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Channel Verification Results for the SCME models in a Multi-Probe Based MIMO OTA Setup

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Abstract—MIMO OTA testing methodologies are being intensively investigated by CTIA and 3GPP, where various MIMO test methods have been proposed which vary widely in how they emulate the propagation channels. Inter-lab/inter-technique OTA performance comparison testing for MIMO devices is ongoing in CTIA, where the focus is on comparing results from various proposed methods. Channel model verification is necessary to ensure that the target channel models are correctly implemented inside the test area. This paper shows that the all the key parameters of the SCME models, i.e., power delay profile, temporal correlation, spatial correlation and cross polarization ratio, can be accurately reproduced in a multi-probe anechoic chamber based MIMO OTA setup.

I. INTRODUCTION

MIMO OTA testing, which is considered as a promising solution to evaluate MIMO capable devices in realistic situations, has attracted huge interest from both industry and academia [1]. Standardization work for the development of the MIMO OTA test methods is ongoing in CTIA, 3GPP and IC1004 [1]. Many different MIMO test methods have been proposed which vary widely in how they emulate the propagation channel. Size and cost of the testing system are also quite different for various proposals [2], [3], [4].

The CTIA MIMO OTA Sub Group (MOSG) has been investigating aspects related to MIMO OTA performance evaluation and inter-lab/inter-technique OTA performance comparison testing campaign has been started since 2012, where the focus is on comparing results of the same methods in different labs and results between different methods [5]. In order to ensure different MIMO OTA techniques render comparable testing results, test prerequisites are defined in detail. That is, ENodeB configuration, MIMO channel models used for evaluation of MIMO devices, emulated base station (BS) setup, device under test (DUT) and DUT orientation are specified. One prerequisite is that target channel models should be correctly implemented inside the test area for all techniques. And hence channel verification measurements are necessary in the test campaign.

In the paper, we first describe the multi-probe anechoic chamber setup used for channel verification measurements and then we present the channel verification results and possible causes for the deviations found in the results.

II. MEASUREMENT SYSTEM

An illustration of multi-probe anechoic chamber setup used for channel verification purpose is shown in Figure 1. Figure 2

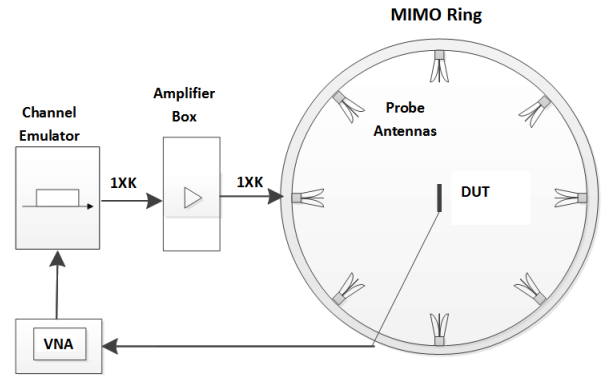


Figure 1. An illustration of the multi-probe based MIMO OTA setup. The main components are a vector network analyzer (VNA), one or several radio channel emulators, an anechoic chamber, OTA probe antennas, power amplifiers (PAs) and the DUT. Spectrum analyzer is used for power doppler spectrum (PDS) measurements.

shows the practical multi-probe setup used for measurements. 16 dual polarized horn antennas are equally spaced and fixed on an aluminum OTA ring with radius 2 meters. Absorbers are used to cover the metallic ring and unused probes to alleviate the reflections (as shown in 3(a)). Radio channels are generated by the radio channel emulator (as shown in 3(b)) and radiated by the probes into the anechoic chamber. Two Elektorbit F8 channel emulators and 8 dual polarized OTA probes are used to generate the SCME models. Measurements were performed at 751MHz, which is at the center of LTE frequency band 13 downlink.

A Satimo sleeve dipole and ETS Lingren magnetic loop were used as measurement antennas for channel verification, as shown in Figure 4(a) and Figure 4(b) respectively. Measurement antenna positions were calibrated carefully with a laser positioner before the measurements. Also phase and amplitude calibrations were performed for each probe before the measurements. The goal of the calibration is to compensate errors caused by cable length difference, measurement setup nonidealities, i.e. probe placement and orientation error, etc. The target is that equal field response at the center should be obtained for all the probes.

III. SCME CHANNEL MODELS

Most parameters in SCME models are random variables defined by their probability density functions (PDFs). In order

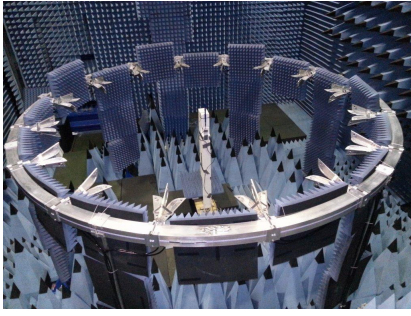


Figure 2. An illustration of the practical anechoic chamber setup in the measurement system.



(a) Absorbers mounted on the OTA ring

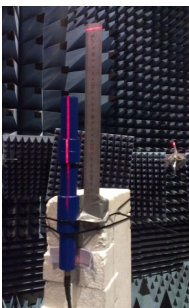


(b) Two channel emulator used in the measurement

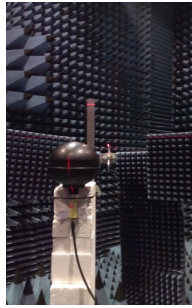
Figure 3. Absorbers and channel emulator used in the setup.

to ensure that channel models with same parameters are implemented between different labs. SCME tapped delay line (TDL) models are used as target channel models, where a set of values for the power, delays, and angular parameters of the paths are defined, as detailed in [6]. Four channel models, namely SCME Uma TDL, SCME Umi TDL, single cluster SCME Uma TDL and single cluster SCME Umi TDL are used in the evaluation of the MIMO OTA performance [5]. Four key parameters of the channel models are required for validation as detailed below:

a) Power delay profile (PDP): All the considered SCME models consist of 6 paths, each associated with a delay and power. Figure 5 illustrates a snapshot of SCME Umi TDL model. The goal of PDP validation is check whether PDP in the implemented channels follow that in the target channels.



(a) Measurement Antenna for vertical polarization



(b) Measurement Antenna for horizontal polarization

Figure 4. Absorbers and channel emulator used in the setup.

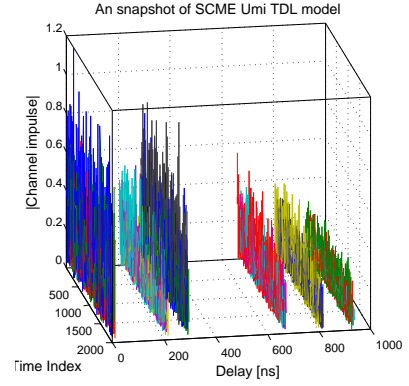


Figure 5. A snap shot of SCME Umi TDL model. The SCME models consist of 6 path (or 18 midpaths).

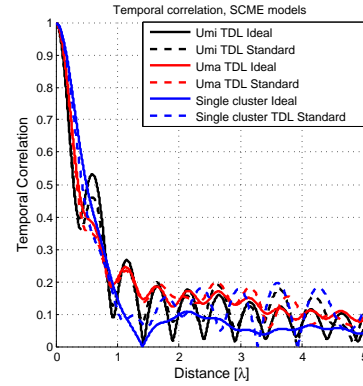


Figure 6. Target TCF for all SCME TDL models. Mobile speed and direction of travel are set according to [5].

Note that single cluster channels models share the same PDP information as generic models.

b) Power doppler spectrum (PDS) and temporal correlation function (TCF): PDS and its Fourier transform pair TCF are used to check how channels evolve with time, as shown in Figure 5. Target PDS can be obtained by the power azimuth spectrum (PAS) of the SCME models and we can transform the PDS to a continuous TCF by Fourier transform [7]. Figure 6 shows the TCF functions for all considered SCME TDL models. “Standard” curves denote that the TCFs are calculated based on [8], where 20 subrays are used to discretize the truncated Laplacian shape clusters, while “ideals” curves represent TCFs for ideal PASs. Deviations are caused by insufficient number of subrays to discretize the PAS and truncation of the Laplacian shape. “Ideal” cuves are used as target TCFs in this paper.

c) Spatial correlation : PAS of SCME models consist of 6 Laplacian shaped clusters, each associated with an angle of arrival (AoA) and azimuth spread (AS). Spatial correlation has been selected as the main figure of merit to characterize the channel spatial information [3]. The goal of the validation is to check whether the implemented channels can reproduce the spatial characteristics of the target SCME models. Target spatial correlation for all SCME TDL models are shown in Figure 7.

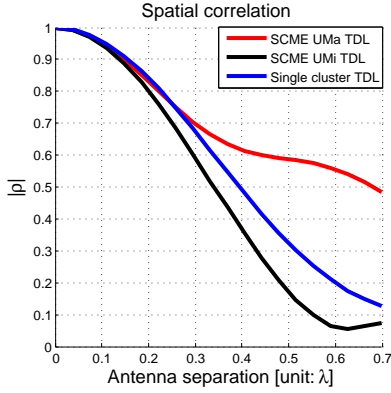


Figure 7. Target spatial correlation for all SCME TDL models. Antenna boresight = 0° .

d) *Cross polarization ratio*: The emulated BS antennas are assumed to be dual polarized equal power elements that are uncorrelated with 45° slanted [5]. Path power will be modified by BS antenna pattern according to angle of departure (AoD) of each path for each polarization. Cross polarization ratio (XPX) is assumed to be 9 dB in all the considered channels. Expected XPRs can be calculated according to BS antenna pattern and XPR information in the channel, as listed in Table III for all the considered channels.

IV. CHANNEL VERIFICATION RESULTS

In this part, measurement results are compared with the target and simulated results. Target results are explained in Section III and specified in [5], while simulation results are based on CIR files in the channel emulator, which are generated by SCME engine [9].

A. PDP

The PDP verification measurement was performed following the appendix of [5] with some exceptions as stated below:

- The span of the VNA was initially set to 200MHz to measure PDP according to [5]. Another round of PDP measurements was performed with the VNA span of 40MHz due to the fact that maximum supported bandwidth of the channel emulator is 40MHz. As shown in Figure 8, in the 200MHz measurements, the signal covers around 60MHz, while only the signal within the 40MHz is valid.
- Since the mid-path cannot be differentiated in the measurement with 40MHz bandwidth, the total power of each cluster, which is obtained by linearly summing the powers of the three mid-paths in each cluster is compared with the measurements.

1) Comparison between target and simulated PDP :

Comparison results between target PDP and simulated PDP for vertical polarization is shown in Table I. Simulated PDP generally follows the target very well for all scenarios with a maximum deviation within 1dB. There is no difference in delay for all scenarios between target and simulations.

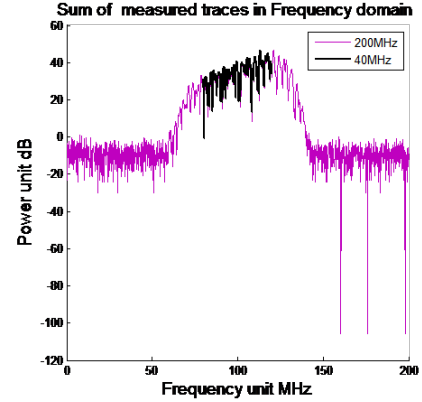


Figure 8. Sum of measured $|H(f)|^2$ in frequency domain with VNA span and 200MHz and 40MHz.

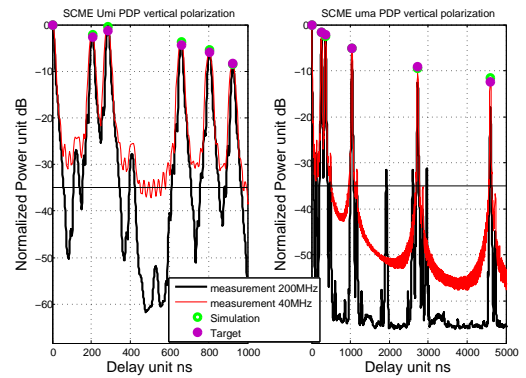


Figure 9. Target, simulated and measured PDPs for SCME Umi TDL and SCME Uma TDL models for vertical polarization.

2) Comparison between measured and simulated PDP:

One problem of measuring with a VNA span of 200MHz is that aliasing is present in the measurements. There are no aliasing issues with the measurement with VNA span of 40MHz. Measurements with 40MHz provide 5 times higher sampling rate than measurements with 200MHz.

Comparison between measured (with 40MHz bandwidth) and simulated PDP for all the scenarios for vertical polarization are shown in Table II. Deviation between measurement and simulation in terms of delay is within 5ns, which is very accurate. Generally speaking, measurements with a VNA span of 40MHz match very well with simulation, with a deviation of up to 0.7dB for all scenarios, while measurements with VNA span of 200MHz generally present worse match compared with 40MHz measurements, deviation in some scenarios are up to 6.5dB, as shown in Figure 9 (6th path of the SCME Uma TDL model). Measurements with 200MHz bandwidth should not be trusted due to aliasing issue.

B. PDS and temporal correlation

1) *PDS*: Raw PDS measurement results with spectrum analyzer for all the considered scenarios are shown in Figure 10. Measured maximum Doppler frequency f_d matches quite well with the expected f_d in the target channels.

Table I
COMPARISON BETWEEN TARGET (T) AND SIMULATED (S) PDP FOR ALL CHANNELS FOR VERTICAL POLARIZATION. ∇ DENOTES THE DEVIATIONS.

Model	Path	Power dB			Model	Power dB			Model	Power dB			Model	Power dB		
		T	S	∇		T	S	∇		T	S	∇		T	S	∇
Umi	1	0	0	0	Uma	0	0	0	Umi single cluster	0	0	0	Uma single cluster	0	0	0
	2	-2.7	-2.2	0.5		-1.7	-1.6	0.1		-2.7	-2.9	-0.2		-1.7	-1.7	0
	3	-1.3	-0.4	0.9		-2.2	-2.5	-0.3		-1.3	-1.3	0.0		-2.2	-2.2	0
	4	-4.3	-3.7	0.6		-5.2	-5.2	0.1		-4.3	-4.4	-0.1		-5.2	-5.2	0
	5	-6.0	-5.4	0.6		-9.1	-9.5	-0.4		-6.0	-5.9	0.1		-9.1	-9.1	0
	6	-8.4	-8.4	-0.1		-12.5	-11.5	1.0		-8.4	-8.5	-0.1		-12.5	-12.5	0

Table II
COMPARISON BETWEEN MEASURED (M) AND SIMULATED (S) PDP FOR ALL CHANNELS FOR VERTICAL POLARIZATION. ∇ DENOTES THE DEVIATIONS.

Model	Path	Power dB			Model	Power dB			Model	Power dB			Model	Power dB		
		S	M	∇		S	M	∇		S	M	∇		S	M	∇
Umi	1	0	0	0	Uma	0	0	0	Umi single cluster	0	0	0	Uma single cluster	0	0	0
	2	-2.2	-2.2	0		-1.6	-2.2	-0.6		-2.9	-3.2	-0.3		-1.7	-1.8	-0.1
	3	-0.4	-0.7	-0.3		-2.5	-2.7	-0.2		-1.3	-1.2	0.1		-2.2	-1.7	0.4
	4	-3.7	-3.8	-0.1		-5.2	-5.9	-0.7		-4.4	-4.7	-0.3		-5.2	-5.4	-0.2
	5	-5.4	-5.5	0.1		-9.5	-10.1	-0.6		-5.9	-6.2	-0.3		-9.1	-9.0	0.1
	6	-8.4	-8.4	0		-11.5	-11.6	-0.1		-8.5	-8.8	-0.3		-12.5	-12.5	0

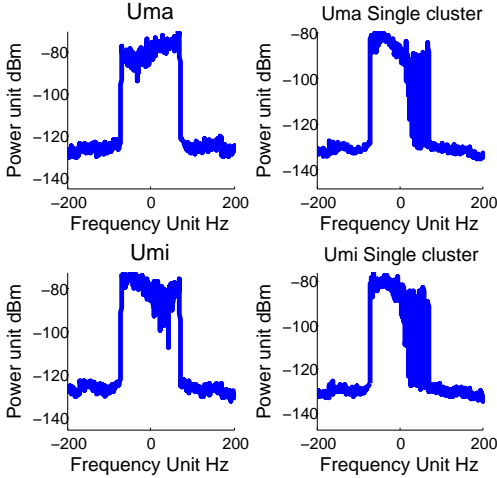


Figure 10. Power Doppler Spectrum for the considered scenarios

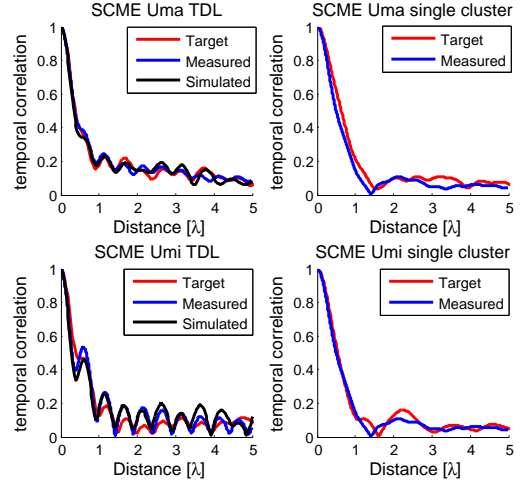


Figure 11. Target, simulated and measured temporal correlations for the considered scenarios.

2) *Temporal correlation*: It is difficult to directly compare PDS due to fact that channels are created by ray based model in the channel emulator. The measured TCF matches pretty well with the simulated and target TCF, as shown in Figure 11. The deviations are likely caused by the reflections in the chamber.

C. Spatial correlation

The positioner is oriented perpendicular to the AoA= 0° orientation as specified in [5]. The measurement procedure is different from [5] to decrease measurement time. The dipole is moved to 0.5λ backwards from the center. In this position, the channel emulator is stopped at each CIR position and the field is measured with a VNA for a total of 1000 CIR positions. The dipole is then moved 0.1λ forward, and the sweep over 1000 CIR values is repeated for this new position. This procedure is repeated 11 times until a full wavelength is covered.

We calculated the correlation between the traces measured at first position and at the rest of the positions. As we can see, a good agreement can be observed between the measured and simulated spatial correlation curves for all scenarios, as shown in Figure 12. In a summarized way, these are the main aspects that we concluded with these results:

- The deviation between the simulated and target spatial correlation is due to the limited number of probes (8 in our measurements) used for channel emulation. The more probes we use, the smaller deviation we should expect. The deviation between simulated and target spatial correlation for different scenarios is different due to the fact that channel emulation accuracy depends on the channel model.
- The deviation between measured and simulated spatial correlation is likely due to the physical limitation of our MIMO OTA multi-probe test setup. In our setup,

the OTA ring of radius 2m is used, while the radius of the test zone is 0.2m. Deviation between spatial correlation in ideal conditions and spatial correlation in physically constrained conditions is not negligible in this measurement, as explained in [10].

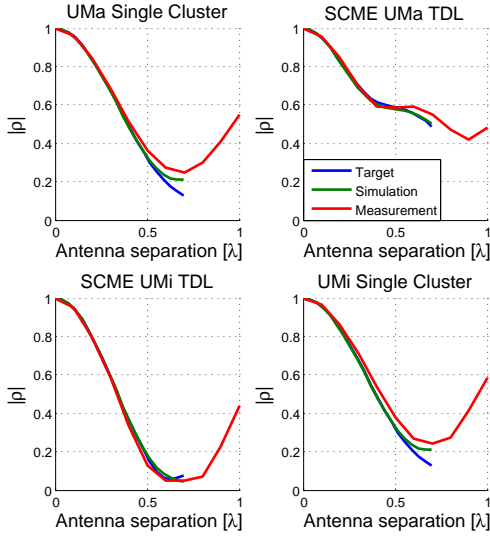


Figure 12. Measured, simulated, and theoretical spatial correlations of the considered scenarios. 0 represents angle of the virtual antenna array bore-sight direction.

D. Cross polarization ratio

The measurement procedure for cross polarization ratio is detailed in [5]. In the measurement, the measurement antenna was located at the center of the ring by using a laser positioner. After calibration, equal field response (both power and phase) can be obtained for all the horn antennas. During the measurement, we rotated the receive antenna 360° for an active horn. The average received power with the magnetic loop and dipole are -29.8dB and -22.5dB, respectively. That is, the antenna gain difference is 7.3dB, which matches well with the value calculated from the antenna specifications.

The measured results for all the target scenarios are illustrated in Table III. As we can see, the measured results after considering the antenna gain difference is around 1dB higher than the target values in all scenarios. The deviations are likely introduced by independent calibrations. Each fader is calibrated with a different antenna, and therefore we have different calibration values. Each calibration value corresponds to the “measurement” antenna being used. The calibration procedure is that it takes the lowest of the outputs, and lowers the rest of the outputs according to this one. If there is 1dB difference in the lowest of the outputs for the horizontal and vertical polarization, we will have 1dB difference.

V. CONCLUSION

This paper describes the multi-probe anechoic chamber setup used to perform the Inter-lab/inter-technique measurements and presents the channel verification results. Good match between measurements and target has been achieved

Table III
RESULTS FOR CROSS POLARIZATION MEASUREMENTS FOR THE CONSIDERED SCENARIOS

	SCME Umi TDL	SCME Umi Single cluster	SCME Uma TDL	SCME Uma Single Cluster
Target	0.83dB	0.83dB	8.13 dB	8.13dB
Simulation	0.76dB	0.68dB	8.12 dB	8.18dB
Raw Measurement	9.73dB	9.0 dB	16.6 dB	16.7dB
Measurement	2.0dB	1.4dB	9.0 dB	9.0dB
Deviation	1.2dB	0.6dB	0.9dB	0.9dB

in terms of PDP, temporal correlation, spatial correlation and cross polarization ratio of the channel. Deviation between measured and simulated PDP in terms of delay is within 5ns, while power deviation of up to 0.7dB is found for all scenarios. The measured TCF matches pretty well with the simulation. The deviations are likely caused by the reflections in the chamber. A good agreement can be observed between the measured spatial correlation curves and theoretical curves for all scenarios. Deviations are mainly due to the physical limitations of the MIMO OTA system. The measured cross polarization ratio is around 1dB higher than the target values in all scenarios. The deviations are likely introduced by separate calibrations for the two polarizations.

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