sample show that the simplified procedure gives consistent results, enabling DPC-ETA evaluations without the need for manufacturer tools.

In the second part of the application note, we demonstrate a simultaneous exposure evaluation of a continuous and a Time-Averaged transmission, which may be combined by means of the Multi-TX Evaluator in DASY8. Note that the procedure may also be applied when the device is transmitting on more than two frequency bands simultaneously.

Appendices

1 Path Loss Estimation in the BSS

The goal of path loss estimation is to determine whether there is enough dynamic range for the Time Averaged SAR measurement; otherwise, a call might be dropped when the DUT uplink power is changed. Note that the absolute accuracy of the path loss in this estimation is not a concern, so long as the DUT TX power can follow the requests from the call box.
Note that the path loss estimation is performed automatically in DASY when the BSS is selected – this section describes the steps to be followed when the BSS is used separately from DASY8. In both cases, the path loss estimation should be performed when the DUT is positioned for testing next to the phantom – changing the position with respect to the phantom will change the losses too.

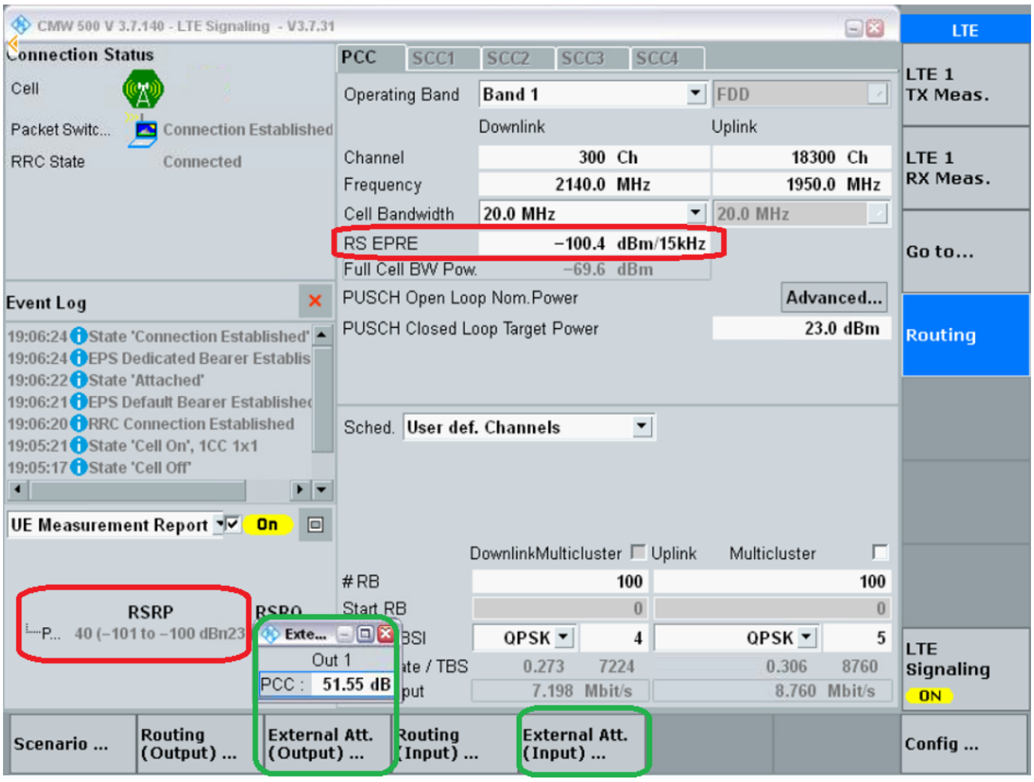


Figure 15: Estimation of loss in the Rohde & Schwarz CMW500

The following steps explain how to use the system to manually perform a path loss estimation in LTE. The procedure is similar for other BSS models and protocols.

1. Enable UE Measurement Report after establishing a call to the DUT.
2. Adjust the External Attenuation input/output (marked in green) in Figure 15) until the reference signal received power (RSRP) and the reference symbol energy per resource element (RS EPRE) values are closely but not necessarily exactly matched. Here, the input and output attenuation can be kept equal, assuming that the uplink and downlink losses are more or less the same.
3. Optionally, a quick reality check can be performed by running an LTE TX Measurement from the Multi Evaluations tab (Figure 16. The TX power should be similar to the requested TX power level – in this case, the maximum power of the DUT.

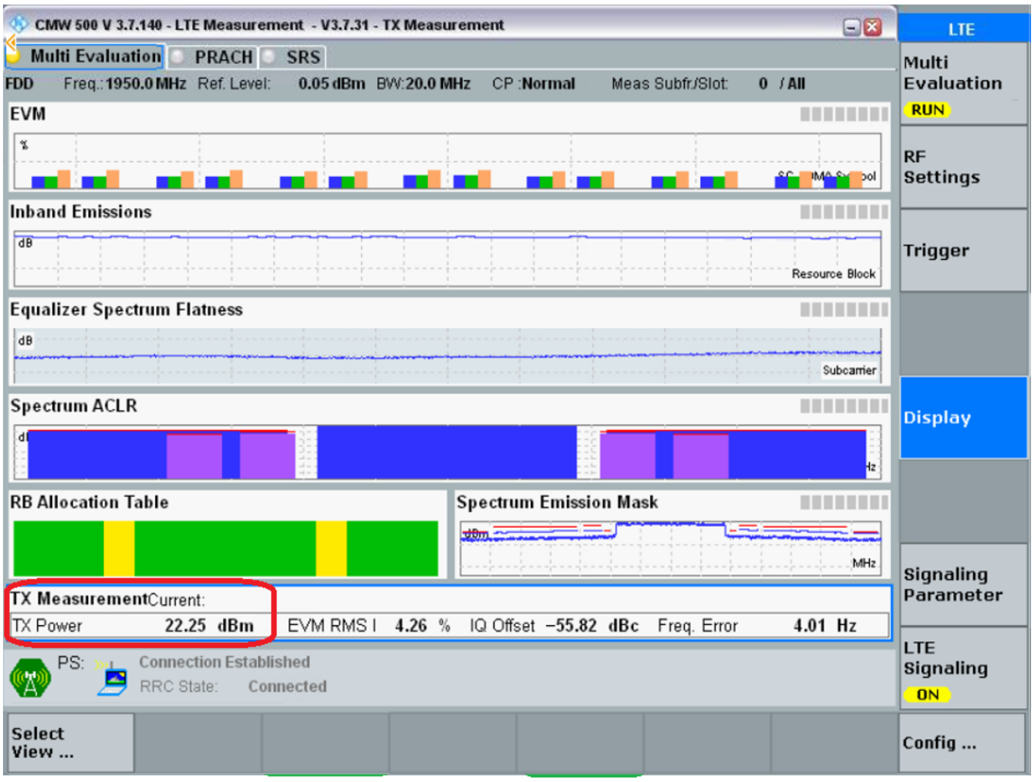


Figure 16: Confirmation of the estimated path loss in TX power.

The procedure described in this application note is based on Open Loop Power Control with Active TPC Setup set to Max Power, also referred to as "All Bits Up". Since Open Loop is used, the results are not as sensitive to operator movement or small changes in the measurement environment.

2 MCC and MNC Considerations

The default values for Mobile Country Code MCC = 001 and Mobile Network Code MNC = 01 used in the BSS automation correspond to Test Public Land Mobile Network (PLMN). Some DPC-ETA implementations will exhibit different behaviors, e.g., different averaging window durations or different power levels, based on the MCC/MNC values. To enable testing for the different combinations, these parameters are exposed in the BSS automation, as shown in Figure 17. When BSS automation is used, these are automatically set in the tester.

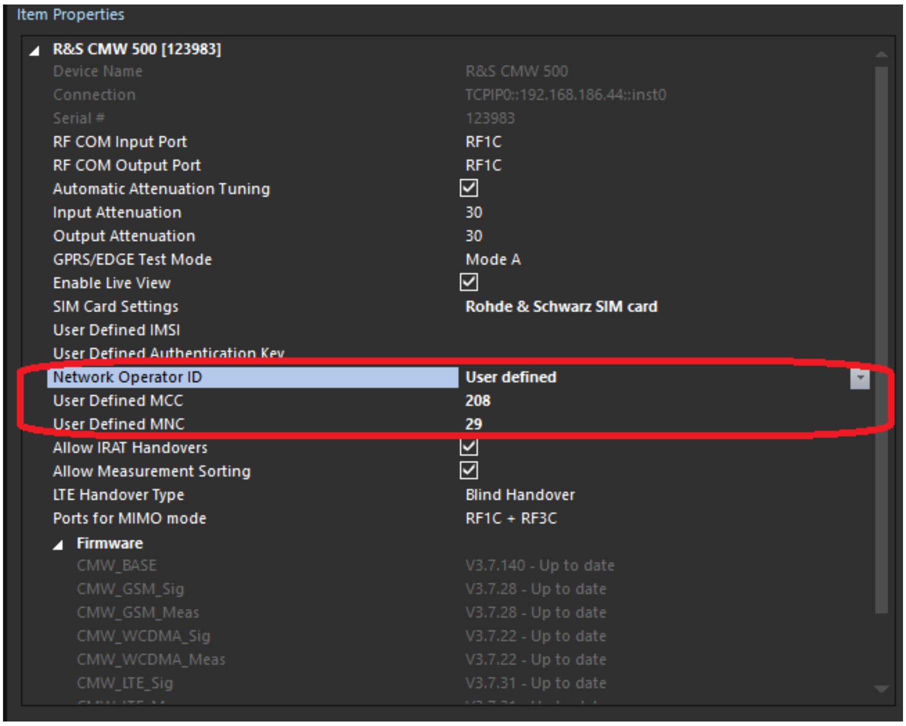
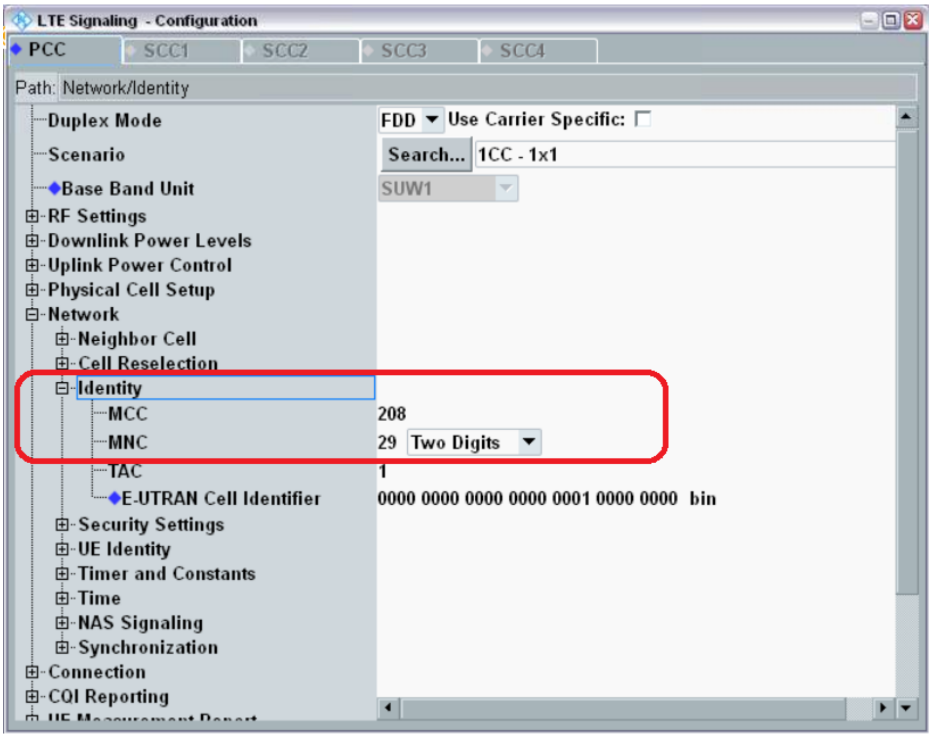
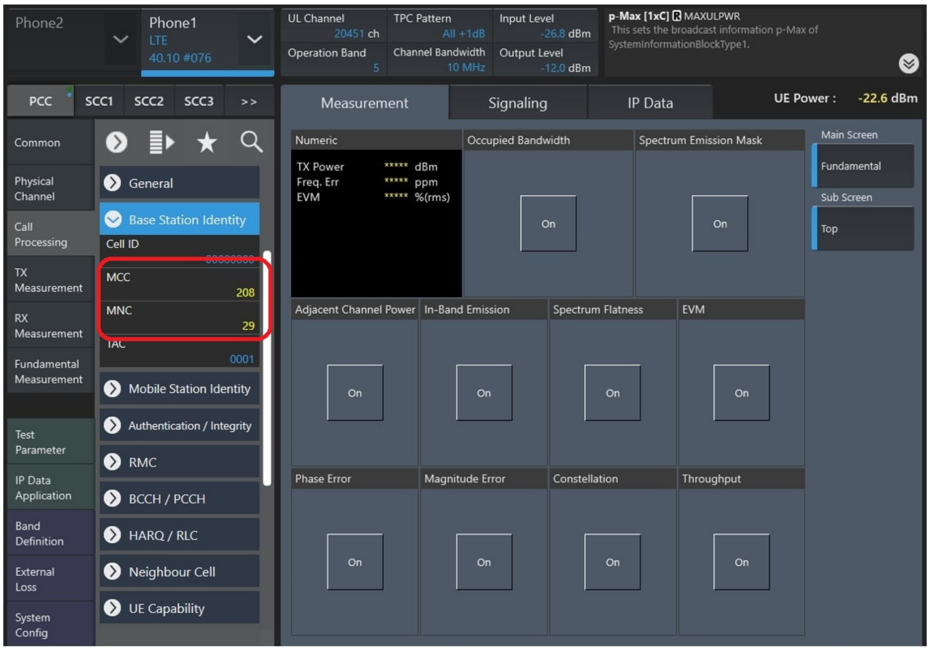


Figure 17: MCC/MNC settings in DASY8.

When the automation setting in DASY8 is not used, these parameters can be manually edited directly in the BSS. The corresponding fields are shown in Figure 18.



(a) Rohde & Schwarz CMW500



(b) Anritsu MT8821C

Figure 18: MCC/MNC settings in the Rohde & Schwarz CMW500 and Anritsu MT8821C systems.