Practical Considerations on MIMO OTA Testing

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1. Introduction

A complete MIMO OTA system can be built as shown in Figure 1 [1-2-3-4-5]. A channel emulator is connected to a test range on which 8 antennas transmit a selected channel models to the device under test (DUT) positioned in the centre of the test range. In this way MIMO enabled terminals can be tested against different scenarios as in a field test with perfect repeatability.

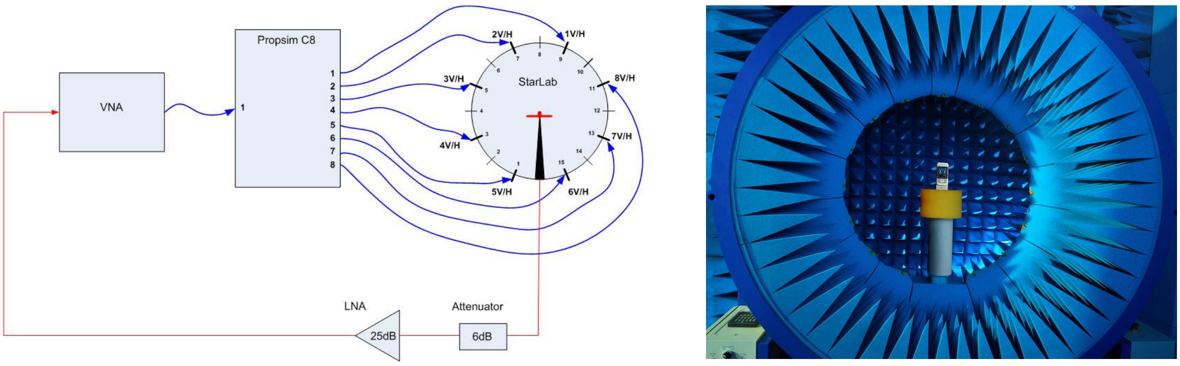

Figure 1. Spatial Fading Emulator – MIMO OTA test system proposal

The above depicted OTA system emulates radio channel profiles directly inside the anechoic chamber representing realistic MIMO environments in which the terminal will eventually operate. Antennas performances of devices like laptops, handsets and PDAs are strictly dependent on the structure of the device hosting them. This OTA test system can guarantee testing radiated performances of terminals without altering the whole structure of the terminal itself.

Accessibility to HW/SW of terminal is sometime difficult for development engineers. Independent test labs can generally access neither HW nor SW of the terminals to be tested. The OTA test system will therefore be required to test “off-the-shelve” HSPA and LTE MIMO capable devices.

In this paper, spatial correlation, and feasibility region will be used as figures of merit in order to see if a specific channel model can be emulate at the centre of an antenna test system (StarLab 15). Throughput will then be used as figure of merit for testing OTA radiated performance of a terminal.

A CDMA2000 1xEVDO data card has been tested by using different channel profiles scenario. Repeatability of throughput measurements has been observed when channel profiles were changed.

2. Measurement set-up

The test range used for the testing campaign is showed in Figure 1, more details are reported in Figure 2. 8 antennas surround the DUT in theta axis, following the arch shape. Odd probes in Figure 2 are connected to the Propsim C8 output connector.

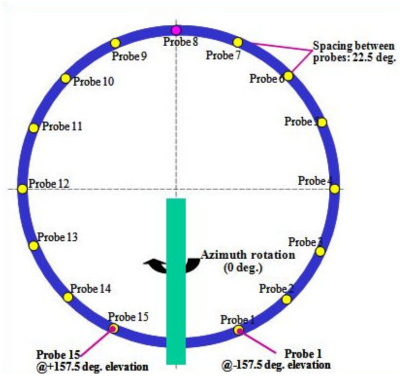

Figure 2. Probes placement around DUT

A	Output level of the tester (e.g. VNA)	-15	dBm
B	Cabling to Propsim Input	-1	dB
C	Propsim total channel gain	-1	dB
D	Cabling to OTA antenna	-3	dB
E	**Signal level at OTA antenna**	**-20**	**dBm**
F	OTA Antenna gain	-10	dBi
G	**Transmit level (EIRP)**	**-30**	**dBm**
H	Path Loss (FSPL: 2GHz/0.45m)	-32	dB
I	**Signal level at DUT**	**-62**	**dBm**
J	DUT antenna gain	2	dBi
K	**Signal level at DUT antenna connector**	**-60**	**dBm**
L	Cables + Attenuator + Antenna Switch + LNA	22.4	dB
Q	**Signal level at VNA input (port 2)**	**-37.6**	**dBm**
R	**Gain**	**-22.6**	**dB**

Table 1. Link/Gain budget calculations

Used probes are spaced 45°, and DUT is placed in the center of the arch at 45cm distance far from the probes (Measurement Antennas), horizontally. Horizontal polarization of probes is used in order to fit with chosen channel models being sent by channel emulator. We used uniform linear array as DUT. It was made of 3 SATIMO dipole series SD2050 centered at 2.05 GHz. Dipoles are placed to be spaced less than $\lambda/2$ (7.5cm at 2GHz frequency). DUT size was 18cm. Dipoles are connected to the single-ended LNA towards a switch card in order not to move dipoles when changing configuration, i.e. measuring received signal from radiating element number 2 with 1 and 3 loaded to 50Ohm. Gain budget of the test range is detailed in table 1.Signal power of -15dBm at Propsim C8 input results in around -62dBm power level at DUT. Typical sensitivity of a 10MHz BW receiver is around -95dBm - -100dBm, it means that implementation loss is within 23-28dB range.

3. Calibration Process

Calibration is done by using a VNA, and a dipole series SD2050 as receiver and DUT respectively. StarLab system is placed in a 3x3x3m anechoic chamber while Propsim C8, and VNA are outside. Set-up is shown in Figure 4. The purpose of the calibration process is to compensate errors caused by measurement set-up non-idealities, i.e. antenna placements [6]. Calibration process starts by sending a signal from each probe at time (1,3,5,7,9,11,13,15) to the DUT, and measuring amplitude and phase of the signal being sent with VNA. If there is a difference, i.e. between signal received from probe 1 to the one received from probe 3 then phase and gain of the RF path is adjusted in the channel emulator in order to compensate for it. Process is repeated for all the probes, 8 in total. Phase and gain adjustments are then stored in the Propsim C8.

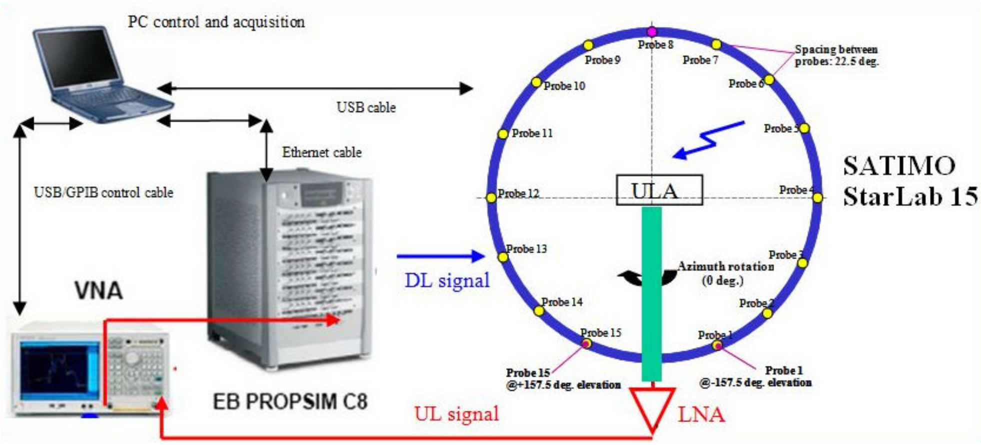

Figure 4. Calibration set-up

4. Measurements

The following lists the used radio channel models:

- 1-to-8 1-path (per channel) constant
- Used in Calibration process, and displacement tests
- SCM Urban Macro, SCM Urban Micro, SCM Suburban Macro
- XPR SCM Urban Macro
- Turn around constant tap (360 IR's 1deg AoA increments)

5. Measured Results

Spatial correlation values are highlighted in table 2. Correlation matches theoretical values when angular spread is 10°, diverging when angular spread increase to 35°. A measurement has been performed in order to address the feasibility region [6] at 2GHz frequency when distance from probes (measurement antenna) to DUT is 45cm (radius of StarLab system). Displacement measurements have been performed by using a SATIMO dipole series SD2050. DUT has been step in X-axis from -15cm (-λ) to 15cm (λ) with 1cm increments. IRs (impulse response) are taken from VNA at each increment. Figure 6 shows a comparison between theoretical and measured feasibility region. The blue curve represents the measured field strength (center point as 15 cm). The Y axis (Absolute value) is the absolute value measured by VNA. The red curve represents the theoretical field strength (Bessel function).

Separation	AS	Incident angle	Roo (theory)	Antennas 1-2	Antennas 2-3
0.5	10	0	0.8640	0.8678	0.8416
0.5	35	0	0.2184	0.3698	0.2534

Table 2. Spatial correlation results

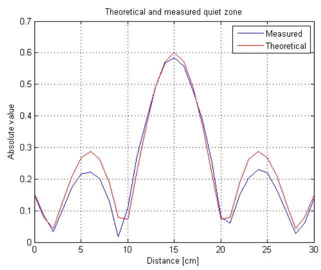

Figure 6. Feasibility region

6. OTA throughput testing

A CDMA 2000 1xEVDO was used as DUT. It is shown in Figure 8. Primary antenna was used for the throughput testing (Diversity OFF). UL signal is within 1850-1910MHz while DL signal is within 1930-1990MHz. An 1xEVDO data call has been placed on Channel600 (TXfrequency=1880MHz,RX frequency=1960MHz) by using a R&S CMu200 as BS (Base Satation). Reference channel 600 was set on BTS along with test time of 1000 frames. Propsim fundamental frequency was set to 1970MHz. DUT has been tested by using SCM Urban Macro, SCM Urban Micro, and SCM Suburban Macro channel models.

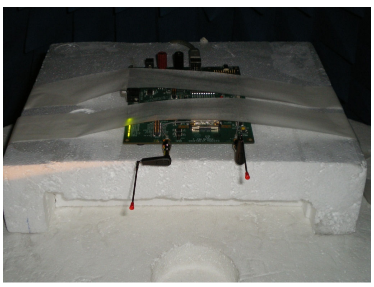

Figure 8. 1xEVDO data card in PCS band

A	Reference channel power	-70	dBm
B	Output level of the tester (e.g. R&S CMu200)	-20	dBm
C	Cabling to Propsim Input	-1	dB
D	Propsim total channel gain	-12	dB
E	Cabling to OTA antenna	-3	dB
F	**Signal level at OTA antenna**	**-36**	**dBm**
G	OTA Antenna gain	-10	dBi
H	**DL signal level**	**-46**	**dBm**
I	Path Loss (FSPL: 2GHz/0.45m)	-32	dB
L	**Signal level at DUT**	**-78**	**dBm**

Table 3. Link\Gain budget calculations

7. Throughput Measured results

Forward Link Throughput versus DL signal power has been measured, and reported in Figure 7, 8, and 9 for the three channel models listed above. Overall TP measurements show good repeatability. Looking also the figures 7-9, we can observe that there are differences between the channel models in terms of the performance.

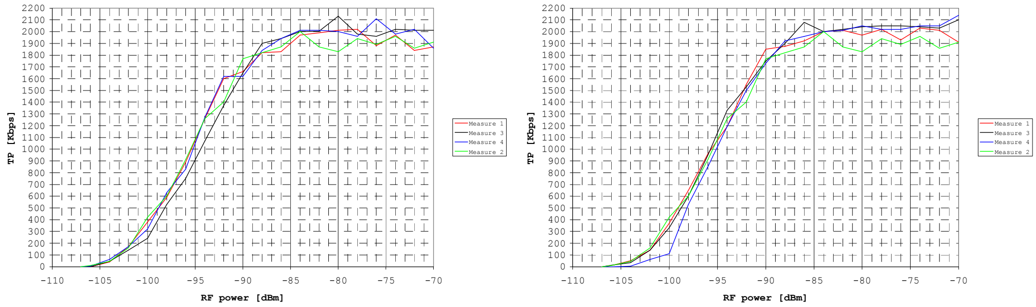

Figure 7-8. Urban Macro (left), and Urban Micro (right) Channel Profiles – TP Vs RF power

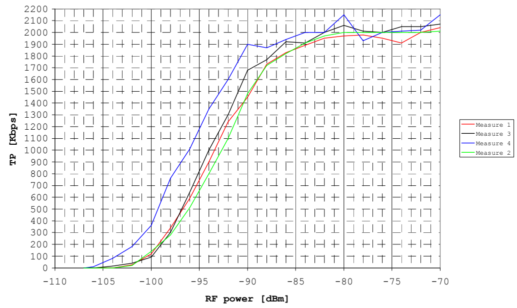

Figure 9. Suburban Macro Channel Profile – TP Vs RF power

8. Conclusion

This TD discussed practical considerations of MIMO OTA reference test set-up based on Spatial Fading Emulator. Special attention was dedicated to throughput measurements when DUT is tested against different channel profiles. Repeatability of results is quite good at the frequency being tested (1960MHz). Feasibility region measurement shows that 45cm distance from probes to DUT is enough to measure DUT at 2GHz frequency. It is also shown that 8 antennas might be enough. Future works include the in depth analysis of the whole results gathered during testing campaign in order to address all the points still open, i.e. AoA accuracy, and throughput measurements of a MIMO capable devices. Effect of both polarizations on testing would be included in the next testing activity as well.

Acknowledgements

Part of this work has been performed in the framework of the CELTIC project CP5-026 WINNER+. The authors would like to acknowledge the contributions of their colleagues to the project.

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