MIMO 2x2 Reference Antennas – Measurement Analysis Using the Equivalent Current Technique

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***Abstract*- The reference antenna concept has been created to eliminate the uncertainties linked to the unknown antenna performances of the LTE 2x2 MIMO reference devices [1]. The wireless industry through the CTIA (The Wireless Association) and 3GPP (3G Partnership Project) standardization bodies has been using such antennas for characterizing the methodologies being proposed for the MIMO OTA tests [2]. The developments on the antenna concept and report on the measured performances at uniform incoming power distribution, figures and correlation between different labs have been presented in [3]. In this paper we present analysis of the measurements by using the equivalent radiating current technique (EQC). This technique is based on an integral equation formulation of the inverse source problem upon rigorous application of the equivalence principle [4]–[9]. The application of EQC enables to investigate the radiating details of the device and measurement setup. The aim of this paper is to show how the measurement set up can impacting the current distributions of the reference antennas and hence the performances.**

I. INTRODUCTION

Long term Evolution (LTE) adopts multi-antenna mechanisms to increase coverage and physical layer capacity. Therefore, Multi-input Multi-Output (MIMO) antenna systems are required on LTE systems.

The MIMO 2x2 Reference Antenna concept was created based on the need of eliminate the unknown antenna performance of the available LTE MIMO 2x2 devices for radiated data throughput measurements. The adoption of the reference antennas, eliminate part of the measurement uncertainty, and increase repeatability among different MIMO OTA test methodologies and test facilities.

The reference antennas were designed to cover three LTE bands (2, 7 and 13) respectively 1.9GHz, 2.7GHz, and 750MHz. Conceptually for each band three antennas were designed to emulate a “good” MIMO antenna system FoM, i.e. low correlation coefficient ($\rho<0.1$), high system efficiency (SE>90%) and low gain imbalance (GI≅0dB). Respectively the “nominal” MIMO antenna system has moderate correlation coefficient ($\rho\leqslant0.5$), moderate system efficiency (SE⩾50%) and low gain imbalance (GI≅0dB). And finally the “bad” MIMO antenna system, having poor correlation coefficient ($\rho\geqslant0.9$), moderate-to-poor system efficiency (SE ⩽50%) and low gain imbalance (GI≅0dB).

Measured data on these antennas have been presented in [3]. This paper will be presenting the analysis of the measurements results by using the equivalent current formulation [4]. The current distributions on the reference antennas will be used for understanding the impact of the measurement set up on the reference antennas performances such as radiation patterns, efficiency, gain imbalance and correlation coefficient.

II. REFERENCE ANTENNA CONCEPT

A. *Reference antennas design*

The reference antennas prototype is shown in figure 1 for the LTE Band 13 Good case.

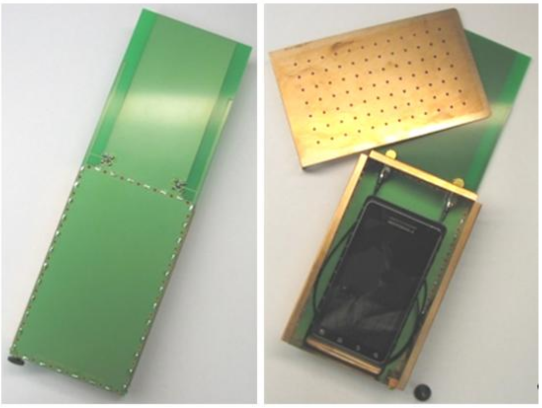

Figure 1. Reference antennas Prototype

The reference antenna needs to solve the potential problem with connecting any external antenna into a portable device (right picture). The connection between the portable device RF port and the external antenna, normally a coaxial cable, can potentially carry current in the outer conductor. The associated radiation perturbs the antenna system radiation and influence system parameters like correlation coefficient, absolute gain and gain imbalance. For this reason the antenna was conceived attaching MIMO 2x2 external antennas to a RF enclosure, where the DUT and its RF connections are located.

B. *Measured Performances*

In Table 1 the reference antennas measured performances are reported:

TABLE I: MEASURED PERFORMANCES OF THE MIMO ANTENNAS

		Antenna 1			Antenna 2			Gain Imbalance (dB)			Mag Complex Cor. Coef.		
		1930MHz	1960MHz	1990MHz	1930MHz	1960MHz	1990MHz						
Band	Configuration	SE (%)	SE (%)	SE (%)	SE (%)	SE (%)	SE (%)	1930MHz	1960MHz	1990MHz	1930MHz	1960MHz	1990MHz
2	"Good" 2x2 MIMO	81	82.7	84.2	83.9	84.2	83.5	-0.28	-0.25	-0.19	0.18	0.18	0.19
	"Nominal" 2X2 MIMO	60.8	59.1	56.3	59.9	57.3	54	0.11	0.19	0.17	0.52	0.48	0.45
Band	Configuration	2620MHz	2655MHz	2690MHz	2620MHz	2655MHz	2690MHz	2620MHz	2655MHz	2690MHz	2620MHz	2655MHz	2690MHz
7	"Good" 2x2 MIMO	81.5	87.8	87.3	80.1	85.6	84.8	0.24	0.26	0.27	0.1	0.07	0.05
	"Nominal" 2X2 MIMO	55.7	61.8	63.3	55.0	61.2	63	-0.03	-0.01	0.02	0.32	0.29	0.27
Band	Configuration	746MHz	751MHz	756MHz	746MHz	751MHz	756MHz	746MHz	751MHz	756MHz	746MHz	751MHz	756MHz
13	MIMO	76.1	78.1	77.2	76	78.1	77.6	0.14	0.07	0.04	0.00	0.01	0.01
	"Nominal" 2X2	50.5	50.9	49.6	50.9	51.5	50.1	0.25	0.22	0.3	0.58	0.53	0.49

The above is a special case of uniform distribution of incoming wave.

It must also be noted that the reference antennas have been tested in a SATIMO StarLab 15 by using coax cable for feeding the antenna under test (AUT). The coax cable influences on the radiation patterns has been studied in the following sections by using the equivalent current technique.

III. EQUIVALENT CURRENT TECHNIQUE

Measurement of small passive antennas often requires a coax cable to be connected to the antenna port. If the AUT is electrically small, as for the case of the reference antennas comparing current flowing back from the radiator to the outer surface of the cable will result in a second radiation and cause the measured radiation pattern to be inaccurate.

The measurement diagnostic and filtering capabilities of the equivalent current technique is used here to detect and then spatial filtering the interactions between the coax cable and the antenna itself. The method is based on the application of the Equivalence Theorem. The electric and magnetic current can be computed on an arbitrary surface by using either the Near Field (NF) or Far Field (FF) measured data. The field is then re-evaluated on the whole sphere. Enforcing explicitly Love's equivalence by a field boundary integral identity, the reconstructed currents are proportional to the actual field on the equivalent surface. The method becomes important for diagnostic and filtering purposes. Figure 2 shows the diagnostic tool when applying to the reference antennas case.

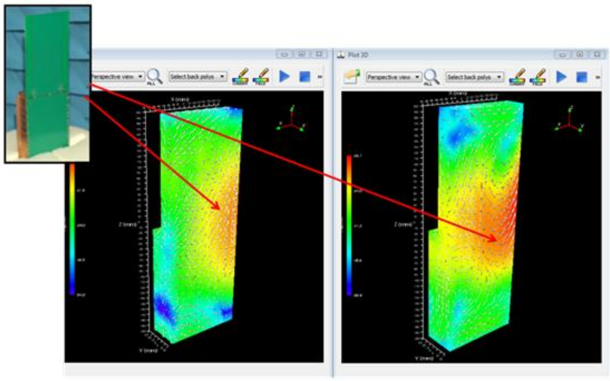

Figure 2. Current distributions on the reference antennas.

IV. MEASUREMENTS ANALYSIS

The LTE BAND 13 (751MHz) Good, and LTE BAND 7 (2.655MHz). Good reference antennas were considered for the analysis. Figure 3 shows the current distributions (J,M) for the LTE BAND 13 Good antenna case.

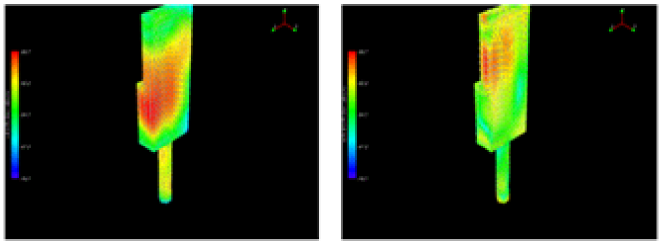

Figure 3. Measured current distributions – J (left), M (right).

It can be seen that there is some energy on the coax cable which could be re-radiated and cause the issue in the radiation pattern. This can be seen by looking at the 2D directivity plot in figure 4 when comparing it with the simulated (no coax cable effect). As anticipated, the equivalent current technique will allow us to spatially filter out the energy on the cable and re-evaluate the field on the whole sphere. Figure 5 shows the comparison of the 2D directivity pattern between simulated and filtered.

It can be seen that the 2D directivity pattern for the filtered case is closer to the simulated pattern than the measured one.

For the LTE BAND 7 Good antenna case, the effect of connecting a balun in between the coax cable and the antenna feeding point is observed. The expected effect is that the currents are choked due to presence of the balun itself. Figure 6 shows a comparison of the J current on the coax cable with and without the balun.

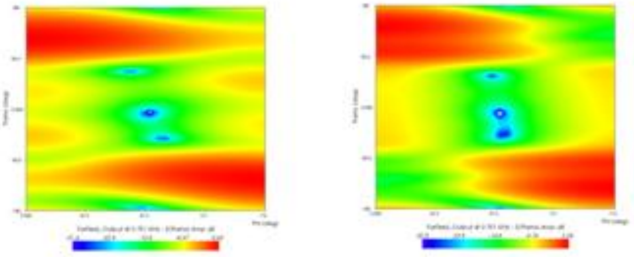

Figure 4. 2D Directivity comparison between simulated (left) and measured(right).

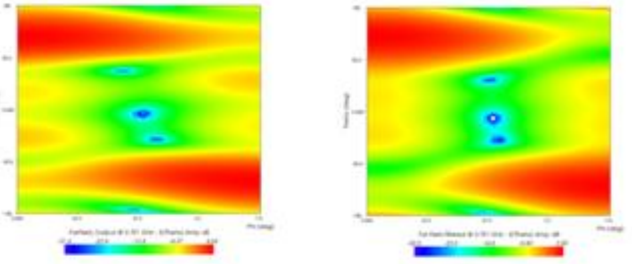

Figure 5. 2D Directivity comparison between simulated (left) and filtered (right).

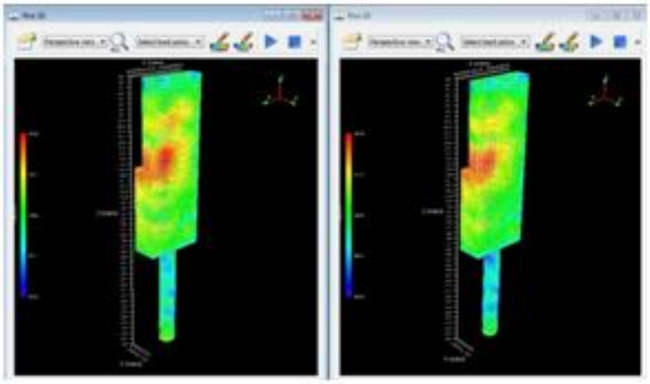

Figure 6. Current distributions comparison – only coax cable (left), with balun (right)

It can be seen that in both cases there is no energy on the cable hence the 2D directivity patterns would expect to be similar. Figure 7 shows the 2D directivity patterns comparison.

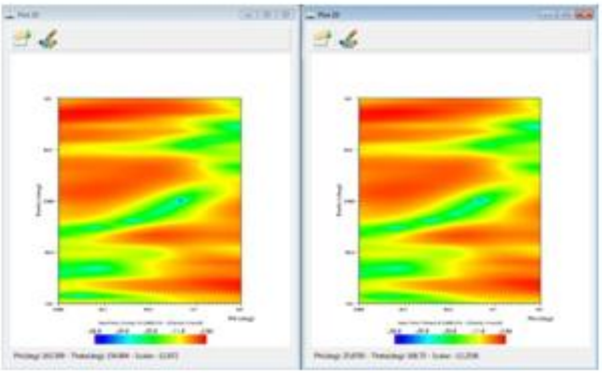

Figure 7. 2D directivity pattern comparison – only coax cable (left), with balun (right)

As expected, there are no substantial differences between the two patterns.

VI. CONCLUSIONS

In this paper the usefulness of an antenna diagnostic tool was shown when testing electrically small antennas. The powerfulness of spatially filtering the currents on the coax cable was also reported by comparing the simulated vs measured and filtered 2D directivity patterns.

Due to the fact that the effect of the balun was not seen for the LTE BAND 7 case, the next step would be to measure the LTE BAND 13 antenna by using a balun in order to see how the current distributions on the coax cable and hence the 2D pattern will be impacted.

ACKNOWLEDGMENT

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